Determination of Electrical Conductivity of Ion Exchange Resins

Myroslav Malovanyy, Kateryna Petrushka

Department of Ecology and Sustainable Nature Management, Lviv Polytechnic National University, UKRAINE, Lviv, S. Bandery street 12, E-mail: mmal@polynet.lviv.ua, petrushka-katja@rambler.ru

Abstract – The paper is devoted to the determination of electrical conductivity of the ion exchange resins. We described the basic conditions under which the research was conducted. The methods used and experimental results are presented too.

Key words – electrical conductivity, ion exchange resins, resistance, cell, “ion exchanger – solution” system.

I. Introduction

Electrodialysis with the resin membranes is one of the main methods in membrane technology. It is the combined method in which the processes of electrolysis and dialysis are combined. Application of the gaskets from insulating materials results in substantial increase of the voltage and reduce of the working surface of membranes during the electrodialysis.

Therefore, the use of ion exchange resins in the form of granules as the intermembrane filling is of great interest. But the necessary condition for successful application of the gaskets from insulating materials in electrodialysis is the preliminary research of conductivity of materials that will be used for the intermembrane backfilling.

Electrical conductivity depends on many factors, including the nature of the substance, the solvent and its concentration, and the temperature. By the value of the electrical conductivity we can determine the content of various substances and their compounds in the investigated solutions. It is determined by measuring the electrical resistance of the layer of fluid contained between two electrodes immersed in the investigated solution using different conductivity measuring instruments.

Requirements to the exact measurements of electrical conductivity, are the following:

- precise temperature control;
- the elimination of polarization of electrodes;
- very high precision of electrical measurements.

Electrometric method of determining the electrical conductivity allows to accelerate and to increase the accuracy of its determination in comparison to other methods [1]. Research of electrical conductivity was began in the late nineteenth century and now domestic and foreign researchers continue this work [2, 3].

Determination of electrical conductivity comes to measurement of resistance because it is inversely proportional to the resistance. The problems of periodicity and the frequency of the current control of the conductivity are relevant. The decision of these problems lays in the automation of measurement of the specified parameter and comparative analysis for determining the quality of the solution and the process of stabilization [4].

Electrical conductivity of fluids (liquid mineral and organic fertilizers, electrolyte solutions, etc.) is used as a measure of their concentrations, and therefore the theory of commutation modes of the measuring electrodes now gets wide practical application. On the border of phase separation electrode-liquid the polarization of contact voltage occurs, which is caused by a potential jump and has a polarity opposite to the polarity of the applied voltage. At the same time molecules seem to form a double layer, whose properties differ from the properties of molecules, polarized at a greater distance from the phase separation surface. Therefore the criterion of the possibility for application of such an approach in a particular experiment can be one that takes into account the impact of the potential jump on the measurement results [5].

In completely dry state ion exchange resins have a high electrical resistance. When the resin swells, there appears the ability to conduct electrical current. This property is used for electrochemical regeneration of ion exchangers.

The ion exchangers are divided into anion and cation exchangers that exchange respectively negatively or positively charged ions and amphoteric exchangers that are able to exchange the both types of ions. The most common organic synthetic ion exchangers are the ion exchange resins. The ion exchange resins are obtained by polymerization or by polycondensation of organic compounds and by chemical transformations of the polymers. Ion exchange resins based on styrene copolymers with divinylbenzene, phenol-formaldehyde resins, polyamines are widespread now.

In case of applying the weak acid cation exchanger in acidic form before the membrane water treatment the partial softening of the water will take place with its full decarbonation and if the pH will be lowered to 3÷4 it will not absolutely affect the work of membranes [3, 4].

II. Problem Statement and Approach to Solving

The known methods of measurement of specific electrical conductivity of granular resin make impossible to carry out the measurements in a wide range of concentrations of the equilibrium solution. That is why we proposed the approach to measure the resistance of the grains layer of granular resin after the removal of the equilibrium solution by centrifugation.

The ion exchange resin was placed in the electrodialysis cell and set in the balance with the investigated solution. We took the ion exchange column with porous bottom and two fixed in the wall electrodes as a measurement cell The equilibrium solution was removed by centrifugation, the cell was placed in a rubber case and kept in a thermostat at a constant temperature of 25 ^{0}C. With the help of the alternating current bridge (1000 Hz) we determined the electrodialysis cell resistance (R_x), on the base of which the value of specific electrical conductivity of the ion exchange resin ($k_{см}$) was calculated. It was defined from:

$$k_{см} = \frac{Г}{R_x} \quad (1)$$

where: Γ – the measurement cell constant determined on the base of known electrical conductivity of the ion exchange resin in the isoelectric point, which has been found from the separate experiment:

$$\Gamma = k_{iso} R_{iso} \quad (2)$$

where: R_{iso} – the measurement cell resistance, measured after centrifugation, when the ion exchange resin was in the equilibrium with the isoelectric solution.

III. The Research Methodology and the Results

We have been studying the system of "the KU-2 ion exchange resin – NaCl solution". The research was carried out according to the following algorithm:

1. A series of NaCl solutions (0.1, 0.2 ... 0.5 M) was prepared.
2. We measured the resistance of each solution in the U-shaped tube which is not filled with a resin (in the cell) with the help of electrodes submerged at the same depth.
3. The dependence of 1/R on the NaCl concentration (where R – the electrical resistance of the U-shaped tube) was built for the sodium chloride solution.
4. The U-shaped tube was filled with ion exchange resin.
5. The ion exchange resin have been set in equilibrium with the 0.1 M solution of NaCl in the U-shaped tube. To do this on one knee of the U-shaped tube we placed the separating funnel at 0.5 liters and from it at a low speed the solution has been supplied. The resistance of the solution which flowed from the tube through the other knee has been recorded periodically. The solution supply from a separating funnel has been stopped when the resistance of input and output solution were the same.
6. Only after that the electrodes have been immersed into the U-shaped tube on the same level and the resistance of the resin-solution system has been measured.
7. Similarly, we have set the equilibrium and then measured the resistance of the resin-solution system for NaCl solutions of other concentrations.
8. The dependence of inverse resistance (1/R) of the resin-solution system on the concentration of the solution was calculated.
9. The point of intersection of the obtained dependencies for pure solution and for resin-solution system allowed to determine the concentration of the isoelectric solution (in this concentration the electric conductivity of the solution is the same as the conductivity of the resin).
10. We prepared 1 liter of solution with the concentration of the isoelectric solution.
11. According to the methodology described above (see 5) we have prepared the ion exchange resin in equilibrium to the concentration of the isoelectric solution.
12. One by one the previously prepared examples of ion exchange resin which were in equilibrium to a certain concentrations have been transferred to a centrifuge cell. This cell had the sizes that allowed her to enter the centrifuge (about 5 cm in height and with the required diameter). Electrodes were installed approximately 1 cm from the porous bottom of the cell. Ion exchange resin was placed into centrifuge cell above the electrodes.
13. The measurement cell has been located in the centrifuge and the excess of solution has been removed by centrifugation.
14. The resistance of the cell with ion exchange resin was measured.
15. According to the reference book we have found specific electrical conductivity of NaCl solution, built the concentration dependency and then determined the value of k_{iso} at C_{iso} value using this dependency.
16. The constant of the cell has been calculated by the formula (2).
17. Using the value of Γ constant, the value of the specific electrical conductivity has been calculated for each concentration of the solution.

Conclusion

The system of "the KU-2 ion exchange resin – NH_4Cl solution" is at the stage of experimental research. The results that will be received during the experiment will allow us to develop an algorithm for calculation of the physical – chemical parameters of ion-exchange purification of model solutions of waste water and industrial multi-component solutions.

References

[1] Y. N. Gomelya, Yu. A. Omelchuk, V. M. Radovenchyk, "Ocenka эffektyvnosti kationytov KU-2-8y Aqualite R-100 FC pry umyagchenii vodы v prysutstvii` yonov zheleza", Эkotexnologii i resursosberezhenye, Vypusk № 3, s. 62-65, 2008.

[2] I. M. Martynyuk, O. D. Bugrov, V. O. Shygimaga, "Vyznachennya elektroprovidnosti dystylovanoyi, bidystylovanoyi, apirogennoyi vody`", Nauk.-texn. byul. In-tu biologiyi tvaryn ta Derzh. n.-d. kontrol. in-tu vetpreparativ ta korm. dobavok, Vypusk 13. № ¾, s. 377-379, 2012.

[3] O. M. Bondar, N. O. Perepych, "Analiz perexidnyx procesiv pry vyznachenni elektroprovidnosti ridyn kontaktnym sposobom", Silskogospodarski mashyny, Vypusk 22, s. 3–8, 2012.

[4] V. F. Morflyuk, V. V. Churkin, "Obyektyvne vyzna-chennya elektroprovidnosti zvolozhuvalnogo rozchynu", Texnologiya i texnika drukarstva: zbirnyk naukovyx pracz, VPI NTUU "KPI", Vypusk 1(39), s. 106–111, 2013.

[5] E. V. Goltvyanyczkaya, T. A. Shablyj, N. D. Gomelya, S. S. Stavskaya, "Ocenka эffektyvnosty` ispolzovaniya slabokyslotnogo kationy Dawex MAC-3 v kationnom umyagchenii vodы", Visnyk NTUU «KPI», Seriya «Ximichna inzheneriya, ekologiya ta resursozbe-rezhennya», № 2(8), s. 87-92, 2011.