

The Islamic University of Gaza
Faculty of Engineering
Civil Engineering Department

Environmental Chemistry
(ECIV 1204)

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W 05 – Lect. 1 & 2

SOLUTIONS

SOLUTIONS

- The Solution Process, Solubility and Concentration
- Standard Solutions and Titrations
- Solution Equilibria
- Colloidal Suspensions

- عملية الذوبان، الذوبانية والتركيز
- المحاليل القياسية والمعايير
- ائزان المحاليل
- المعلقات الغروية

Definitions

A solution is a homogeneous mixture of two or more substances, consisting of ions or molecules.

A colloid, although it also appears to be homogeneous, consists of comparatively large particles of a substance dispersed throughout another substance.

The solute is the dissolved substance. In the case of a solution of a gas or solid in a liquid, it is the gas or solid.

The solvent is the dissolving medium. Generally it is the component of greater amount.

المحلول هو خليط متجانس من مادتين أو أكثر، ويتكون من أيونات أو جزيئات

الغرواني، على الرغم من أنه يبدو متجانساً أيضاً، إلا أنه يتكون من جزيئات كبيرة نسبياً من مادة منتشرة في مادة أخرى.

المذاب هو المادة التي تذوب في السائل. في حالة محلول غاز أو مادة صلبة في سائل، يكون المذاب هو الغاز أو المادة الصلبة.

المذيب هو الوسط الذي يُذيب المادة. وعادةً ما يكون المكون الأكبر كميةً.

Definitions

dissolving the mixing of a solid with a liquid to make a solution.

mixture Two or more substances that are mixed together but are not chemically joined.

saturated A solution containing the maximum amount of solute that it can hold.

soluble A substance that can dissolve in a solvent.

solubility A measure of how much solute can dissolve in a solvent at a given temperature.

إذابة: مزيج من مادة صلبة وسائلة لتكوين محلول.

مزيج: مادتان أو أكثر ممزوجتان معًا دون أن تكونا مرتبطتين كيميائيًا.

مشبع: محلول يحتوي على أقصى كمية من المذاب التي يمكنه استيعابها.

قابل للذوبان: مادة تذوب في مذيب.

الذوبانية: مقياس لكمية المذاب التي يمكن إذابتها في مذيب عند درجة حرارة معينة.

Types of solutions: Solutions may exist as **gases, liquids, or solids**

a. Gaseous solutions: Fluids that dissolve in each other in all proportions are said to be **miscible fluids**.

If two fluids do not mix, they are said to be **immiscible**.

For example, air is a solution of oxygen, nitrogen, and smaller amounts of other gases.

The solubility of a gas in a liquid is directly proportional to its pressure (**Henry's Law $S_g = kP_g$**).

Henry's Law Constants (k) for Some Gases in Water at 25°C

Gas	$K, \text{mol} \times \text{L}^{-1} \times \text{atm}^{-1}$
O ₂	1.28×10^{-3}
CO ₂	3.38×10^{-2}
H ₂	7.90×10^{-4}
CH ₄	1.34×10^{-3}
N ₂	6.48×10^{-4}
NO	2.0×10^{-4}

أنواع المحاليل: قد توجد المحاليل في صورة غازات أو سوائل أو مواد صلبة.

أ. المحاليل الغازية: تُسمى الموائع التي تذوب في بعضها البعض بأي نسبة موائع قابلة للامتزاج.

أما إذا لم يمتزج مائعان، فيُقال إنهما غير قابلين للامتزاج.

على سبيل المثال، الهواء محلول من الأكسجين والنيتروجين وكميات أقل من غازات أخرى.

تناسب ذوبانية الغاز في الموائع تناسبًا طرديًا مع ضغطه (قانون هنري: $S_g = kP_g$).

Henry's Law Constants (k) for Some Gases in Water at 25°C

Gas	$K, \text{mol} \times \text{L}^{-1} \times \text{atm}^{-1}$
O ₂	1.28×10^{-3}
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NO	2.0×10^{-4}

b. Liquid solutions are the most common types of solutions found in the chemistry lab.

Many inorganic compounds are soluble in water or other suitable solvents.

Rates of chemical reactions increase when the likelihood of molecular collisions increases.

This increase in molecular collisions is enhanced when molecules move freely in solution.

Many factors affect solubility, such as **temperature** and, in some cases, **pressure**

There is a limit as to how much of a given solute will dissolve at a given temperature.

A saturated solution is one holding as much solute as is allowed at a stated temperature

ب. المحاليل السائلة هي أكثر أنواع المحاليل شيوعاً في مختبر الكيمياء.

تذوب العديد من المركبات غير العضوية في الماء أو المذيبات المناسبة الأخرى.

تزداد سرعة التفاعلات الكيميائية مع ازدياد احتمالية تصادم الجزيئات.

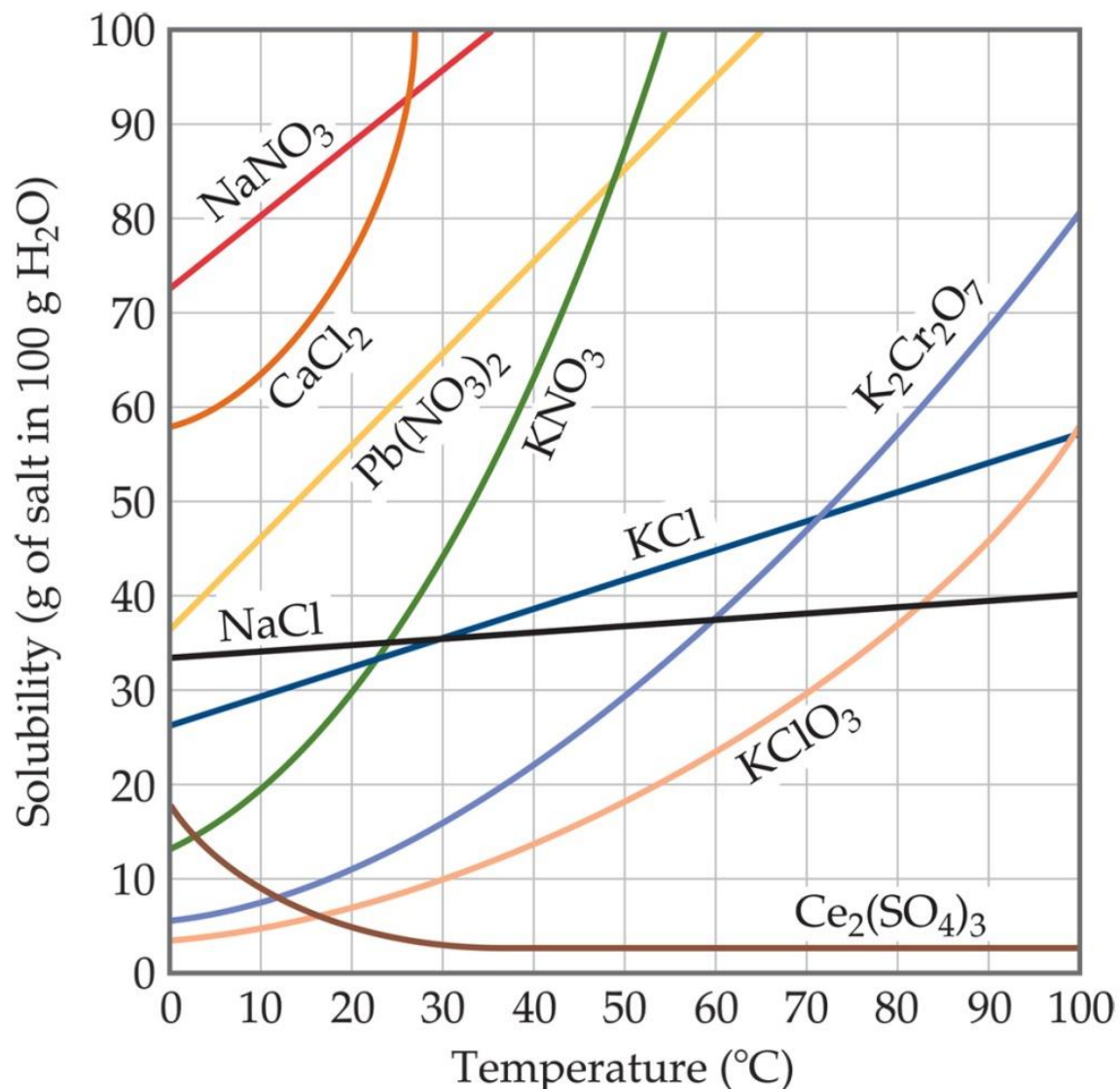
ويزداد هذا التصادم عندما تتحرك الجزيئات بحرية في المحلول.

تؤثر عوامل عديدة على الذوبانية، مثل درجة الحرارة، وفي بعض الحالات، الضغط.

هناك حد أقصى لكمية المذاب التي يمكن إذابتها عند درجة حرارة معينة.

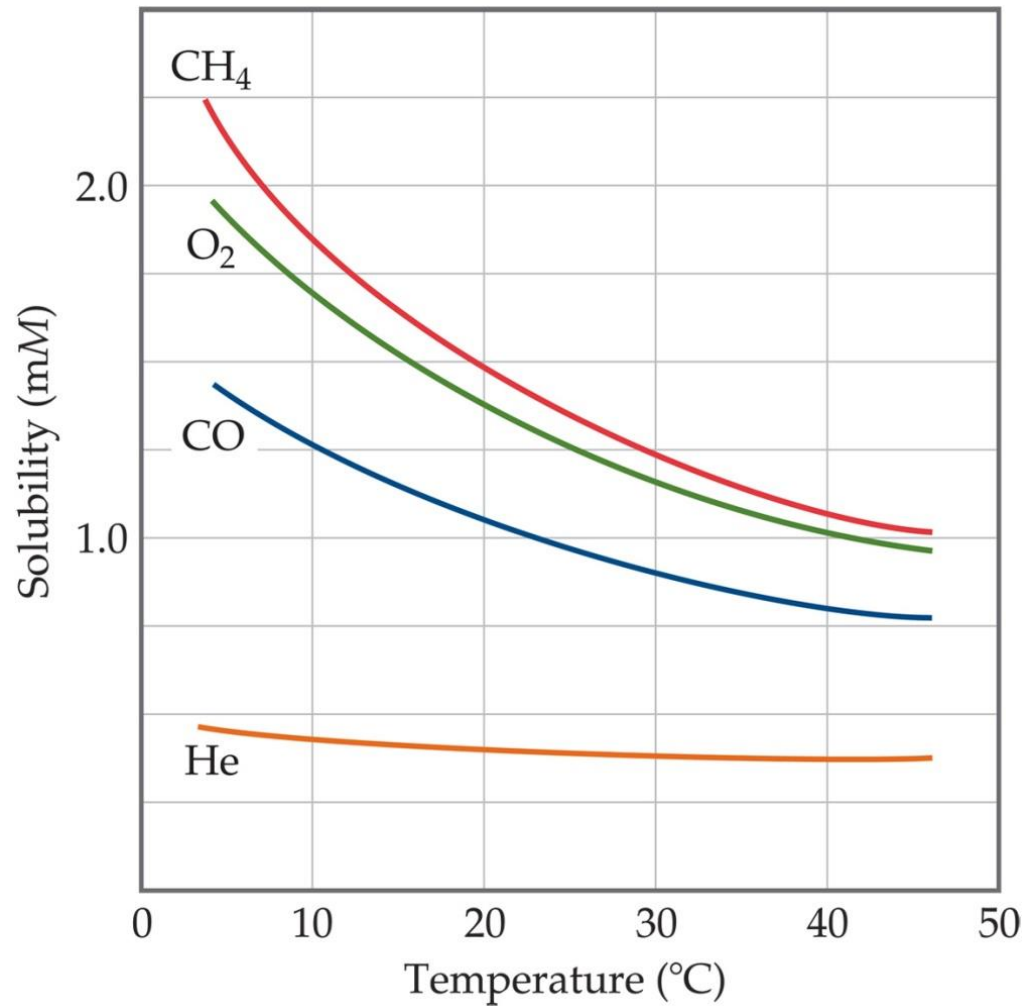
المحلول المشبع هو المحلول الذي يحتوي على أكبر كمية ممكنة من المذاب عند درجة حرارة محددة.

The solubility of solid solutes in liquid solvents increases with increasing temperature.



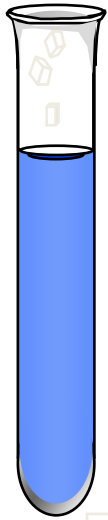
The solubility of gases solutes in liquid solvents decrease with increasing temperature

Warm lakes have less O₂ dissolved in them than cool lakes

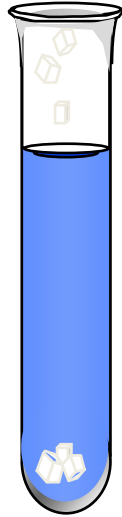


Solubility

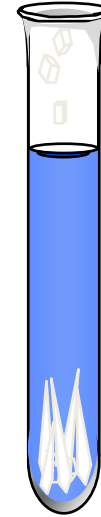
UNSATURATED SOLUTION
more solute dissolves



SATURATED SOLUTION
no more solute dissolves



SUPERSATURATED SOLUTION
becomes unstable, crystals form



concentration

Unsaturated: Less than the maximum amount of solute for that temperature is dissolved in the solvent.

Saturated: Solvent holds as much solute as is possible at that temperature.

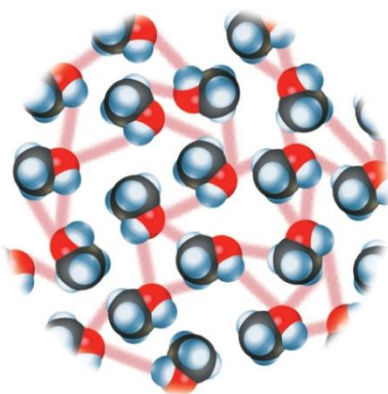
Supersaturated: Solvent holds more solute than is normally possible at that temperature. These solutions are unstable; crystallization can usually be stimulated by adding a “seed crystal” or scratching the side of the flask.

Factors affecting the solubility

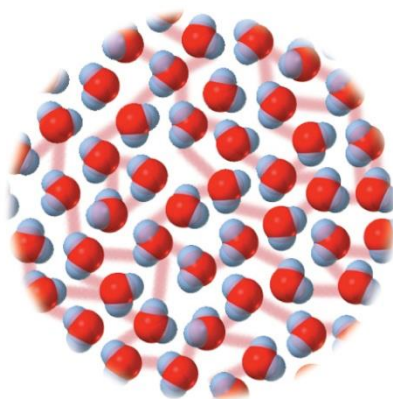
Like Dissolves Like

Two substances form a solution

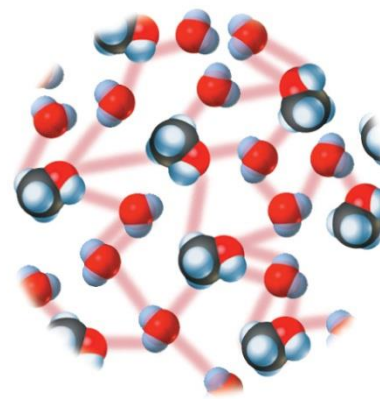
- when there is an attraction between the particles of the solute and solvent
- when a polar solvent (such as water) dissolves polar solutes (such as sugar) and/or ionic solutes (such as NaCl)
- when a nonpolar solvent such as hexane (C_6H_{14}) dissolves nonpolar solutes such as oil or grease



Methanol (CH_3OH) solute



Water solvent



Methanol-water solution
with hydrogen bonding

Factors affecting the solubility

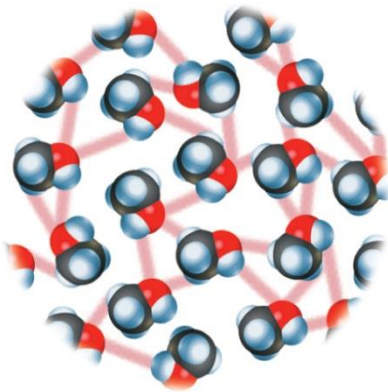
Like Dissolves Like



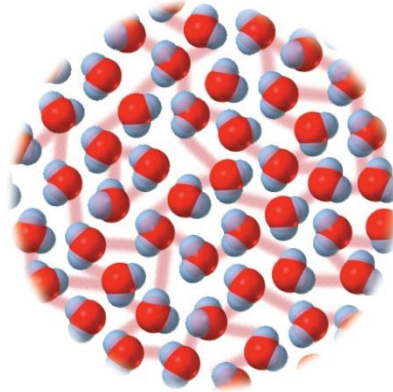
• عندما يكون هناك تجاذب بين جزيئات المذاب والمذيب

• عندما يذيب مذيب قطبي (مثل الماء) مواد مذابة قطبية (مثل السكر) و/أو مواد مذابة أيونية (مثل كلوريد الصوديوم)

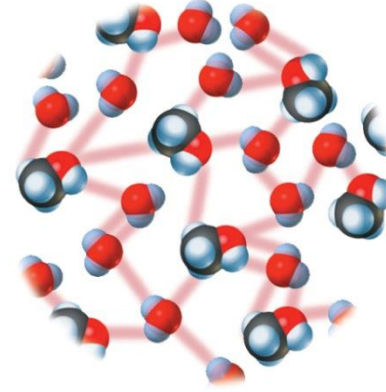
• عندما يذيب مذيب غير قطبي (مثل الهكسان) مواد مذابة غير قطبية (مثل الزيت أو الشحم)



Methanol (CH_3OH) solute



Water solvent



Methanol-water solution
with hydrogen bonding

Important Organic Solvents

Solvent	Solvent Use (may have many other nonsolvent uses)	Approximate Annual U.S. Production, millions of kilograms
Acetone	Solvent for spinning cellulose acetate fibers and for spreading paints and other protective coatings.	1,000
Benzene	Dissolves grease and other organic compounds.	6,500
Perchloroethylene	Best solvent for dry cleaning, also used for degreasing metals and extraction of fats.	125
Stoddard solvent	Mixture of alkanes and aromatic hydrocarbons containing from 7 to 12 C atoms per molecule used as a solvent for organic materials	17
Toluene	Dissolves grease and other organic materials; substitute for benzene, but not so toxic	2,700
Trichloroethylene	Vapor degreasing of metal parts; solvent for greases, oils, fats, waxes, and tars; fabric cleaner; waterless dyeing; ingredient of formulations of adhesives, lubricants, paints, varnishes, paint strippers	90

c. Solid solutions of metals are referred to as alloys (سبائك).

- Brass is an alloy composed of copper and zinc. ج. تُعرف المحاليل الصلبة للمعادن باسم السبائك.
- Bronze is an alloy of copper and tin. • النحاس الأصفر سبيكة تتكون من النحاس والزنك.
- Pewter is an alloy of zinc and tin (قصدير). • البرونز سبيكة تتكون من النحاس والقصدير.
- البيوتر سبيكة تتكون من الزنك والقصدير.



Ways of Expressing Concentration

a. Molarity

The **molarity** of a solution is the moles of solute in a liter of solution.

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

Example, 0.20 mol of ethylene glycol dissolved in enough water to give 2.0 L of solution has a molarity of

$$\frac{0.20 \text{ mol ethylene glycol}}{2.0 \text{ L solution}} = 0.10 \text{ M}$$

b. Mass percentage of solute

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

Example, a 3.5% sodium chloride solution contains 3.5 grams NaCl in 100.0 grams of solution.

c. Molality

The **molality** of a solution is the moles of solute per kilogram of solvent.

$$\text{molality}(\mathbf{m}) = \frac{\text{moles of solute}}{\text{kilograms of solvent}}$$

Example 0.20 mol of ethylene glycol dissolved in 2.0×10^3 g (= 2.0 kg) of water has a molality of

$$\frac{0.20 \text{ mol ethylene glycol}}{2.0 \text{ kg solvent}} = 0.10 \mathbf{m}$$

d. Formality moles per kilogram of solution (mol/ kg Solution)

$$\text{Formality} = \frac{\text{Moles of solute}}{\text{Kilogram of Solution}}$$

Example: What is the molality of a solution containing 5.67 g of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, dissolved in 25.2 g of water?

First, convert the mass of glucose to moles

$$5.67 \text{ g } \text{C}_6\text{H}_{12}\text{O}_6 \times \frac{1 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6}{180.2 \text{ g } \text{C}_6\text{H}_{12}\text{O}_6} = 0.0315 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6$$

divide it by the kilograms of solvent (water).

$$\text{Molality} = \frac{0.0315 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6}{25.2 \times 10^{-3} \text{ kg solvent}} = 1.25 \text{ m } \text{C}_6\text{H}_{12}\text{O}_6$$

f. Mole Fraction

The **mole fraction** of a component “A” (χ_A) in a solution is defined as the moles of the component substance divided by the total moles of solution (that is, moles of solute and solvent).

$$\chi_A = \frac{\text{moles of substance A}}{\text{total moles of solution}}$$

For example, 1 mol ethylene glycol in 9 mol water gives a mole fraction for the ethylene glycol of $1/10 = 0.10$.

Example: An aqueous solution is 0.120 m glucose. What are the mole fractions of each of the components?

A 0.120 *m* solution contains 0.120 mol of glucose in 1.00 kg of water. After converting the 1.00 kg H₂O into moles, we can calculate the mole fractions.

$$1.00 \times 10^3 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.0 \text{ g}} = 55.6 \text{ mol H}_2\text{O}$$

$$\chi_{\text{glucose}} = \frac{0.120 \text{ mol}}{(0.120 + 55.6) \text{ mol}} = 0.00215$$

$$\chi_{\text{water}} = \frac{55.6 \text{ mol}}{(0.120 + 55.6) \text{ mol}} = 0.998$$

j. Parts per Million and Parts per Billion

Parts per Million (ppm)

$$\text{ppm} = \frac{\text{mass of A in solution}}{\text{total mass of solution}} \times 10^6 = \text{mg/l}$$

Parts per Billion (ppb)

$$\text{ppb} = \frac{\text{mass of A in solution}}{\text{total mass of solution}} \times 10^9 = \mu\text{g/l}$$

Physical Properties of Solutions

The physical properties of solutions are those properties that depend on solute concentration.

1. vapor pressure reduction: Chemists have observed that the vapor pressure of a volatile solvent can be reduced by the addition of a nonvolatile solute.

Raoult's law states that the vapor pressure of a solution containing a nonelectrolyte nonvolatile solute is proportional to the mole fraction of the solvent.

$$P_{\text{solution}} = (P_{\text{solvent}}^0)(\chi_{\text{solvent}})$$

where

P_{solution} is the vapor pressure of the solution,

χ_{solvent} is the mole fraction of the solvent,

P_{solvent}^0 is the pure vapor pressure of the solvent.

If a solution contains a **volatile solute**, then each component contributes to the vapor pressure of the solution.

$$P_{\text{solution}} = (P^{\circ}_{\text{solvent}})(\chi_{\text{solvent}}) + (P^{\circ}_{\text{solute}})(\chi_{\text{solute}})$$

- The vapor pressure of the solution is the sum of the partial vapor pressures of the solvent and the solute.
- Volatile compounds can be separated using fractional distillation.

2. Boiling Point Elevation: The **normal boiling point** of a liquid is the temperature at which its vapor pressure equals 1 atm.

- Because vapor pressure is reduced in the presence of a nonvolatile solute, a greater temperature must be reached to achieve boiling
- The **boiling-point elevation**, ΔT_b , is found to be proportional to the **molal concentration**, c_m , of the solution.

$$\Delta T_b = (K_b)(c_m)$$

The constant of proportionality, K_b (called the **boiling-point-elevation constant**), depends only on the solvent.

3. Freezing Point Depression

- The **freezing-point depression**, ΔT_f , is a colligative property equal to the freezing point of the pure solvent minus the freezing point of a solution.
- Freezing-point depression is also proportional to the **molal concentration**, c_m , of the solute.

$$\Delta T_f = (K_f)(c_m)$$

- where K_f , the **freezing-point-depression constant**, depends only on the solvent.

Molal Boiling Point Elevation/Freezing Point Depression Constants for Various Solvents

Solvents				
<u>Solvent</u>	<u>Normal BP (°C)</u>	<u>K_b (°C/m)</u>	<u>Normal FP (°C)</u>	<u>K_f (°C/m)</u>
H ₂ O	100.0	0.52	0.0	1.86
Benzene, C ₆ H ₆	80.1	2.53	5.5	5.12
Ethanol, C ₂ H ₅ OH	78.4	1.22	-114.6	1.99
CCl ₄	76.8	5.02	-22.3	29.8
Chloroform, CHCl ₃	61.2	3.63	-63.5	4.68

Example: An aqueous solution is 0.0222 m in glucose. What are the boiling point and freezing point for this solution?

From the Table K_b and K_f for water as 0.512 °C/m and 1.86 °C/m, respectively. Therefore,

$$\Delta T_b = (K_b)(c_m) = 0.512^\circ \text{C} / m \times 0.0222 m = 0.0114^\circ \text{C}$$

$$\Delta T_f = (K_f)(c_m) = 1.86^\circ \text{C} / m \times 0.0222 m = 0.0413^\circ \text{C}$$

The boiling point of the solution is 100.011°C and the freezing point is −0.041°C.

4. Osmotic pressure is a colligative property of a solution equal to the pressure that, when applied to the solution, just stops osmosis.

osmotic pressure, π , of a solution is related to the **molar concentration** of the solute.

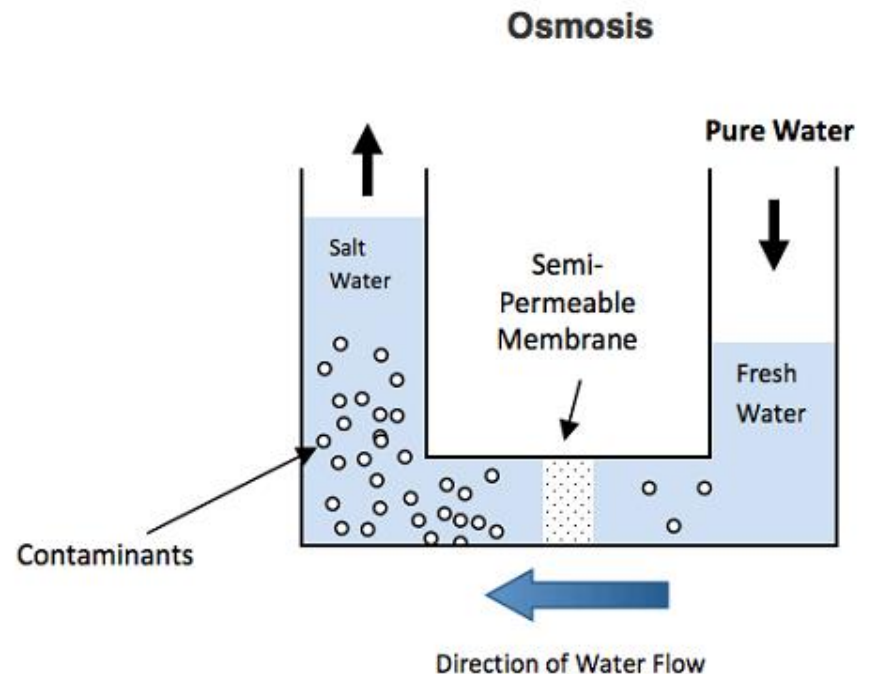
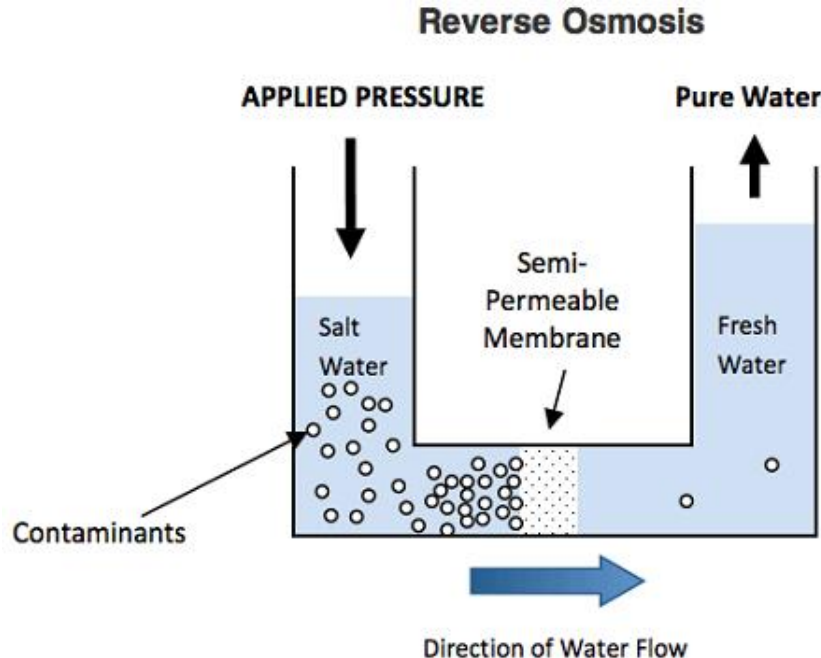
$$\pi = iRTM$$

I = The van't Hoff factor, symbol i , expresses how many ions and particles are formed (on an average) in a solution from one formula unit of solute,

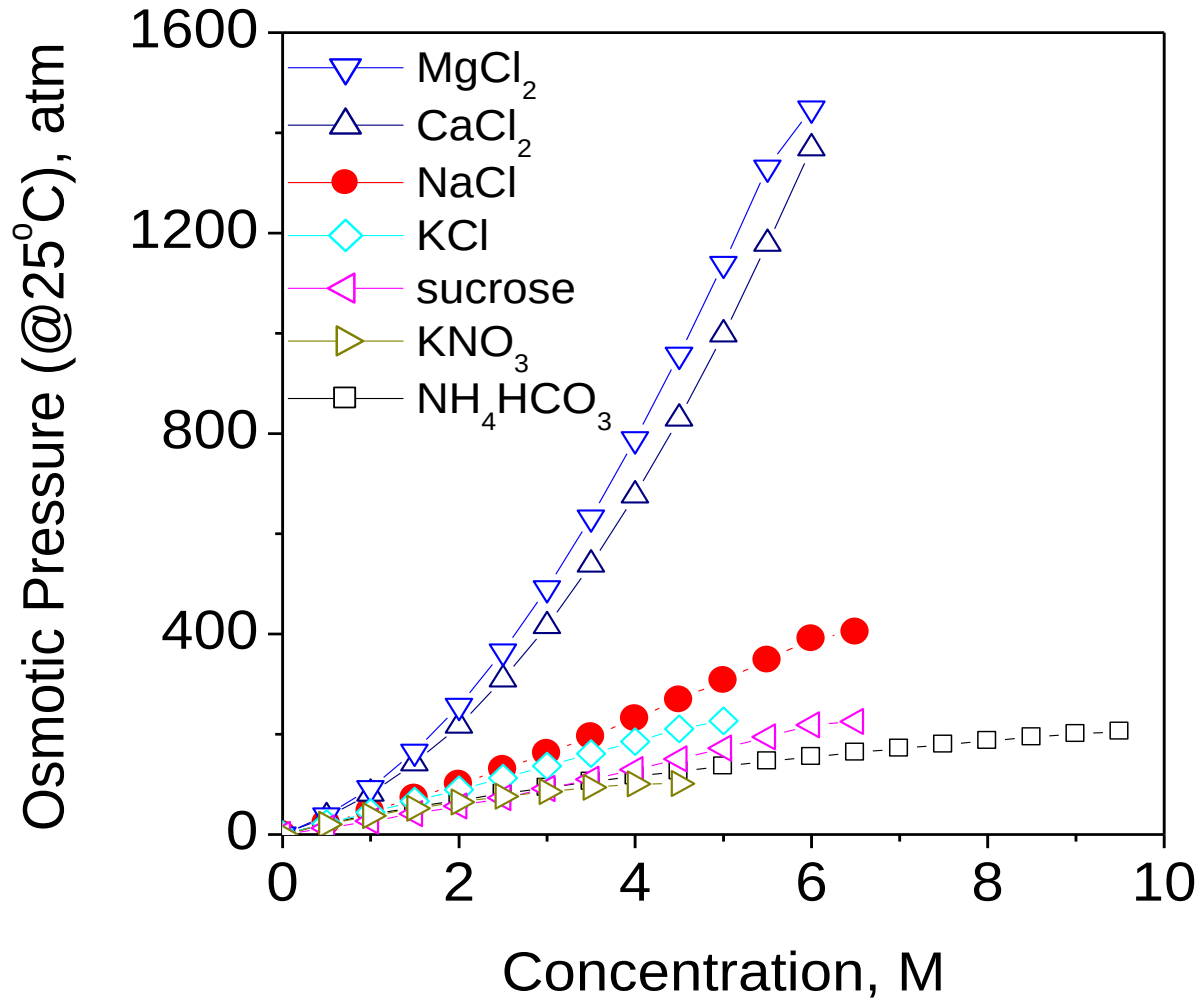
M is the concentration in mole.

R is the ideal gas constant ($0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$)

T is the absolute temperature (Kelvin).



Osmotic Pressure for different solutions



STANDARD SOLUTIONS AND TITRATIONS

Titration: is a method for determining the concentration of a solution by reacting a known volume of that solution with a solution of known concentration.

If you wish to find the concentration of an acid solution, you would titrate the acid solution with a solution of a base of known concentration.

You could also titrate a base of unknown concentration with an acid of known concentration.

Analyte: the solution of unknown concentration but known volume.

المعايرة: هي طريقة لتحديد تركيز محلول ما عن طريق تفاعل حجم معلوم منه مع محلول معلوم التركيز.

إذا أردت معرفة تركيز محلول حمضي، تُعاير هذا المحلول الحمضي بمحلول قاعدة معلوم التركيز.

كما يُمكن معايرة قاعدة مجهولة التركيز بحمض معلوم التركيز.

المحلول المراد تحليله: محلول مجهول التركيز ولكن حجمه معلوم.

STANDARD SOLUTIONS AND TITRATIONS

Titrant: the solution of known concentration.



Equivalence Point: the point at which exactly the right volume of titrant has been added to complete the reaction.

End point: Related to the physical sign that associate with the condition of chemical equivalence. Ideally, the end point and equivalent one coincide. (variation may be to color change of indicator)

Indicator: substance that changes color when an excess of titrant has been added (phenolphthalein, bromocresol green).

المحلول المعايير: محلول معلوم التركيز.

المحلول المراد تحليله + المحلول المعايير ← النواتج

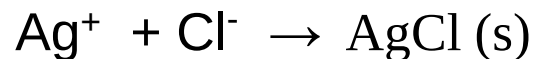
نقطة التكافؤ: النقطة التي يُضاف عندها الحجم الصحيح تمامًا من المحلول المعايير لإتمام التفاعل.

نقطة النهاية: علامة فيزيائية تدل على التكافؤ الكيميائي. في الحالة المثالية، تتطابق نقطة النهاية مع نقطة التكافؤ. (قد يختلف ذلك بتغير لون الكاشف).

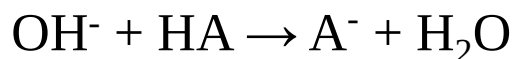
الكاشف: مادة يتغير لونها عند إضافة كمية زائدة من المحلول المعايير (مثل الفينول فتالين، أو بروموكريسول الأخضر).

Types of Titrimetry

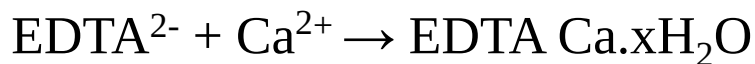
1- Precipitation:



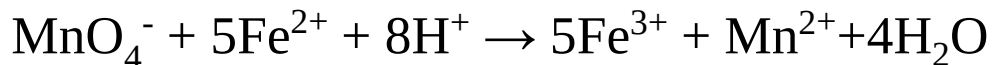
2- Acid Base titration:



3- Complex formation



4- Oxidation Reduction



Calculating the results of Titration

Needs: the volume and molarity of the titrant



(Titrant) (substance titrated)

No. of m.moles of A = Volume of A titrated (ml) . Molarity of A (M) Or $\text{mmoles}_A = \text{ml}_A \cdot (M_A)$

No. of m.moles of B is obtained by multiplying the No. of mmoles of A by the combining ratio (b/a)

$$\text{mmoles}_B = \text{mmoles}_A \times (b/a) = \text{ml}_A \times (M_A) \times (b/a)$$

$$M_B = \frac{\text{ml}_A \times M_A}{\text{ml}_B} \times \frac{b}{a}$$

Example 1: Calculate the molar concentration of the HCl if 50.0 mL (0.0500 L) of HCl solution were titrated with 0.0100 M standard NaOH, requiring 40.0 (0.0400 L) mL of the titrant solution.

$$M = \frac{\text{Moles solute}}{\text{Volume solution}}$$

In this case, as shown by Reaction $\text{HCl}_{(\text{aq})} + \text{NaOH}_{(\text{aq})} \longrightarrow \text{NaCl}_{(\text{aq})} + \text{H}_2\text{O}$

the number of moles of HCl in the sample exactly equals the number of moles of NaOH at the end point, which leads to the relationship

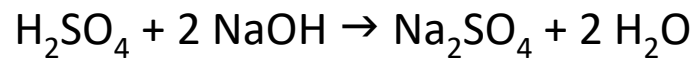
$$M_{\text{HCl}} \times \text{Volume HCl} = M_{\text{NaOH}} \times \text{Volume NaOH}$$

where the subscript formulas denote HCl and NaOH solutions. This equation can be rearranged and values substituted into it to give the following:

$$M_{\text{HCl}} = \frac{M_{\text{NaOH}} \times \text{Volume NaOH}}{\text{Volume HCl}}$$

$$M_{\text{HCl}} = \frac{0.0100 \text{ mol/L} \times 0.0400 \text{ L}}{0.0500 \text{ L}} = 0.00800 \text{ mol/L}$$

Example 2: How many ml of 0.25 M NaOH will react with 10.0 ml of 0.10 M H₂SO₄



$$\text{mmol NaOH} = 2 \text{ mmol H}_2\text{SO}_4$$

$$\left(\frac{1}{2}\right) \times M_{\text{NaOH}} \times V_{\text{mL}(\text{NaOH})} = M_{(\text{H}_2\text{SO}_4)} \times V_{\text{mL}(\text{H}_2\text{SO}_4)}$$

$$0.25 \times V_{\text{mL}} = 2 \times 0.10 \times 10$$

$$V_{\text{mL}} = 8 \text{ ml}$$

Example 3: 0.4671 g sample containing NaHCO_3 (FW = 84.01 mg/mmol) was dissolved and titrated with 0.1067 M HCl requiring 40.72 mL. Find the percentage of sodium bicarbonate in the sample.

write the equation in order to identify the stoichiometry



Now it is clear that the number of mmol of sodium bicarbonate is equal to the number of mmol HCl from the equation:

$$M_1 \cdot V_1 (\text{HCl}) = M_2 \cdot V_2 (\text{NaHCO}_3)$$

$$\text{mmol NaHCO}_3 = \text{mmol HCl}$$

$$\text{mmol} = M \times V_{\text{mL}}$$

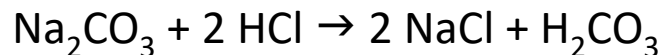
$$\text{mmol NaHCO}_3 = (0.1067 \text{ mmol/ml}) \times 40.72 \text{ mL} = 4.345 \text{ mmol}$$

$$\text{mg NaHCO}_3 = 4.345 \text{ mmol} \times (84.01 \text{ mg/mmol}) = 365.01 \text{ mg}$$

$$\% \text{ NaHCO}_3 = (365.01 \times 10^{-3} \text{ g} / 0.4671 \text{ g}) \times 100 = 78.14\%$$

Example 4: A 0.1876 g of pure sodium carbonate (FW = 106 mg/mmol) was titrated with approximately 0.1 M HCl requiring 35.86 ml. Find the molarity of HCl.

The first thing writing the equation of the reaction.



from the equation

2 mmol HCl react with 1 mmol carbonate

mmol HCl = 2 mmol Na_2CO_3 **or**

$$M_{\text{HCl}} \times V_{\text{ml}} \times 1/2 = \text{mmol Na}_2\text{CO}_3$$

substitute for mmol carbonate by mg carbonate/FW carbonate. This gives

$$M_{\text{HCl}} \times 35.86 = 2 \times 187.6 \text{ mg} / (106 \text{ mg/mmol})$$

$$M_{\text{HCl}} = 0.09872 \text{ M}$$

Colloids

A colloid: is a dispersion of particles of one substance (the dispersed phase) throughout another substance or solution (the continuous phase).

A colloid differs from a true solution in that the dispersed particles are larger than normal molecules.

Tyndall effect: The scattering of light by colloidal-size particles.

الغرواني: هو عبارة عن تشتت لجزيئات مادة ما (الطور المنتشر) في مادة أخرى أو محلول (الطور المستمر).

يختلف الغرواني عن المحلول الحقيقي في أن جزيئاته المنتشرة أكبر من جزيئات المادة العادية.

تأثير تيندال: تشتت الضوء بواسطة جزيئات ذات حجم غرواني.

Colloids

Types of Colloids

A **sol** consists of solid particles dispersed throughout a liquid.

An **aerosol** consists of liquid droplets or solid particles dispersed throughout a gas.

An **emulsion** consists of liquid droplets dispersed throughout another liquid

أنواع الغروانيات

المحلول الغرواني: يتكون من جزيئات صلبة منتشرة في سائل.

الهباء الجوي: يتكون من قطرات سائلة أو جزيئات صلبة منتشرة في غاز.

المستحلب: يتكون من قطرات سائلة منتشرة في سائل آخر.

Colloids

Hydrophilic and Hydrophobic Colloids

A **hydrophilic colloid (Water love)** is a colloid in which there is a strong attraction between the dispersed phase and the continuous phase (water).

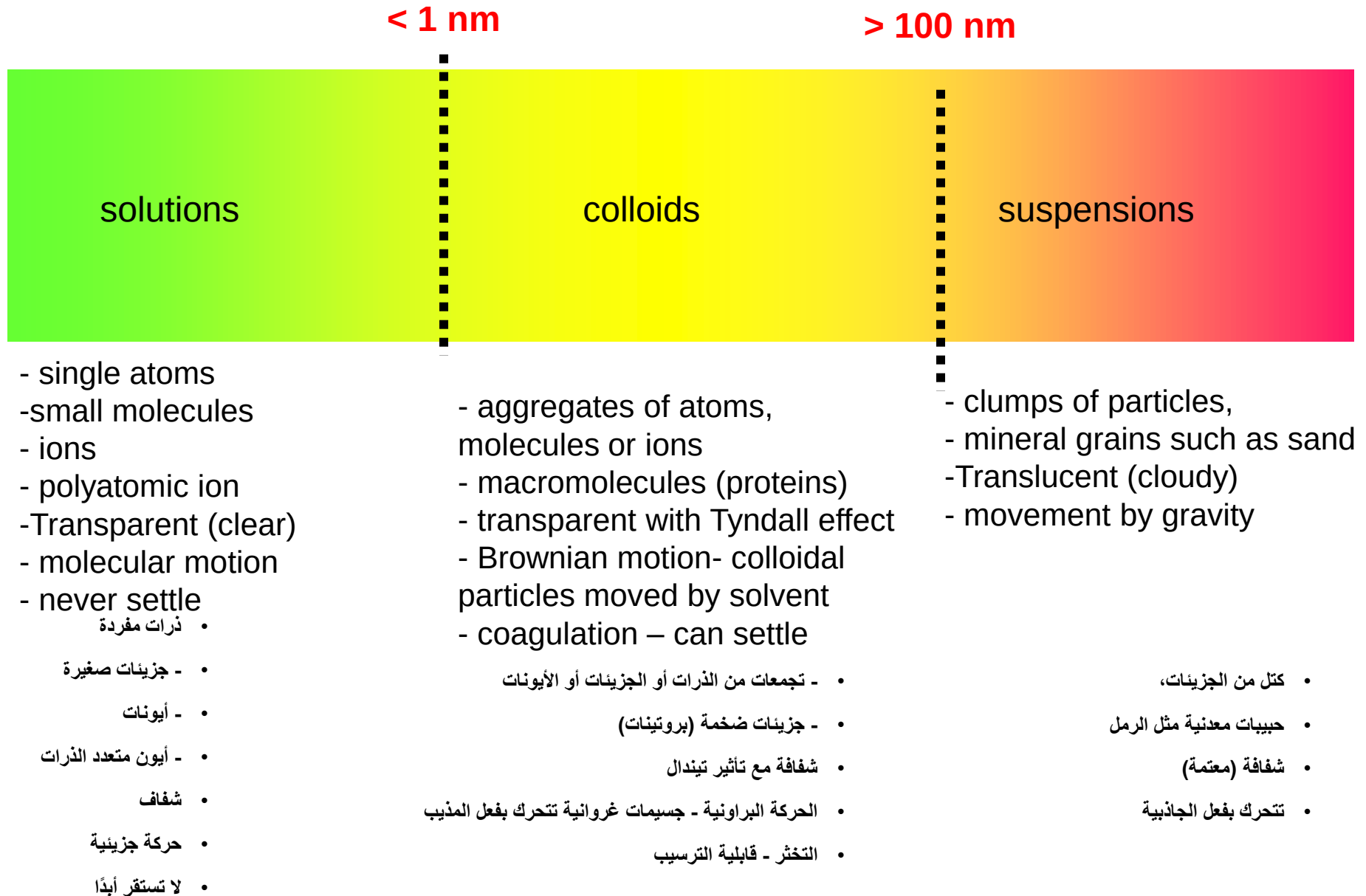
A **hydrophobic colloid (Water hate)** is a colloid in which there is a lack of attraction of the dispersed phase for the continuous phase (water).

الغرويات المحبة للماء والكارهة للماء

الغرواني المحب للماء هو غرواني يتميز بوجود تجاذب قوي بين الطور المنتشر والطور المستمر (الماء).

أما الغرواني الكاره للماء فهو غرواني لا ينجذب فيه الطور المنتشر إلى الطور المستمر (الماء).

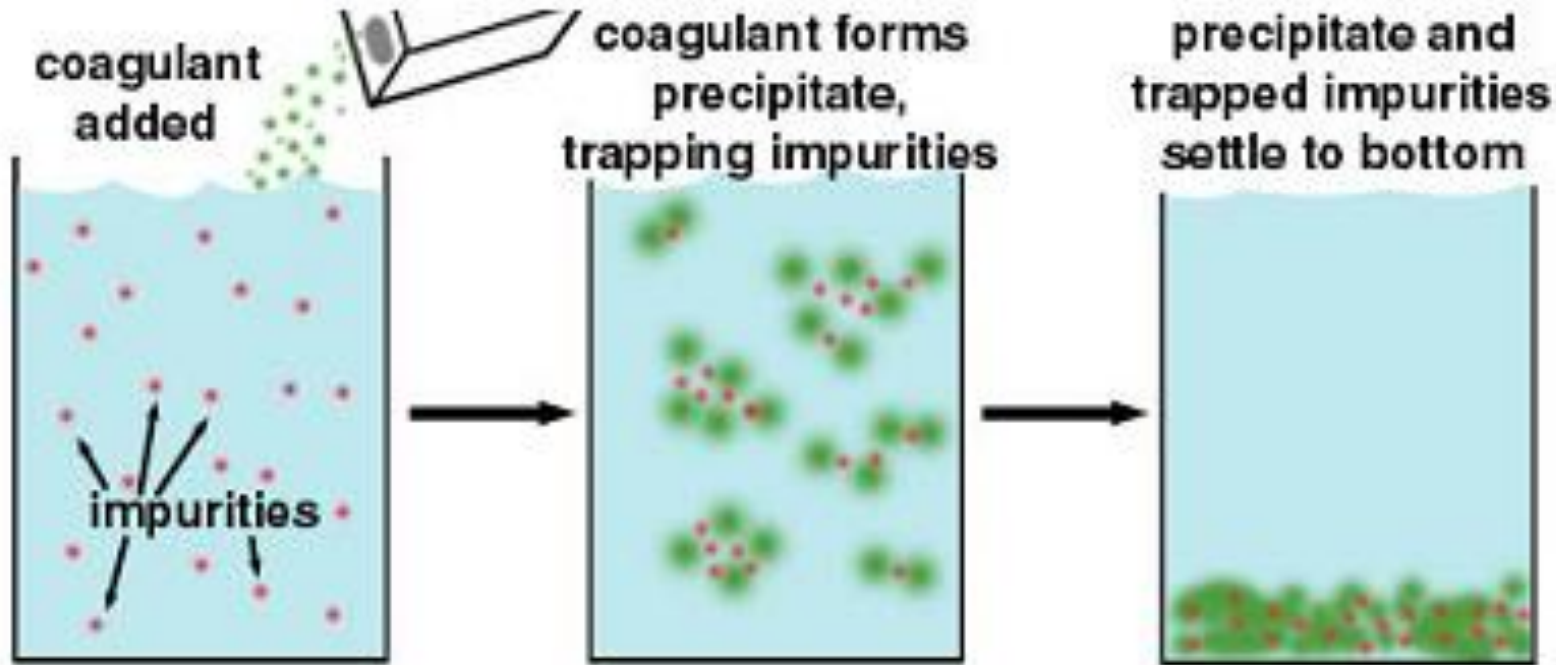
Comparison of Solutions, Colloids, and Suspensions



Coagulation

Coagulation is the process by which the dispersed phase of a colloid is made to aggregate and thereby separate from the continuous phase.

التخثر هو العملية التي يتم من خلالها جعل الطور المنتشر من الغرواني يتجمع وبالتالي يفصل عن الطور المستمر.



Homework No. 4

1. Determine the vapor pressure of a solution of 92.1 g of glycerin, $\text{C}_3\text{H}_5(\text{OH})_3$, in 184.4 g of ethanol at 40 °C. The vapor pressure of pure ethanol is 0.178 atm at 40 °C, and glycerin is essentially nonvolatile.
2. Find the boiling point of a solution of 92.1 g of iodine in 800.0 g of chloroform.
3. Calculate the freezing point of a solution of 0.724 g of calcium chloride in 175 g of water, assuming complete dissociation by the solute.
4. Determine the osmotic pressure of a solution with a volume of 0.750 L that contains 5.0 g of methanol ($i=1$) in water at 37 °C.
5. List the following aqueous solutions in order of their expected freezing points: 0.050 m CaCl_2 , 0.15 m NaCl , 0.10 m HCl , 0.050 m $\text{HC}_2\text{H}_3\text{O}_2$, and 0.10 m $\text{C}_{12}\text{H}_{22}\text{O}_{11}$.
6. A solution of 4.00 g of a nonelectrolyte dissolved in 55.0 g of benzene is found to freeze at 2.32 °C. What is the molar mass of this compound?
7. A solution of 35.7 g of a nonelectrolyte in 220.0 g of chloroform has a boiling point of 64.5 °C. What is the molar mass of this compound?