EFFECT OF THE MAGNETIC FIELD ON THE ION-EXCHANGE PROCESSES

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INTRODUCTION

Modern society imposes stringent requirements on water parameters. Increasing water needs will require the development of innovative purification technologies. Water treatment, when seawater surface or underground water are used as the source, may be performed using ion exchange membrane and electrolysis methods. Polarization and the decrease in the conductivity of the membrane, release of gasses at the electrodes (electrolysis), duration of the process and the destruction of the electrodes reduce the effectiveness of electrodialysis water purification technology. Magnetic field can change the equilibrium in the «ion exchanger – solution» system. Therefore studying of the influence of magnetic field on ion exchange processes is important.

The main goal of the research is to study the influence of magnetic field on the electrodialysis processes and the equilibrium in «ion exchange resin – solution» system.

EXPERIMENTAL RESEARCH

Installation for electrodialysis of aqueous solutions contained a DC source, a liquid junction cell and an oscilloscope. We used two magnets with remanent magnetization 1.2 T. Electrodialysis cell was made of polymethylmethacrylate. Anion-exchange membrane (MA-40), cation-exchange membrane (MC-40) and a NaCl aqueous solution with concentration of 10 g/l were used.

Each series of experiments included electrodialysis: magnetic fields of two polarities with respect to the direction of the electric field and without the field. Sodium chloride solution was prepared once for all measurement cycles at a known concentration.

LeCroy oscilloscope was used for registration of current in the circuit through the electrodialysis cell. Oscillograms of the voltage with load resistance of 5.1 Ohm with magnets fixed in the longitudinal direction are shown in Fig. 1. Repeatability of graph shapes is observed.

It was revealed that when the magnet's North Pole is oriented towards the cathode, the effect is stronger. In the magnetic field there is a simultaneous compression of the graph along the time axis and an increase in the maximum current value. The area under the curve depends on the polarity of the magnetic field. With the same number of ions that can be explained by the influence of magnetic field on water electrolysis at the electrodes.

The effect of the magnetic field can be related to polarization of the dipoles of water. Magnetic field acts on ions in thermal motion. The hydrogen atoms of the water molecules are oriented along the magnetic field lines due to the Lorentz force. The cross section of the water molecule decreased in the direction of the electric field [1].

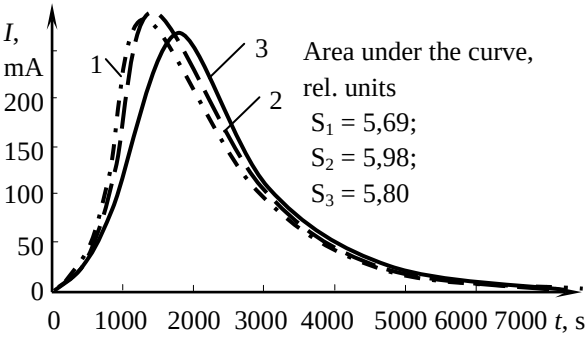

Figure 1. Electrodialysis current dependence on time. 1 - North Pole near the cathode, 2 - South Pole near the cathode a, 3 - without a magnetic field.

Orientation of water molecules must change the diffusion rate of ions in an aqueous solution in a magnetic field. We registered the rate of propagation of NaCl solution and Ni(NO3)2 along the height of the water column in a magnetic field for estimating the influence of magnetic field on the diffusion coefficient. For this two rectangular cuvettes were set into Jamin interferometer: one with distilled water and another with saturated saline solution at the bottom. The diffusion coefficient was evaluated by the movement of the leading edge of a saturated solution, which was registered at the wavelength of a helium-neon laser of the interferograms.

Selection of compounds can be explained by the fact that NaCl contains mainly spin nuclei, but Ni(NO3)2 has spinless nuclei. It has been proven that the magnetic field is less than 1.2 T, and its orientation relative to the direction of diffusion does not influence diffusion coefficient in the range of measurement error. It is known that the magnetic field does not affect the electrical conduction in solution [2].

We determined the rate of ion exchange between aqueous Li2SO4 (analytical grade) and ion-exchange resin KU-2, placed in a magnetic field. Water was leaking through the column and fell into the collector of desalinated water in the form of drops. The time of appearance of lithium ions at the output of the column was determined without magnetic field and with

magnets. Flow rate of the solution through the column was 17 ml/min. Experimental data are shown in the table. It can be seen that the external magnetic field increases the time before the appearance of Li+ ions at the outlet of the ion exchange column.

Table 1 - Experimental data

$[Li_2SO_4]$, %	1	1,95	2,5
$(t_0 - t_м) : t_0$, %	14,0	13,9	13,8
$[Li_2SO_4]$, %	3	3,48	4
$(t_0 - t_м) : t_0$, %	10,3	11,3	9,9

Increasing the speed of the ion exchange is caused by the impact of magnetic field on the ion exchanger. In this case the leading edge of concentration of the ion exchange resin being saturated becomes steeper and, therefore the ions need more time to reach the output of the column.

Vibration parameters of Na+ ions in the monomer ion exchange resin KU-2, shown in Figure 2 [3,4] and excess charge are calculated using the HyperChem 8.0.8. The most mobile Na+ ion oscillates at a frequency of 6,7×1013 Hz and an amplitude of 9,5 Å.

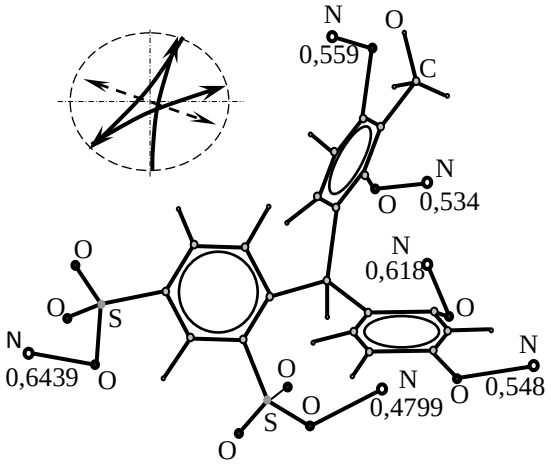

Figure 2. Graphic structure of the exchange resin KU-2 monomer ion

The calculated values of excess charges and counter-vibration amplitudes or Na^+ ions are shown in Table 2.

Table 2 - Counterions parameters of ion exchange resin KU-2

Excess charge (e)	wave number, $см^{-1}$	Amplitude, Å
0,643	398,99	23,5
0,479	390,15	23
0,618	351,02	21
0,547	364,96	22,5
0,559	178,91	11,5
0,534	364,96	22,5

Ion exchange happens upon a collision of the solution ion and the counter ion (Na^+). In a magnetic field, the effective cross section where the ion exchange happens is equal to the area of the circle - the trajectory described by the counter without a magnetic field. The magnetic field increases the probability of ion exchange. In a magnetic field, at a low salt concentration, the total absorption of the cations occurs at a smaller distance than without the field.

Lorentz force acts on the moving ions in a magnetic field. Therefore, Na+ ion trajectory is an arc with variable curvature relative to its center. Each extra arc trajectory is shifted relative to the previous one (inset in Fig. 2). In a magnetic field, the effective cross section of interaction of ions and counterion becomes equal to the area of a circle whose radius is equal to the amplitude of oscillation. Therefore, in a magnetic field full absorption of cations takes place at a smaller distance than without a field. This effect of accelerating the exchange of ions between the resin and the solution in the magnetic field also increases the conductivity of the membrane.

CONCLUSION

Research results suggest the following:

1. The skip time of ions through the resin bed increases up to to 14% in a magnetic field of 1.2T.
2. The external magnetic field of 1.2T increases electrodialysis current by 9%.
3. The influence of the magnetic fields of less than 1.2 T on the diffusion of inorganic ions in aqueous solutions have not been detected.

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