EQUILIBRIUM IN THE TERNARY SYSTEM - EXTRACTION

INTRODUCTION

Consider a three-component system consisting of two non-dissolving liquids, called solvents and a substance that dissolves in both liquids. In this case, the substance will dissolve and divide between the two solvents reaching in equilibrium the concentrations denoted, for example, c_1 and c_2. The thermodynamic equilibrium of the system is achieved when the chemical potentials of the substance dissolve in both phases are equal. This is the condition of thermodynamic equilibrium:

$$\mu_1 = \mu_2 \tag{1}$$

The chemical potentials of the solute depend on the concentration and are described by the equation:

$$\begin{aligned} \mu_1 &= \mu_1^o + RT \ln c_1 \\ \mu_2 &= \mu_2^o + RT \ln c_2 \end{aligned} \tag{2}$$

where:
μ_1, μ_2 – chemical potentials of substances in solvents 1 and 2
μ_1^o, μ_2^o – standard potentials of substances in solvents 1 and 2
c_1, c_2 – equilibrium concentrations of substances in solvents 1 and 2

In thermodynamic equilibrium, equation 1 takes the form of:

$$\mu_1^o + RT \ln c_1 = \mu_2^o + RT \ln c_2 \tag{3}$$

Equation (3) after transformation takes the form known as Nernst's distribution law:

$$\frac{c_1}{c_2} = e^{\left(\frac{\mu_2^o - \mu_1^o}{RT}\right)} = K = const. \tag{4}$$

It shows that the concentration ratio of the substance divided between the two non-dissolving liquids is constant and independent of the amount of this substance and the amount of solvents. If several different substances are dissolved in a solvent, then the distribution law applies to each of them, regardless of the presence of others.

EXERCISE PURPOSE

The aim of the exercise is to determine the partition coefficient of acetic acid in a water-butanol system.

APPARATUS

Shaker.

LAB GLASS

Tripod with a paw to the burette.
Burette 50 cm^3
Funnel

Graduated flasks	100 cm^3	3 pcs.
Conical flasks with stoppers	100 cm^3	4 pcs. (for shaking)
Conical flasks	100 cm^3	3 pcs. (for titration)
Flasks	20 cm^3	4 pcs.
Pipette	25 cm^3	1 pc.
	10 cm^3	1 pc.
	2 cm^3	2 pc.

CHEMICALS

Solution of CH_3COOH	0.1 M.
Solution of NaOH	0.1 M.
n-Butanol	
Phenolphthalein	

EXPERIMENT PROCEDURES

On the basis of 0.1 M acetic acid solution, prepare the solutions of concentrations: 0.075, 0.050, and 0.025 M. By titration of these solutions with 0.1 M NaOH, determine the acid content in the prepared samples and in the sample at a concentration of 0.1 M - make three titrations in the presence of phenolphthalein (1-2 drops). Subsequently, add 2 ml butanol portions to four conical flasks and 10 cm^3 of an appropriate solutions of acetic acid: 0.1, 0.075, 0.05, and 0.025 M. Shake the capped conical flasks on a shaker for 20 minutes. After shaking the contents of the flasks pour them into the vials, and wait for separation of the aqueous and butanol layers (both layers will be clear). After separation, pipette 2 cm^3 of water phase (bottom). Titrate the sample to determine the acid concentration after the extraction process - perform three titrations.

Based on the concentration of acetic acid in the organic and aqueous phases (after the extraction process), calculate the Nernst distribution coefficient for acetic acid in the water-butanol system.

ATTENTION!

The Nernst distribution coefficient is expressed in terms of concentrations, i.e. intensive parameters - independent of the mass of the system. In these calculations, the concentration is expressed in terms of cm^3 of titrant (NaOH) an extensive parameter that depends on the volume of the sample. Therefore, the calculation should take into account five times less volume of the organic phase in relation to the volume of the aqueous phase.

STUDY RESULTS

The results obtained in the above exercise should be summarized in the table with the given diagram:

	CH_3COOH Concentration Expressed as cm^3 of NaOH 0.1 M					
CH_3COOH Concentration M	c_0 Starting value	c_0 Average value	c_1 Final value in aqueous layer	c_1 Average value	$c_2 = (c_0 - 5c_1)$ Final value in butanol layer	$K = \frac{c_1}{c_2}$
0.1	*1.* *2.* *3.*		*1.* *2.* *3.*			$K_1 =$
0.075	*1.* *2.* *3.*		*1.* *2.* *3.*			$K_2 =$
0.050	*1.* *2.* *3.*		*1.* *2.* *3.*			$K_3 =$
0.025	*1.* *2.* *3.*		*1.* *2.* *3.*			$K_4 =$

Template of the table and draft of the study

……………………………... *Faculty* ………………………………. *Field of study* *Full-time/ part-time studies*	……………………………………………… *Name and surname*	………………………………….... *Date:*
Group no.: ………………… *Team no.:* …………………	……….…………… *Exercise no.:*	……………………………………. *Instructor:*

……………………………... *Wydział* ………………………………. *Kierunek* *Studia stacjonarne/niestacjonarne*	……………………………………………… *Imię i Nazwisko studenta*	………………………………….... *Data wykonywania ćwiczenia:*
Nr grupy: …………………... *Nr zespołu:* …………………..	……….…………… *Nr ćwiczenia:*	……………………………………. *Nazwisko Prowadzącego:*

1. Temat ćwiczenia
2. Cel ćwiczenia:
3. Wstęp teoretyczny:
4. Pomiary:
5. Obliczenia:
6. Wykresy:
7. Wnioski

1. Exercise title:
2. The aim of the exercise:
3. Theoretical introduction:
4. Results:
5. Calculations:
6. Graphs:
7. Conclusions: