CHAPTER 5

SOLUTIONS

SOLUTIONS

Solutions = homogeneous mixture composed of two or more substances. Solutions are obtained by dissolving a substance called solute into another substance called solvent.

Exemples

- **liquid solutions**
- **solid solutions**
- **gaseous solutions**

http://chemistry.about.com/od/imagesclipartstructures/ig/Science -Pictures/Transition-Metal-Solutions.htm

SOLUTIONS

Liquid solutions:

- **gas dissolved in liquid (CO_2 in water)**
- **liquid dissolved in liquid (ethanol in water)**
- **solid dissolved in liquid (copper sulfate in water, naphtalene in benzene)**

Solid solutions = homogeneous alloys

Gaseous solutions = homogeneous mixtures of gases, i.e. air.

Bare de aur de Petr Kratochvil

Solvents

Water = the most common dissolving agent.

It can dissolve many solid, liquid or gaseous substances.

Other solvents = ethanol, acetone, toluene, carbon tetrachloride.

Substances are dissolved in solvents differently.

For example, fats are not dissolved in water, but are well dissolved in petrol.

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Dissolution

Dissolution is a consequence of molecular movement. When a substance is dissolved, the molecules of the solvent arrange themselves around the molecules of the solute. The higher the number of particles separated in the time unit, the faster the dissolving process.

The rate of dissolution increases with:

- agitation
- temperature
- higher surface area in contact with the solvent

The thermal effect of dissolution

Dissolution is accompanied by a thermal effect: either heat absorption or heat release. Dissolution might be an endothermic or exothermic process.

For example, dissolving one mole of potassium nitrate KNO_3 in a large quantity of water requires 36 kJ absorbed from the environment. This is an endothermic process.

The thermal effect of dissolution

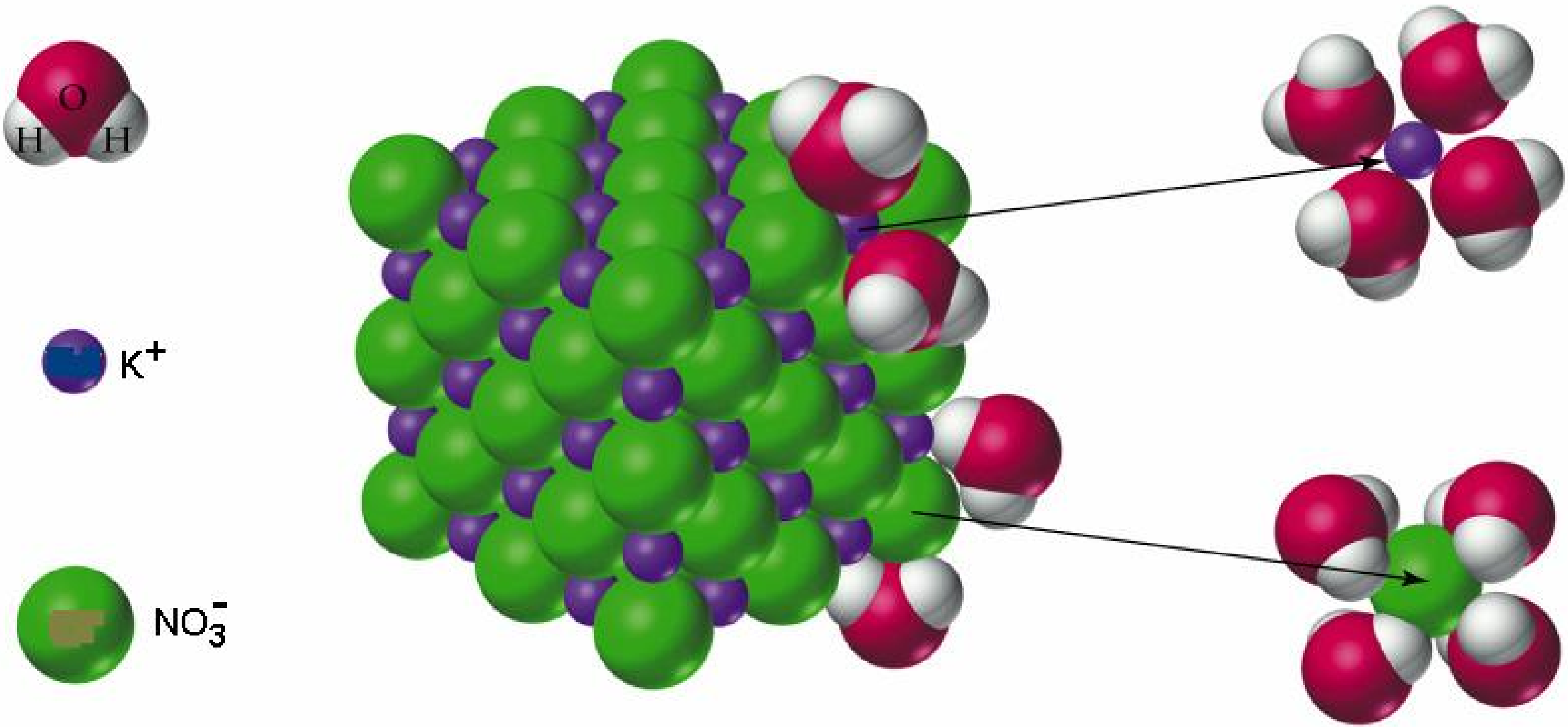
The dissolution of an ionic substance (KNO_3), takes place in two successive steps:

• extraction of K^+ and NO_3^- ions from the crystal lattice, process that requires energy from the exterior,

• solvation of the ions, process that takes place with heat release.

Solvation (hydrating) = the process of attaching solvent molecules to the separated ions from the crystal lattice.

The dissolution of potassium nitrate in water:



The thermal effect of dissolution

Because the energy absorbed for the extraction of the ions from the crystal lattice is higher than the energy released during the solvation of the ions, the dissolution of potassium nitrate is an endothermic process, meaning that dissolving potassium nitrate in water the solutions will cool down.

Concentration of the solutions

Concentration expresses the *quantitative* relation between the components of the solution. There are several ways to express concentration of solutions:

1. Mass percentage: represents the mass of substance expressed in grams dissolved in 100 g of solution.

$$c\% = \frac{m_d}{m_s} \cdot 100 \quad [\%]$$

where: m_d = the mass of the dissolved substance, g;

m_s = the mass of the solution, g.

2. Volume percentage: represents the volume of substance expressed in m^3 dissolved in $100m^3$ of solution:

$$c\%(vol.) = \frac{V_d}{V_s} \cdot 100 \quad [\%]$$

where: V_d = the volume of the dissolved substance;

V_s = the volume of the solution.

This way of expressing the concentration of solutions is used especially in the case of liquids dissolved in other liquids. 80% (v) ethanol contains 80 volumes of pure ethanol and 20 volumes of water. 80° alcohol means 80% (v).

3. Molarity: represents the number of moles of substance dissolved in 1L of solution:

$$c_M = \frac{m_d}{M_d \cdot V_s} \quad [\text{mol L}^{-1}]$$

where: Md = the molecular mass of the dissolved substance;

Vs = the volume of the solution (L).

4. Molality: represents the number of moles of substance dissolved in 1kg of solvent:

$$c_m = \frac{m_d}{M_d \cdot m_{solv}} \quad [\text{mol kg}^{-1}]$$

Unlike molarity, which depends on temperature, the molality is independent on temperature.

5. Molar fraction (mole fraction) : is the number of moles of solute divided by the total number of moles of a solution.

If a solution contains n_A moles of compound A and n_B moles of compound B the mole fractions will be:

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

Mole fraction of A

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

Mole fraction of B

The sum of the mole fractions of compounds A and B is 1.

6. Titer: represents the mass of dissolved substance (expressed in g) that is found in 1mL of solution:

$$T = \frac{m_d}{V_s}$$ [g mL^{-1}] or [g cm^{-3}]

This way of expressing concentration is commonly used in analytical chemistry.

Transformation relations between different ways of expressing concentration:

Way of expressing concentration	Percentage $c\%$	Molarity c_M	Molality c_m
Percentage $c\%$		$c\% = c_M \frac{100M_d}{\rho_s}$	$c\% = c_m \frac{100M_d \cdot m_{solv}}{m_s}$
Molarity c_M	$c_M = c\% \frac{\rho_s}{100M_d}$		$c_M = c_m \frac{m_{solv} \cdot \rho_s}{m_s}$
Molality c_m	$c_m = c\% \frac{m_s}{100M_d \cdot m_{solv}}$	$c_m = c_M \frac{m_s}{\rho_s \cdot m_{solv}}$	

Solubility

The solution that at a certain temperature contains the maximum amount of dissolved substance is called **saturated solution**.

For example, at 20°C, 35.8g NaCl is the maximum quantity of NaCl that can be dissolved in 100g of water.

The maximum concentration of the substance in the saturated solution represents the **solubility**.

Solubility depends on the nature of the substances and on temperature.

Solubility

If solubility > 1 g solute / 100 g solvent at 20 °C → **soluble**

If solubility < 1 g solute / 100 g solvent at 20 °C → **slightly soluble**

Ex.: **Soluble** substances in water are: NaCl, KNO_3, $AgNO_3$, KBr, NaOH, sodium acetate, sulfuric acid, sugar, etc.

Ex.: **Slightly soluble** substances in water are: AgBr, $PbSO_4$, $Fe(OH)_3$, $CaCO_3$, $BaSO_4$.

Solubility

The variation of solubility with temperature is represented by the **solubility curves**.

❖ The solubility of salts usually increases with increasing temperature. Some exceptions: $Ce(SO_4)_3$ or $Ca(OH)_2$ - the solubility decreases with increasing temperature.

❖ The solubility of liquids increases with increasing temperature.

❖ The solubility of gases decreases with increasing temperature. The solubility of gases is also influenced by the pressure of the gas above the solution. The higher the pressure of the gas, the higher the solubility.

Solubility curves for some solid substances