RESEARCH OF ION EXCHANGE RESINS CAPACITY IN EXTERNAL CONSTANT MAGNETIC FIELD

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Annotation

This article shows that the external magnetic field affects the saturation time of ion exchange resins in water sorption of lithium sulfate. The data on the resin saturation time of the salt concentration in a constant magnetic field and without the field are obtained. There is also a model explaining the experimental data.

Ion exchange techniques are widely used for obtaining fresh water from solutions such as seawater. The increasing demands for fresh water require the development of innovative techniques of water purification from dissolved salts. One of the factors that can change the balance in the system ion exchanger. - the solution is the magnetic field.

Magnetic treatment prevents precipitation of scale-forming salts from the water on the inner surface of tubes and significantly reduces the deposition of organic substances such as paraffins. [1].

Effect of the magnetic field on the water is complex and associated with changes in the structure of water, hydrated ions, physical and chemical properties and behavior of dissolved inorganic salts [2, 3]. In a magnetic field rates of chemical reactions change due to the competing processes of dissolution and precipitation of dissolved salts, the formation (decay) of colloidal systems in water. [4]

The goal of this work is studying the influence of magnetic field on the saturation time of ion exchange resins in water solution of lithium sulfate.

The principal flow sheet of the ion-exchange column for experimental studies of the influence of the magnetic field on the time of its protective effect is shown in Fig. 1. For the formation of ion-exchange columns a vertically installed glass tube with an inner diameter of 1.5 cm and a length of 77 cm is used. The lower end of the tube is filled with plastic granules and the diameter of tube is decreased to 3 mm. The top of the inert filler is covered with granular exchange resin KU-2. The amount of ion exchange resin in all the measurements was 7 grams.

Permanent magnets remanence 1.2 T and dimensions 3×5×1 cm are installed around ion exchange resin.

In the experiments, the lithium sulphate was diluted in distilled water and poured into the ion exchange column. Water seeped through the resin filler fell into a receiver of demineralized water in the form of droplet. Periodically drops are selected on a copper plate. The presence of lithium ions in the sample was determined by the appearance of the crimson glow of the solution on the plate in the flame of a spirit lamp. The time of appearance of the output columns of lithium ions without magnetic field and with established magnets is determined. Flow rate of the solution through the column is 17 ml / min.
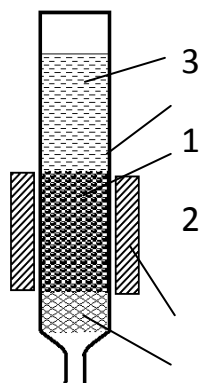
Fig. 1. Scheme of the ion exchange column. 1 – the tube, 2 – ion exchange resin, 3 – water solution, 4 - permanent magnet, 5 – inner filler

Table 1 shows the times of onset of lithium ions at the outlet from the exchange column (resin saturation time) without the field and with the magnetic field. It can be seen that with increasing concentrations of lithium sulphate the influence of an external magnetic field is greatly reduced.

Table 1. Dependence of Li_2SO_4 solution concentration on resin saturation time without the field and with the magnetic field

$[Li_2SO_4]$, %	1	1,95	2,5	3	3,48	4
t_0, s	1655	1434	1338	825	796	769
t_m, s	1887	1634	1523	910	886	845
δt	0,1402	0,1395	0,1383	0,103	0,1131	0,0988

With the help of this table we can see that resin saturation time is increased in the magnetic field.

The relative magnitude of the magnetic field at the time of the protective action of the resin is determined by the formula

$$\delta t = \frac{t_m - t_0}{t_0}$$,

where t_m, t_0 are protective action of the resin in a magnetic field and without it respectively.

For understanding of experimental results let us consider the structure of resin KU-2 which is shown in figure 2. Every monomer of resin includes 6 ions of Na^+, which can be replaced by ions of water solution.[5]

Using the program HyperChem 8.0.8 the following parameters of resin are calculated: oscillation frequencies of different atoms and ions in the monomer, the amplitude of thermal fluctuations, the excess charge distribution of selected atoms. The most mobile ions Na^+ (marked in Fig. 2) have the most intensive oscillation frequency with wave number 220.26 cm^{-1} (f = 6,7 * 10^{13} Hz, T = 1.49 * 10^{-13} seconds). The amplitude of the oscillation is A = 9,5 Å.

In monomer of resin KU-2 ions of active groups oscillate with certain frequency and amplitude because of thermal motion. Also all ions of active groups have effective square of exchanging $\sigma_{эфф}$ which is perpendicular to the direction of electromigration in which ion exchanging is possible.

Because of a slower speed of electromigration relative to the speed of vibrational motion exchanged ions repeatedly collide in the same point.

In the magnetic field Lorentz force influences the motion of atoms with excess charge. For selected ions Na^+ (in Fig. 2 from left to right) the excess charge calculated with HyperChem 8.0.8, is 0,559e and 0,618e respectively. The velocity of the ions in oscillatory motion has sinusoidal character: the maximum in the equilibrium position, the minimum on peripheral points. For this reason at any distance trajectory of ions Na^+ is an arc with varying curvature and every next arc moves from the previous one within a certain circle, determined by the amplitude of the thermal vibrations that can be seen in figure 3.
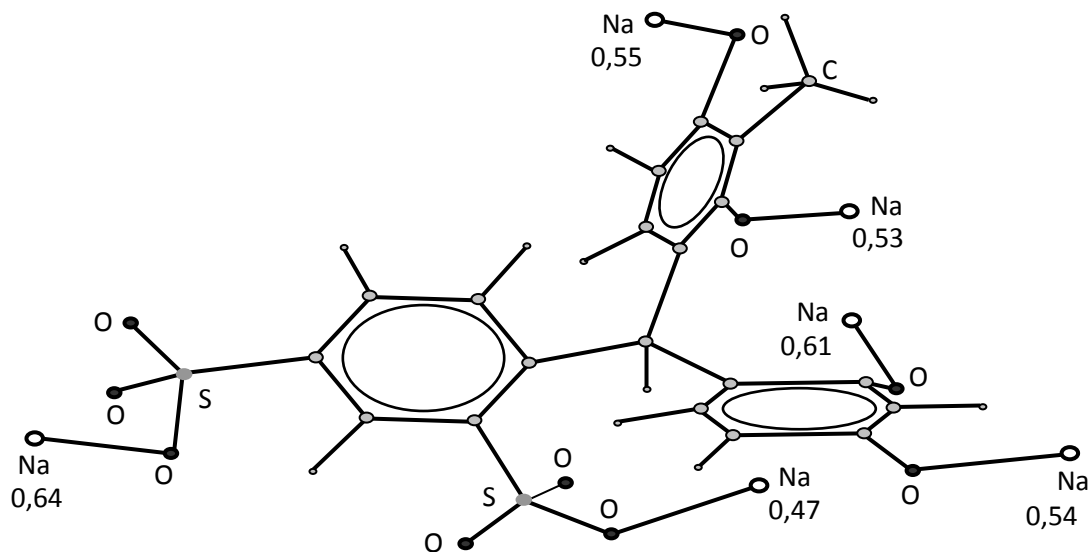

Fig. 2. Graphical structure of exchanging resin monomer KU-2

After a number of oscillations position of the arc path in space repeats because the sodium ion has consistently bypassed the point of the circle described by the ion trajectory without a magnetic field.

Because of increasing of effective interaction square and low speed of ion motion in solution the probability of exchanging is increased.

Effective square of ion exchanging in magnetic field is changed to $\sigma_{эфф}^{/}$.
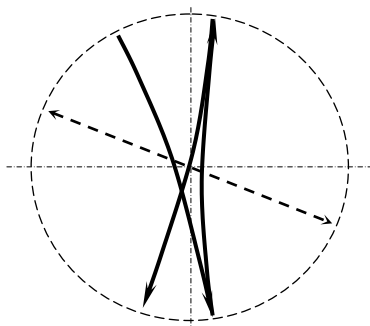

Fig. 3. Trajectory of ion oscillation of active groups within external magnetic field (solid), without it (dotted line)

Let us estimate the effect of the magnetic field on the system of ion exchange resin - solution. Without magnetic

field the Na^+ ion ranges linear path, hence the value of the site covered in a plane perpendicular to the field $\sigma_{эфф} = 2*d*A \approx 4{,}237*10^{-19}$ m^2, where d is effective diameter of Na^+. Within the magnetic field a part of the ions Na^+, moving perpendicular to the field begin to move in an arc, the radius of which is continuously changed due to the dependence of the forward velocity of the deviation from the equilibrium position. The rest of the Na^+ ions in the resin have less effect from the magnetic field due to the deviation from the perpendicular angle between the field intensity and speed.

If the ion in solution does not intersect the path of the thermal vibrations of Na^+ ion, then the exchange probability is negligible. In a magnetic field due to the continuous motion of the thermal vibrations of the position trajectory there is a nonzero probability of exchange within the circle described by the trajectory without a magnetic field, because of it the magnetic field increases ion exchange probability. In a magnetic field at low salt concentration, the total absorption of ions occurs at a smaller distance than without the field, so the appearance of the first ions at the end of the column takes a longer period of time. Increasing the concentration of salt increases the distance at which the total absorption of ions takes place. Therefore, the efficiency of the magnetic field decreases slightly.

CONCLUSION: The effect of increasing time of protective effect of ion-exchange columns in an external constant magnetic field is experimentally observed. It is shown that the effect is present is due to increasing of the effective areas and due to the Lorentz force, which occurs within the ion exchange.

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