

General and Inorganic Chemistry Department,
National Technical University “Kharkiv Polytechnic Institute”

PROPERTIES OF SOLUTIONS



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Kharkiv 2026



DEFINITIONS

- **Solution** is a variable composition homogeneous system being in chemical equilibrium

- Classification

- STATE OF AGGREGATION: gas, liquid, solid (amorphous, crystal)

- The mechanical mixtures and colloids have special names

Other comp.	Basic component		
	gas	liquid	solid
gas	–	foam	porous systems
liquid	fog	emulsion	capillars
solid	smoke, aerosol	suspension	solid solution

- Gel is a 3D-structure formed by polymeric component with cavities in this structure filled with another component.
- Sol is dispersed system based on a liquid (lyosol) or gas (aerosol).



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 - STATE OF AGGREGATION: gas, liquid, solid (amorphous, crystal)
 - DEGREE OF DISPERSION:

mechanical mixtures ($d \geq 10^3$ nm)

colloids ($10^{-2} < d < 10^3$ nm)

fine solutions ($d < 10^{-2}$ nm)

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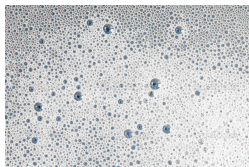
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gel



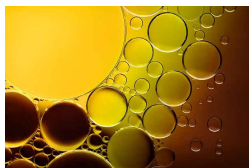
foam



porous pumice



fog



emulsion



capillars



smoke



suspension



solid solution



SOLUTION COMPOSITION

- **Solvent** and **solute** is a pure substances from which the solution is prepared
- Solvent is a component
 - which determines the solution state of aggregation whose amount is greatest
- The ways of describing solution composition
- Solubility, s is a maximum concentration of solution



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 - ① which determines the solution state of aggregation
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- The ways of describing solution composition

- Molar concentration, c is a ratio of amount of solute to volume of solution
- Molar fraction, x is a ratio of amount of solute to amount of solution
- Molar fraction, X is a ratio of amount of solute to amount of solvent
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- Solubility, s is a maximum concentration of solution
 - Solution having such a concentration is a saturated one
 - Unsaturated solutions have a concentration lower than s



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CRYSTALLINE HYDRATES

- **Crystalline hydrates** is a crystals which content a certain amount of water
 - because solute "binds" the water
 - An examples: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$
 - Hygroscopicity is an ability to absorb water vapour from the air
- A problem. In 100 g of water 40 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is dissolved. What is the CuSO_4 mass fraction $\omega(\text{CuSO}_4)$ in this solution?



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 - An examples: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$
 - Hygroscopicity is an ability to absorb water vapour from the air
- A problem. In 100 g of water 40 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is dissolved. What is the CuSO_4 mass fraction $\omega(\text{CuSO}_4)$ in this solution?

- $$\omega(\text{CuSO}_4) = \frac{m(\text{CuSO}_4)}{m_{\text{soln}}}, m_{\text{soln}} = 100 + 40 = 140 \text{ g}$$

- $$\frac{m(\text{CuSO}_4)}{M(\text{CuSO}_4)} = \frac{m(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})}{M(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})} = n_{\text{hydrate}}$$

- $$m(\text{CuSO}_4) = \frac{M(\text{CuSO}_4) \cdot m(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})}{M(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})} = \frac{159.5 \cdot 40}{249.5} \approx 26 \text{ g}$$

- $$\omega(\text{CuSO}_4) = \frac{26}{140} = 0.1857 \approx 19\%$$



IDEAL SOLUTION

- **Ideal solution** is a solution in which there is no specific chemical interaction between the components
 - particles are mixed homogeneously
 - very diluted solutions of one weak-polar substance in another one are very close to ideal
- Properties of ideal solution determines by its composition, not by nature of its components!
- Dependence of quantity P for ideal solution can be expressed as follows:

$$P_{\text{soln}} = x_1 \cdot P_1 + x_2 \cdot P_2 + \dots + x_i \cdot P_i = \sum_n x_n \cdot P_n$$

- For example, for the density ρ of two-component ideal solution:

$$\rho_{\text{soln}} = x_1 \cdot \rho_1 + x_2 \cdot \rho_2$$



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RAOULT'S LAW

- The vapour pressure above the solution is determined by its composition
- Total vapour pressure above the solution: $p_{\text{tot}} = p_A + p_B$
Notations: A is a solute; B is a solvent
- **Raoult's law** (1886): a vapour pressure of solvent above the solution is proportional to solvent mole fraction $p_B = p_B^\circ x_B$, where p_B° is vapour pressure above the pure solvent
- Another formulation: relative decrease in vapor pressure of solvent is equal to mole fraction of solute:

$$\frac{p_B^\circ - p_B}{p_B^\circ} = x_A$$

- The constrain is that solute A must be non-volatile, $p_A \approx 0$. The solution of sugar in water, for example.



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- If solute A is volatile ($p_A \gg 0$) it is impossible to neglect its vapour pressure
- Henry's law (1803): $x_A = kp_A$ – gas solubility x_A is proportional to its partial pressure
- As a consequence, abrupt pressure drop causes releasing of gas dissolved
- The *Decompression sickness* can be mentioned for example
- The increase in pressure always increases the solubility of gases in liquids (carbonated drinks)



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RAOULT'S LAW USAGE

- The vapour pressure lowering influent on boiling and freezing points of solution
- The solution boils when the vapour pressure is equal to atmospheric one
- The solution freezes when the vapour pressure due to the solid phase becomes equal to the vapour pressure due to the liquid phase
 - The vapour is present even due to the solid solvent as well liquid
 - Boiling and freezing temperatures are lower in the first
 - Normally, pure solvent crystallizes out of the solution
- It is known, that the solution boils at higher temperature and crystallizes at lower temperature than the pure solvent. Why?



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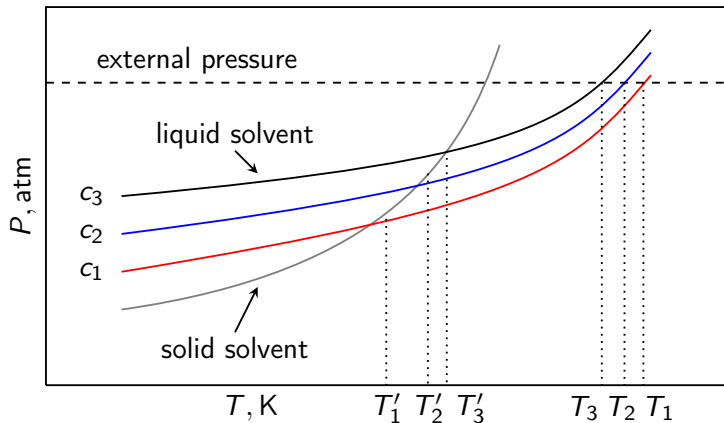
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RAOULT'S LAW ILLUSTRATION

- Vapor pressure above solutions ($c_3 < c_2 < c_1$):

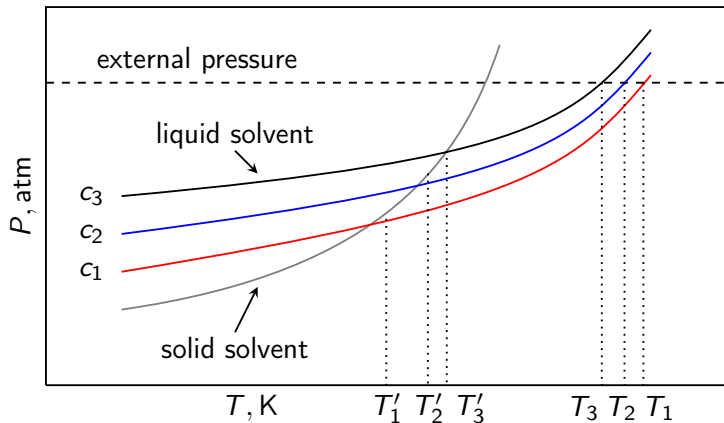


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EBULLIOSCOPY AND CRYOSCOPY

- The change of temperature of freezing and boiling points is used on analysis
 - Ebullioscopy is a technique of solution boiling point elevation ΔT_{boil} measurement;
 - Cryoscopy is a technique of solution freezing point depression ΔT_{freez} measurement;
- There is a simple relationship between ΔT and the composition of the solution

- Molar mass of solute A:

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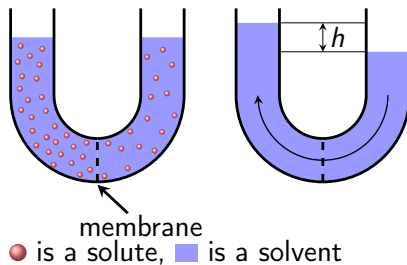
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OSMOSIS

- Osmosis is a phenomenon of spontaneous selective diffusion through semi-permeable membrane

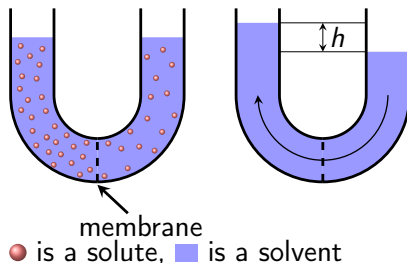


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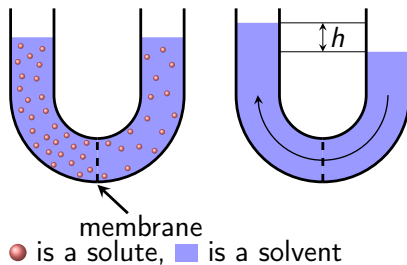


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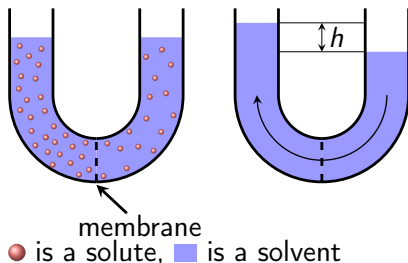


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