LECTURE 3 SOLUTIONS. CONCENTRATIONS of SOLUTIONS

Senior teacher

PhD in physical chemistry

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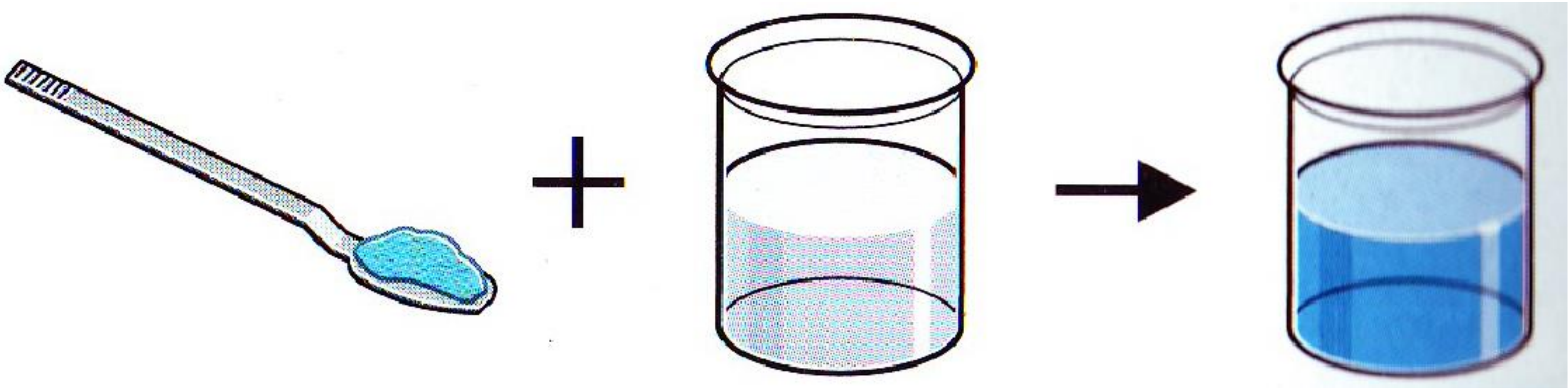
Pure?!

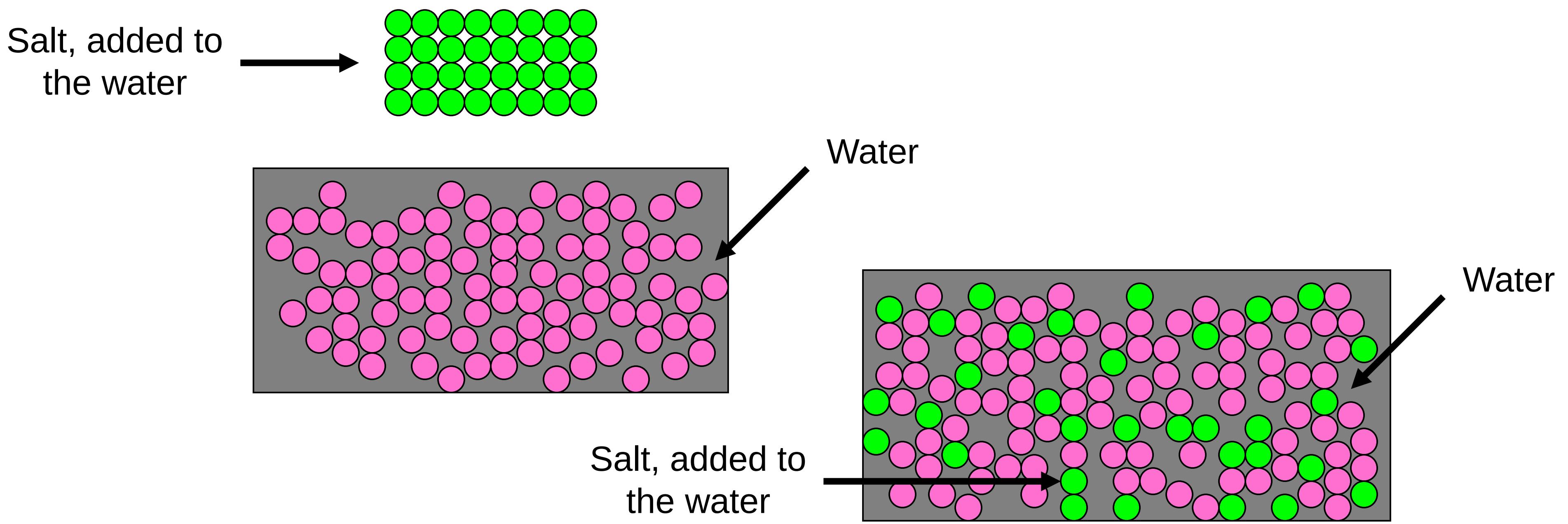
- Even though the water still looks 'pure', this term is wrong. Pure would mean there were only water particles, however we now have water particles + sugar particles!
- The sugar has not disappeared - instead it has dissolved in the water we would call the water + sugar a **solution**
- A solid dissolved in a liquid makes a **solution**
- In a solution the liquid is called the **solvent**, and the solid is called the **solute**



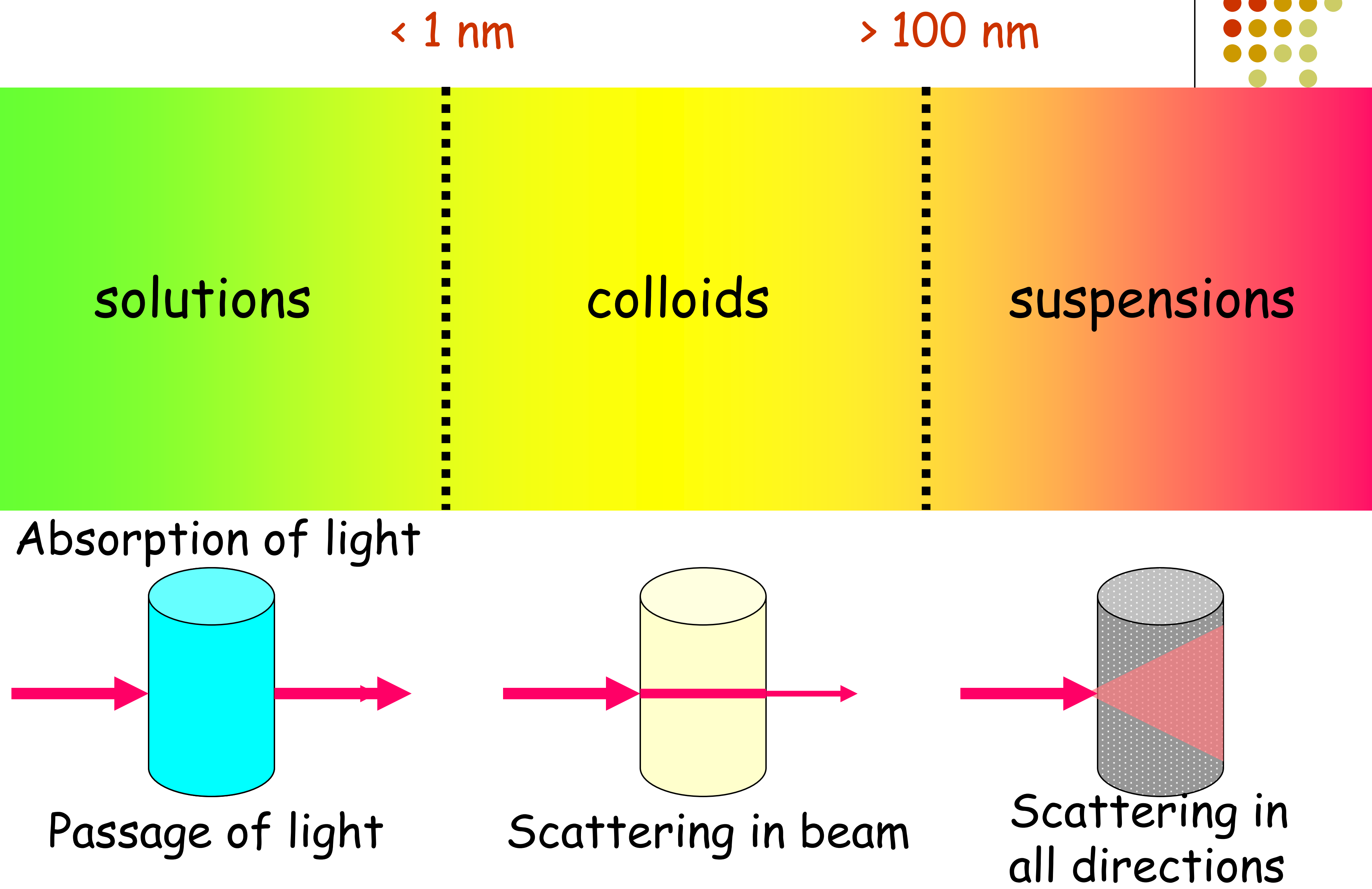
Solute Solvent Solution

The main terms of the topic

- ***Solutions*** are homogeneous systems consisting of two or more components and the products of their interaction.
- Compulsory components of the solution are the ***solvent*** and the ***solute***.
- The ***solvent*** is the solution component present in greatest quantity or the component that determines the state of matter in which a solution exist.



Comparison of Solutions, Colloids, and Suspensions



Solutions: homogeneous mixtures

- Absence of settling
- Two components (at the least)-
  - **<u>Solute</u>** – the substance being dissolved (the dissolved particles)
  - **<u>Solvent</u>** – a substance which dissolves another substance (the dissolving medium)

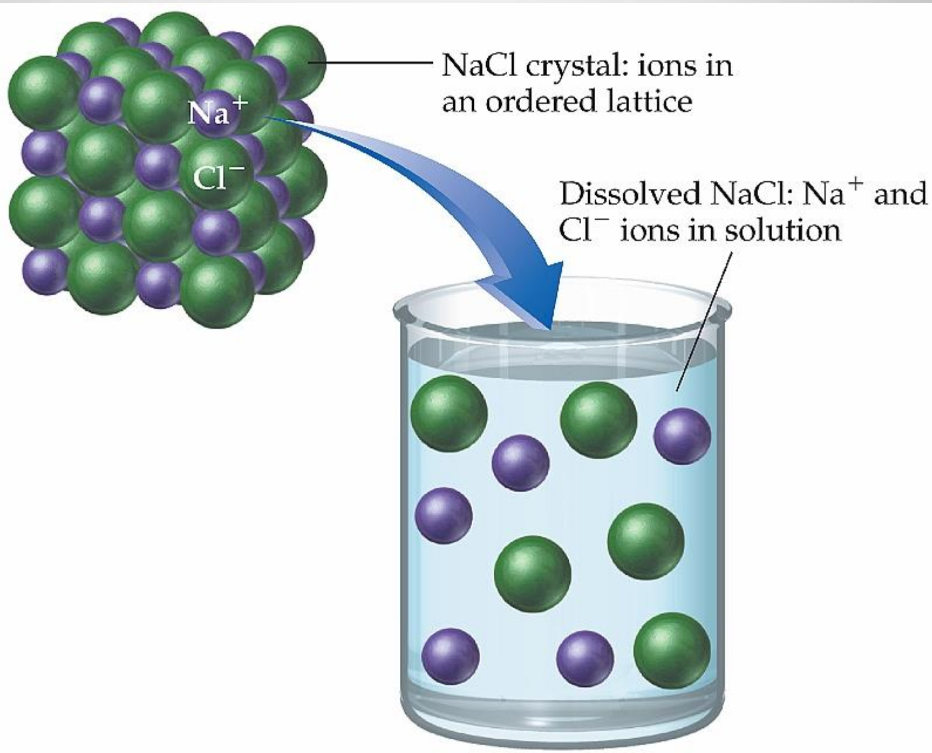
A solution in which water is the solvent is called an **<u>aqueous solution</u>**.

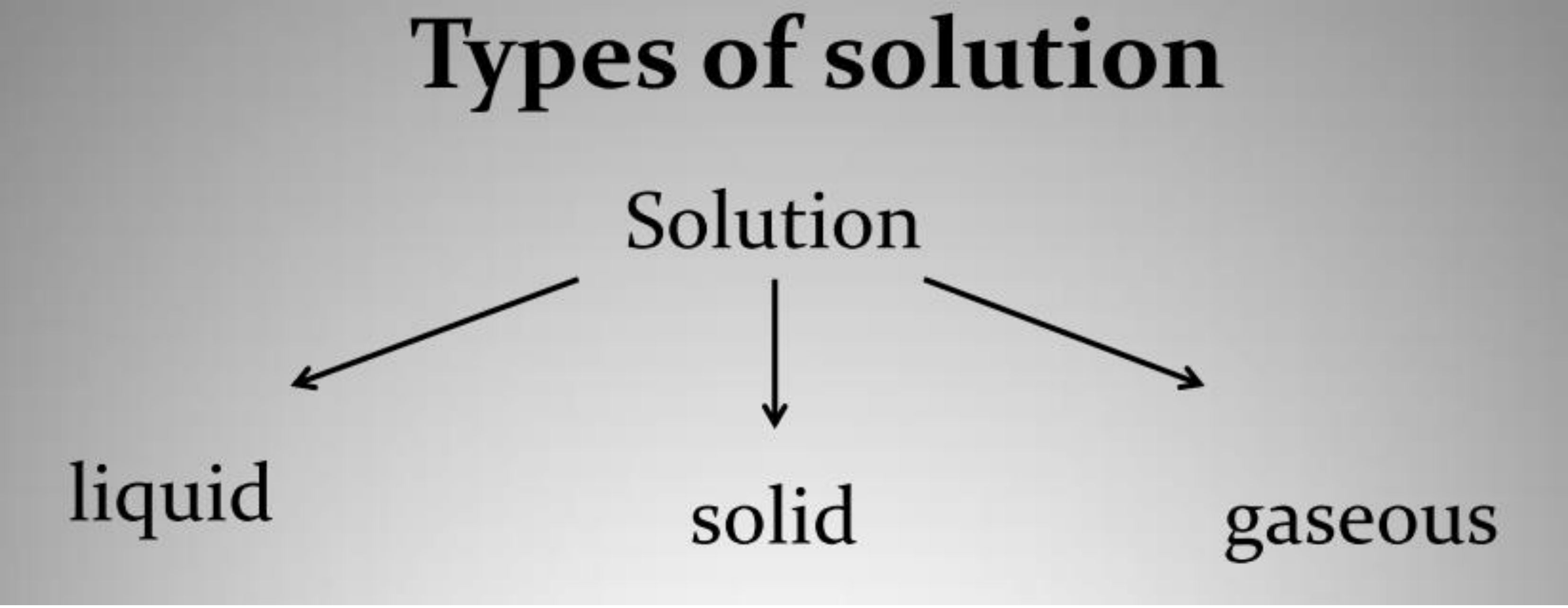
Solution: a homogeneous mixture of two or more substances

Solution= <u>Solute + Solvent</u>

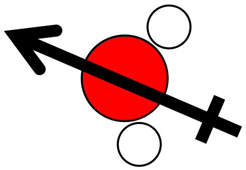
A solution containing a relatively large quantity of solute is said to be **concentrated**.

If the quantity of solute is small, the solution is **dilute**.





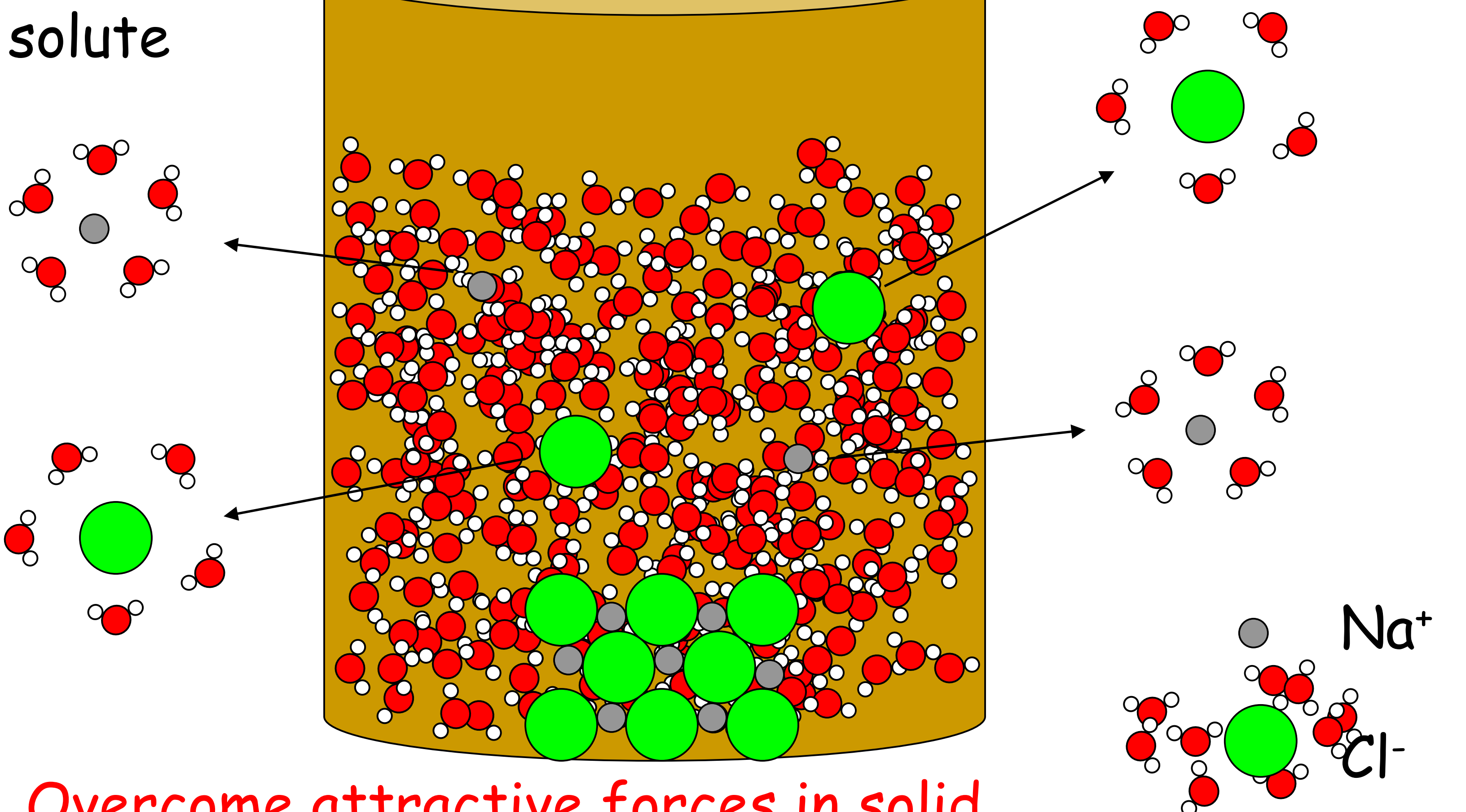
Gas	Gas	Air (oxygen in nitrogen)
Gas	Liquid	Soda water (carbon dioxide in water)
Solid	Liquid	Ocean water (salt in water)



Dissolving process in water

2. Hydration of solute

Orientation of water molecules around solute



1. Overcome attractive forces in solid

In a **liquid solution** the **solvent** is a **liquid** substance.

For examples: gasoline is mixture of a number of liquid hydrocarbons.

Seawater is an aqueous solution of sodium chloride and other ionic solids.

Carbonated water is an aqueous solution of CO_2.

All gaseous mixtures are solutions.

The best known example of a gaseous solution is air, which consists of N_2, O_2, CO_2 and other gases.

In a solid solution the solvent is a solid substance. The ability to form solid solution is particularly common among metals, and such solid solutions are called **alloys**. For example: an alloy of nickel and copper, an alloy of gold and silver.

Dissolving of a substances in solvent.

Solubility

Dissolving of substances in solvent are:

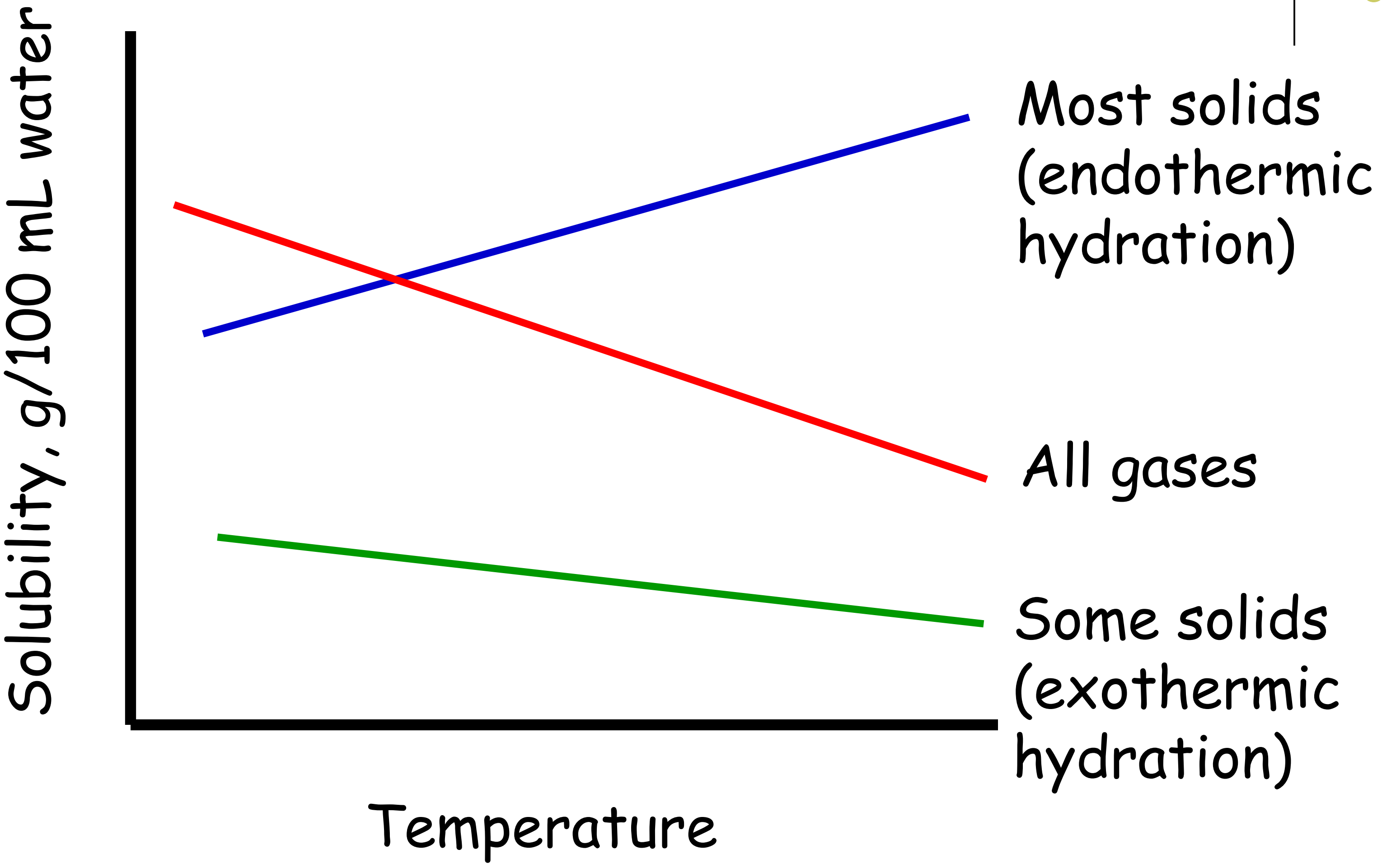
1. The destruction of crystalline lattice.

2. The interaction of the solvent with the particles of the solute.

3. The uniform distribution of one substance in the whole volume of another substance.

Dissolve - mixing of a substance in a liquid
Soluble - a substance which can dissolve (mix in a liquid)
Insoluble - a substance which cannot dissolve (mix in a liquid)

Solubility of Solutes in Water



Solubility is the ability of the substance to uniformly distribute in the whole volume of another substance.

$\frac{\text{g of solute}}{\text{100 g water}}$

Solubility (s) is the maximum amount of solute that dissolves in a specific amount of solvent.

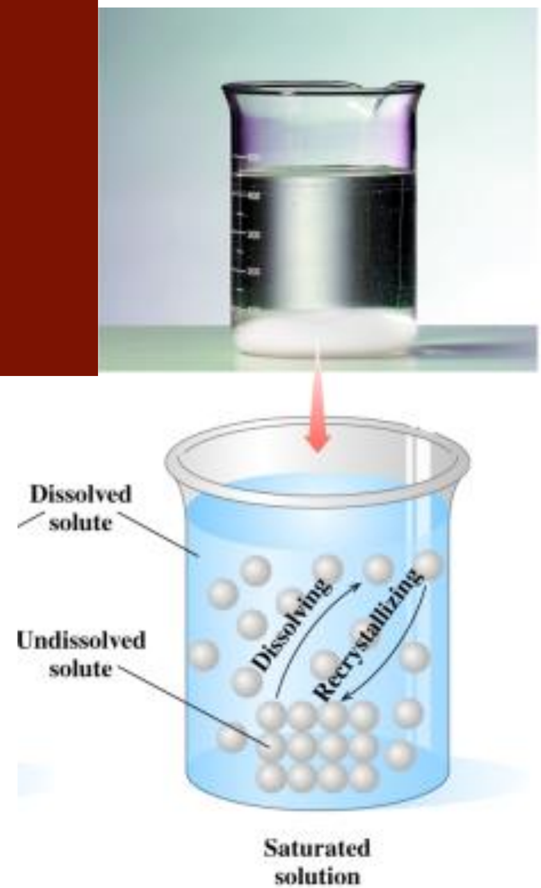
- expressed as grams of solute in 100 grams of solvent water.

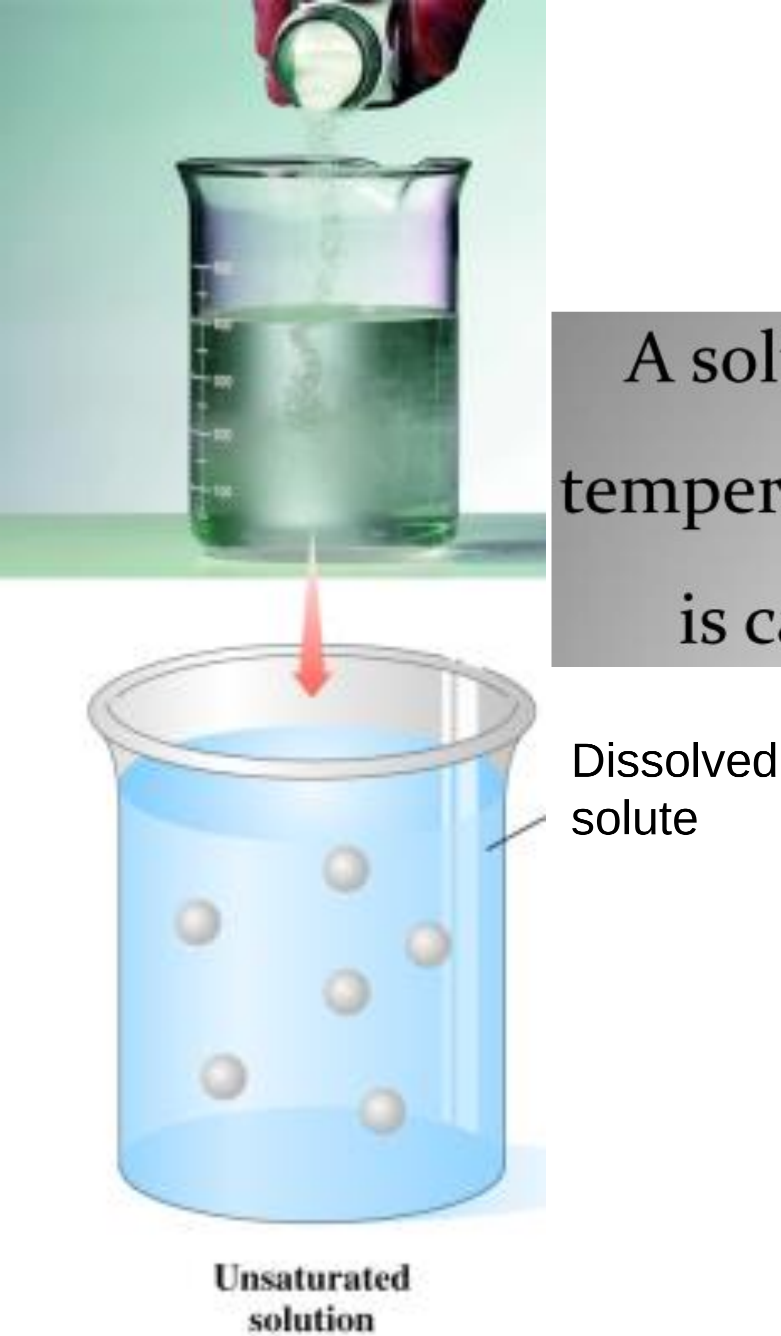
Solubility depends on the nature of substances, temperature and pressure. For example, solubility of solid substances increases and gases decreases with the raising of temperature. Solubility of gases increases with raising pressure.

A solution in which under the certain temperature the solute cannot be dissolved any more is called a **saturated** solution.

Saturated solutions

- contain the maximum amount of solute that can dissolve.
- have undissolved solute at the bottom of the container.





A solution in which under the certain temperature more solute can be dissolved is called an **unsaturated** solution.

contain less than the maximum amount of solute.

- can dissolve more solute.

Supersaturated Solutions

An unstable solution that contains an amount of solute greater than the solute solubility.

- Also has undissolved solute at the bottom of the container.

(a) A seed crystal of $NaC_2H_3O_2$ being added to the supersaturated solution.

(b) Excess $NaC_2H_3O_2$ crystallizes from the solution.

(c) The solution arrives at saturation.

Learning Check

At 40°C, the solubility of KBr is 80 g/100 g H_2O. Identify the following solutions as either
1) saturated or (2) unsaturated. Explain.

A. 60 g KBr added to 100 g of water at 40°C.

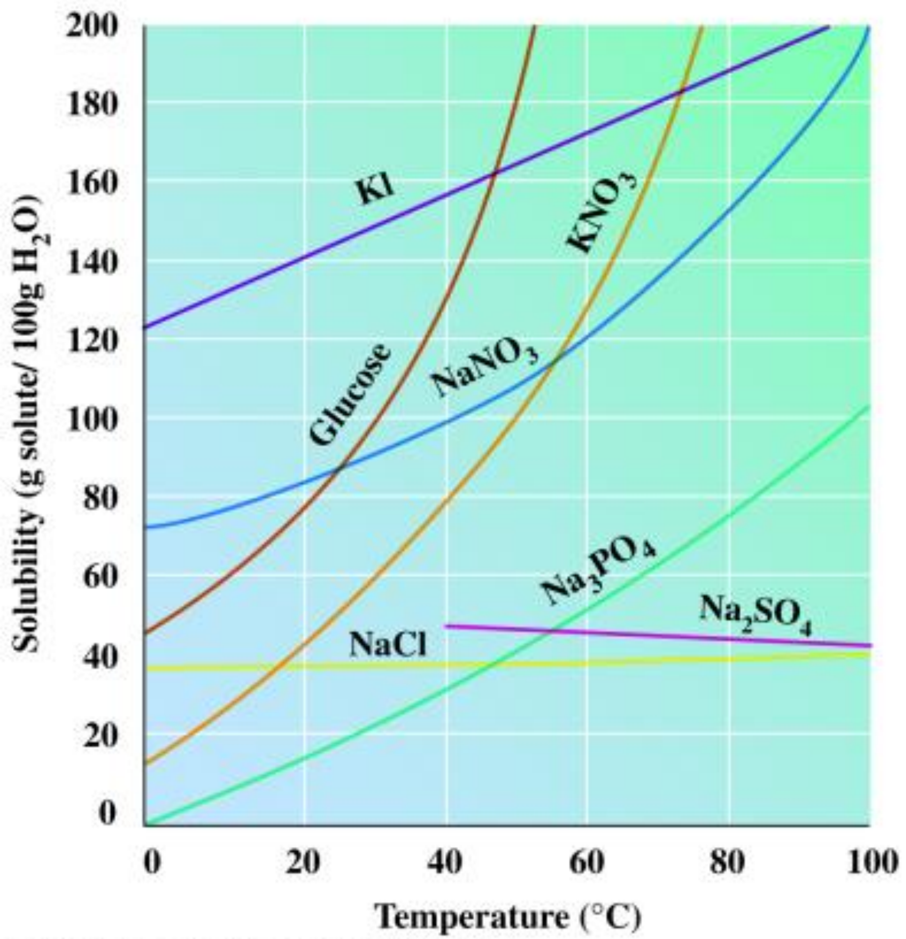
B. 200 g KBr added to 200 g of water at 40°C.

C. 25 g KBr added to 50 g of water at 40°C.

Effect of Temperature on Solubility

Solubility

- Depends on temperature.
- For most solids increases with increase of temperature.
- For gases decreases as temperature increases.

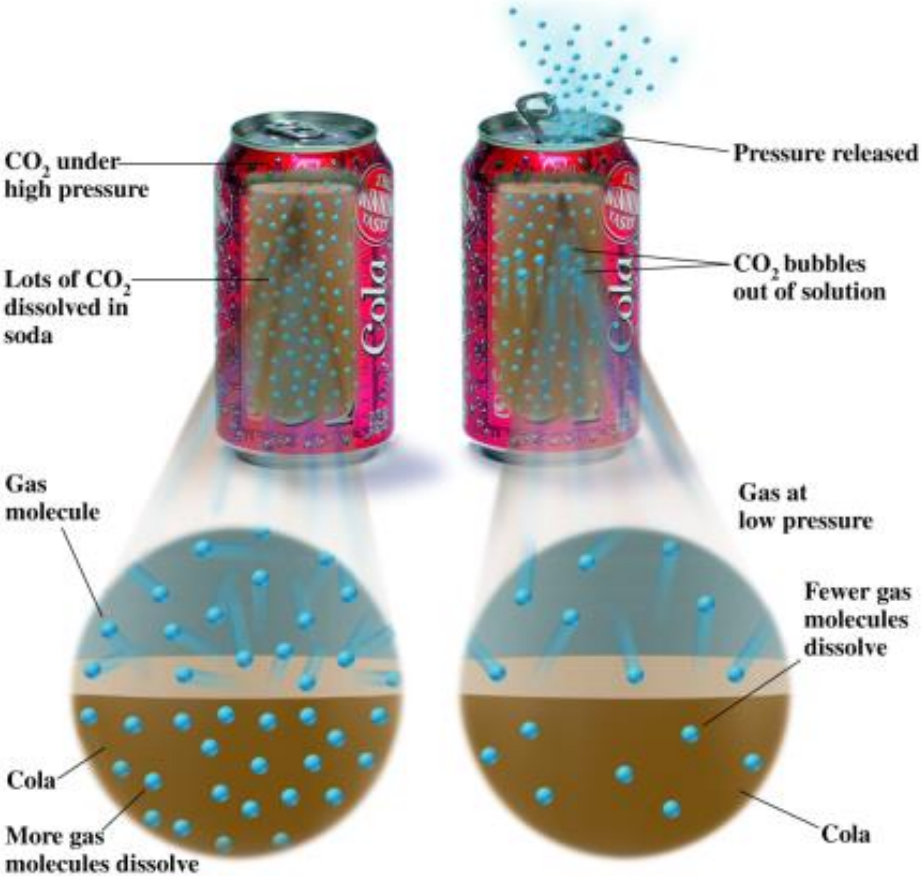


Solubility and Pressure

Henry's Law

states

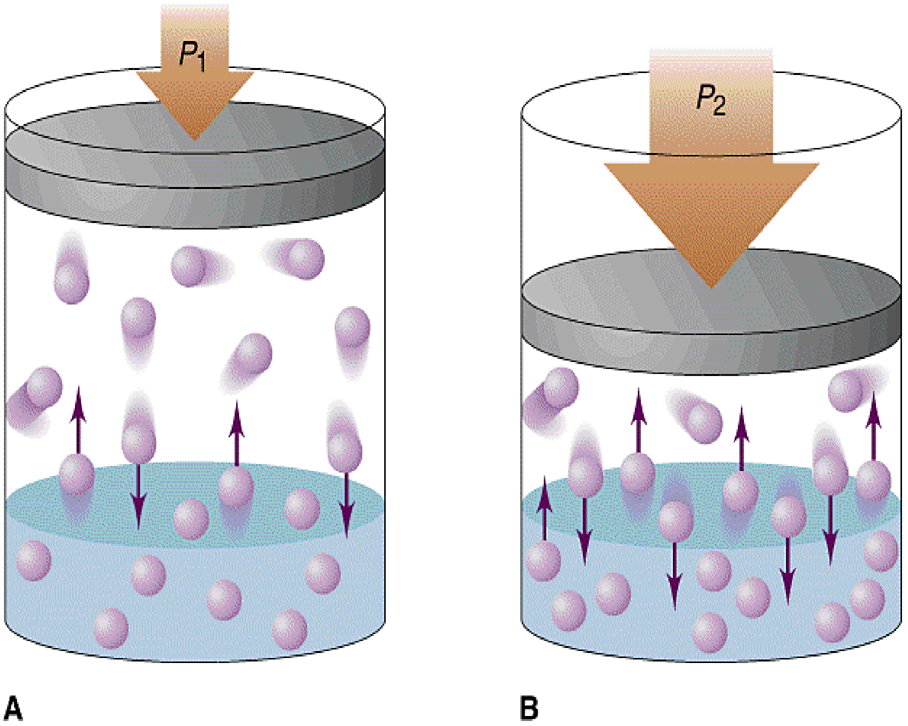
- the solubility of a gas in a liquid is directly related to the pressure of that gas above the liquid.
- at higher pressures, more gas molecules dissolve in the liquid.



Pressure affect on gases

Pressure:

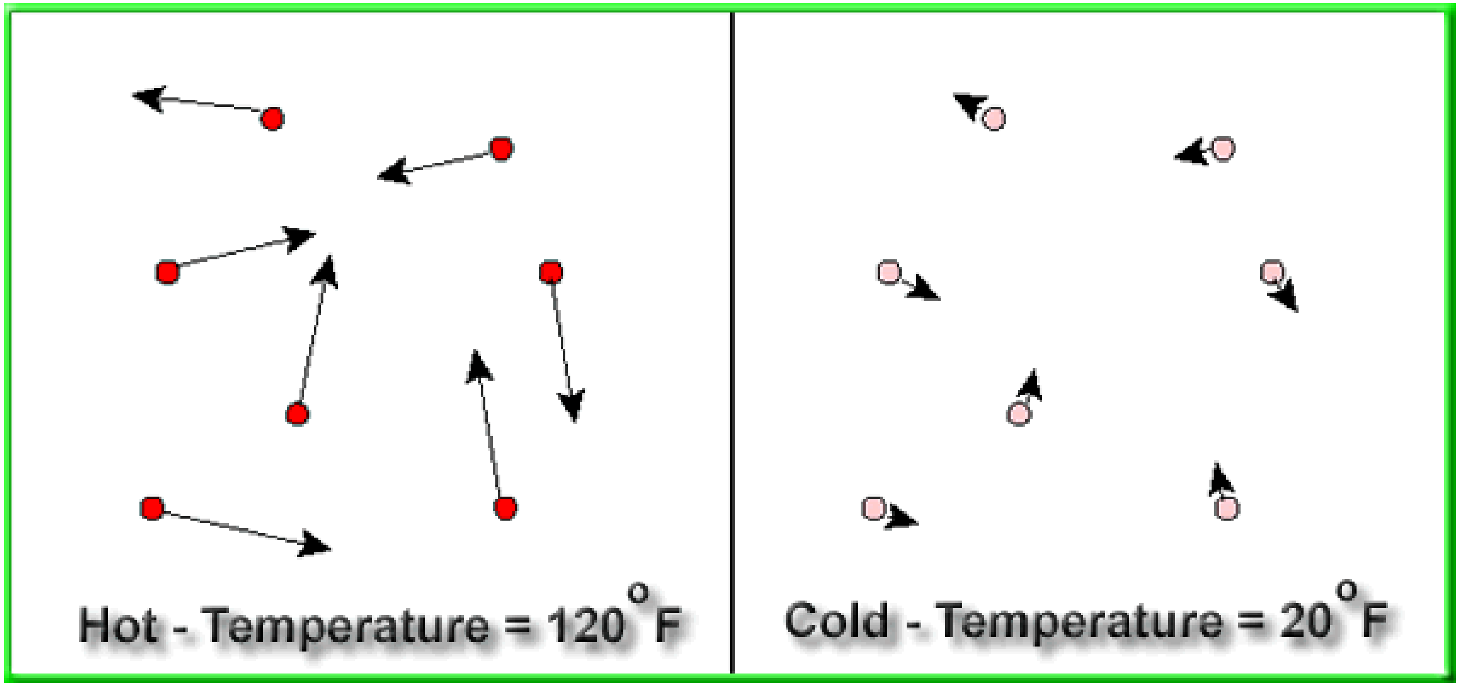
- affects the solubility of gaseous solutes. The solubility of a gas in any solvent increases as the pressure above the solution increases



3 common ways to increase the collisions between solute and solvent

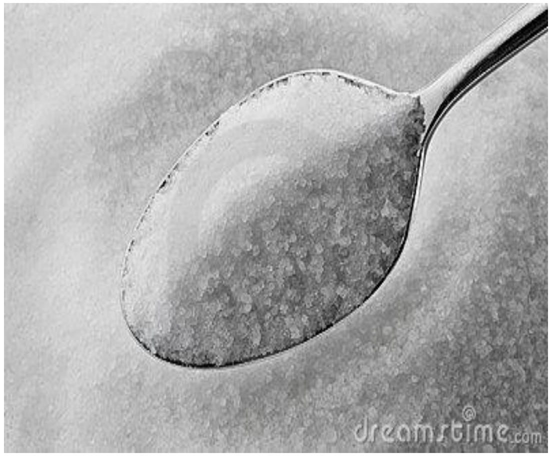
- Temperature
- Amount of Surface Area Exposed
- Agitation

- Temperature: raising the temperature increases the kinetic energy of the particles, resulting in more frequent and forceful collisions.



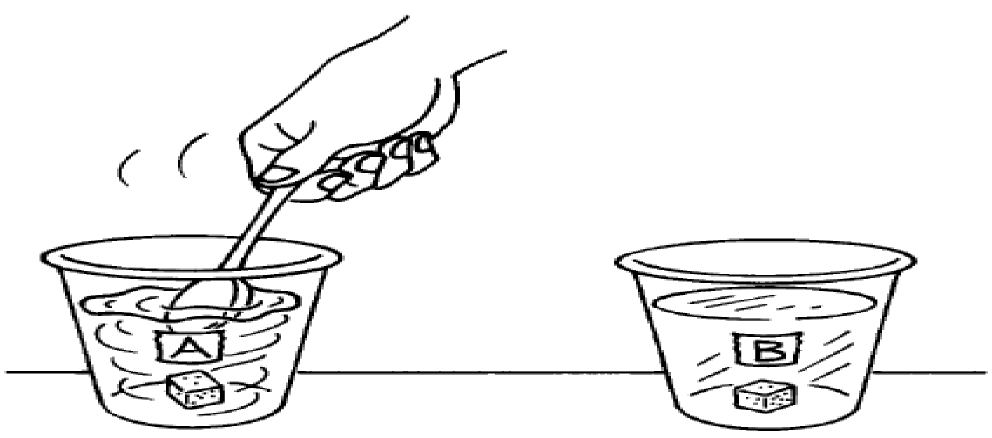
Amount of Surface Area Exposed

- Amount of Surface Area Exposed: breaking the solute into smaller pieces increases its surface area. A greater surface area allows more collisions to occur and therefore, faster

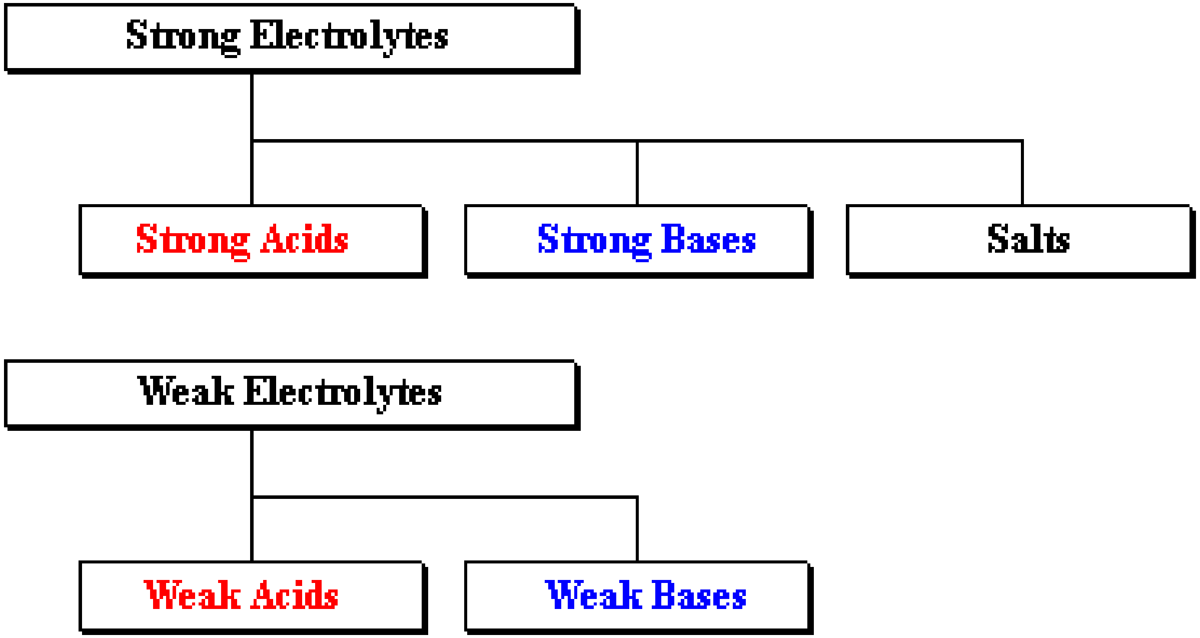


Agitation (mixing, stirring, etc.)

- Agitation: stirring moves dissolved solute particles away from the contact surfaces more quickly and thereby allows new collisions between solute and solvent particles to occur. Without stirring, solvated particles move away from the contact areas slowly.



Strong and weak electrolytes



Strong Electrolytes	Weak Electrolytes	Nonelectrolytes
HCl, HBr, HI	CH_3CO_2H	H_2O
$HClO_4$	HF	CH_3OH (methyl alcohol)
HNO_3		C_2H_5OH (ethyl alcohol)
H_2SO_4		$C_{12}H_{22}O_{11}$ (sucrose)
KBr		Most compounds of carbon (organic compounds)
NaCl		
NaOH, KOH		
Other soluble ionic compounds		

Dissociation of weak electrolytes

KtAn ↔ Kt^+ + An^-

For CH_3COOH we have $CH_3COOH \leftrightarrow CH_3COO^- + H^+$

$$K_g = \frac{\vec{k}}{\overleftarrow{k}} = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}.$$

if concentration of CH_3COOH is C, α – the degree of dissociation, so, concentrations of ions will be αC, and concentration of non dissociated molecules is (1−α)C, we have:

$$K_g = \frac{(\alpha C)^2}{(1-\alpha)C}$$

$$K_g = \frac{\alpha^2}{1-\alpha}C$$

for weak electrolytes α is too low, so we have:

$$K_g = \alpha^2 C,$$

$$\alpha = \sqrt{\frac{K_g}{C}}.$$

For strong electrolytes we use a (activity) instead of concentration

$$a = f \cdot C$$

Where ***f*** is activity coefficient, ***C*** is molarity of electrolyte

f of some ion depends on its charge (**Z**) and ionic strength of the solution (**I)**

$$I = ½ \, \Sigma \, C_i \, Z_i^2$$

Concentration is a measure of the amount of solute dissolved in a given amount of solvent.

PERCENT by MASS concentration :

the number of grams of solute per 100 grams of solution

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

Parts of solute per 100 parts of solution.

mass of solution = mass of solute + mass of solvent

The statement "5% aqueous solution of NaCl"

has the following meaning:

the solution contains 5g of NaCl in 100g

of solution.

The solution contains 5g of NaCl and

100-5=95g of H_2O.

MOLARITY (M): the number of moles of solute dissolved per liter of solution.

Note: Here, volume refers to the total volume of the solution in L, not the volume of the solvent.

- Molarity (M) = $\dfrac{\text{moles of solute}}{\text{volume of solution (L)}}$
- M is pronounced “molar”

Molal concentration (Molality)

Molality (C_m) is a concentration of a solution expressed as number of moles of solute per kilogram of solvent.

$$\text{molal } \mathit{concentration}\ (C_m) = $$

$$= \frac{\textit{number of moles solute}}{\textit{number of kilograms solvent}}$$

$$Cm = \frac{\upsilon}{m_{solvent}(kg)}$$

Mole Fraction

- A mole fraction equals the number of moles of solute or solvent in a solution divided by the total number of moles of solute and solvent

$$X_A = \frac{n_A}{n_A + n_B}$$

X_A = mole fraction of substance A

n_A = moles of A

n_B = moles of B

C_N - Normality

$$N = \frac{\text{Weight of solute in gram}}{\text{Equivalent mass} \times \text{Volume in litre}}$$

- Relation between normality and molarity.

  N × Eq. wt = Molarity × Molar mass

  N = Molarity × Valency

  N = Molarity × Number of H^+ or OH ion.

$$C_N = \frac{\upsilon}{f_{eq} \bullet V_{solute}(L)}$$

$$f_{eq} = \frac{1}{n}$$

$$\text{Normality (N)} = \frac{\textit{gram equivalent of the solute}}{\textit{volume of solution}\,(L)}$$

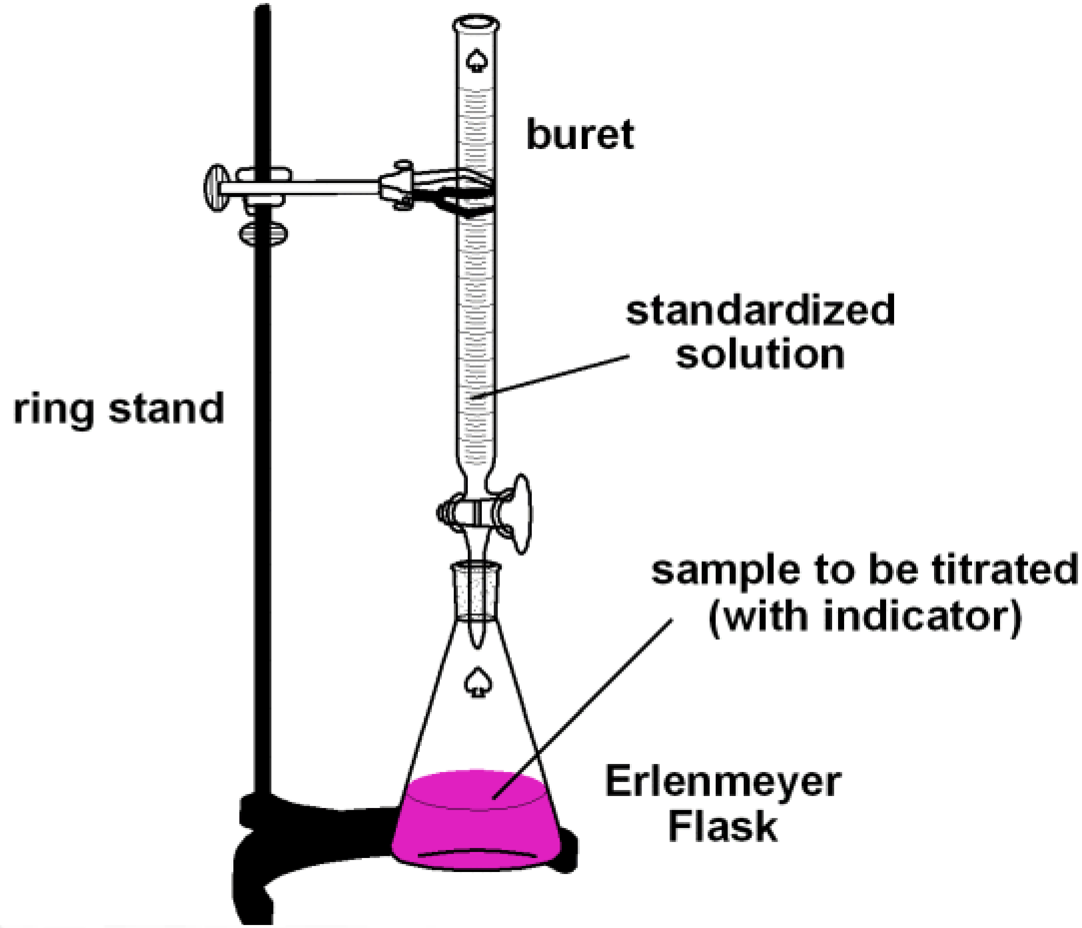
Titration

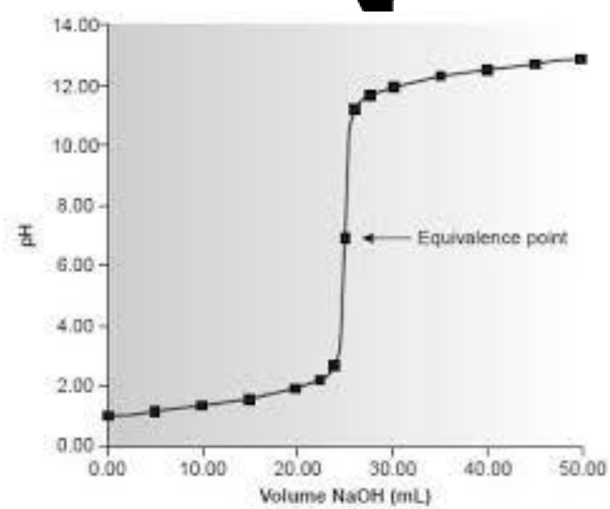
Law of equivalents

$V_1 x C_{N1} = V_2 x C_{N2}$

Titer shows mass of solute in grams dissolved in volume of solution in mL

$$T = \frac{mass\, in\, g}{V\, in\, mL}$$





Conclusions

MEASURING CONCENTRATION *

molarity = moles / liters ← SOLUTION VOLUME

molality = moles / kg ← SOLVENT MASS

mole fraction = moles / total moles

% solution = (grams / total grams) x 100 %

normality = equilivalents / liters ← MOLES OF H^+ OR OH^-

THE NUMERATORS IN ALL OF THE EQUATIONS REFER TO THE SOLUTE

More information you can find in our site:

chem.teset.sumdu.edu.ua

Information for students. Teacher Yanovska A.

Thank you for your attention!