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1962

SovietRxiv

Abstract

Full Text

Physical Chemistry

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Continuous Countercurrent Ion-Exchange Method of Separation

(Presented by Academician V. I. Spitsyn, September 21, 1961)

Most of the countercurrent ion-exchange processes known from the literature are not continuous, either because the motion of the solid and liquid phases is carried out alternately (as, for example, in the contactors of Higgins (1-3) and Porter (4)), or because the zones of phase conversion increase during operation.

In the present work we set forth the essence of a continuous countercurrent ion-exchange process for separating ions that are similar in properties, which we have proposed. The separation is carried out in an apparatus consisting of two countercurrent ion-exchange columns, in which the cation exchanger moves uniformly opposite to the flow of solution. The general scheme of the apparatus is shown in Fig. 1.

In column *I*, into the upper part of which an ion exchanger saturated with ion C is fed, a continuous frontal analysis of the salts being separated, AZ and BZ, is carried out. Ion C is displaced from the ion exchanger by ions A and B in section *ab*. The resulting solution CZ, whose concentration is equal to the concentration of the mixture being separated, is removed from the upper part of the column. The exchanger leaving the lower part of the column, saturated with ions A and B, enters column *II*, where solution DZ is supplied countercurrently to it. Ion D displaces ions A and B from the ion exchanger in section *cd*. The resulting solution AZ and BZ is removed from the upper part of the column and is fed, either directly or after the necessary treatment, into the lower part of column *I*. At this stage the feed with the mixture to be separated is effected. From the lower part of column *II* the ion exchanger, saturated with ion D, is sent to regeneration, during which ion D is completely displaced from the ion exchanger by solution CZ. In this operation the solution CZ leaving column *I*, previously brought to the required concentration, is used. The ion exchanger obtained as a result of regeneration, saturated with ion C, is fed into the upper part of column *I*, and solution DZ is used for displacement in column *II*. The conditions in the system are chosen so that sections *ab* and *cd* do not increase in size during operation, i.e., the regime of parallel transfer is maintained in them. Only in this case can a continuous process be carried out.

Fig. 1. Scheme of a countercurrent ion-exchange apparatus.

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In a number of studies of the dynamics of sorption and ion exchange ($^{5-13}$), it was shown theoretically that the formation of a stationary front can be observed only in the case of a convex sorption or exchange isotherm. For ion exchange these propositions were experimentally confirmed in works ($^{11-15}$) carried out on a fixed bed of ion exchanger. We confirmed it experimentally also for exchange in a moving bed of ion exchanger (^{16}).

Therefore the choice of ions C and D may be based on a study of ion-exchange equilibrium. As ion C one may use ions that are absorbed by the resin more weakly than the ions being separated; as ion D, ions that are absorbed more strongly.

As a result of the fact that one of the components, for example B, is retained by the exchanger more strongly than the other, ion A gradually accumulates in column I, and B in column II. If conditions are selected (cation exchanger, solvent, solution concentration, etc.) under which the single-stage separation coefficient of A and B is sufficiently large, then after some time in column I, below point a, continuous withdrawal of a solution containing only AZ can be carried out, while in column II, above point d, solution BZ can be withdrawn; moreover, the concentration of AZ will be equal to the sum of the concentrations of AZ and BZ in the mixture being separated, and the concentration of BZ will be equal to the concentration of the displacing solution DZ.

The proposed countercurrent method, in the essence of the chemical processes, is close to the nonspreading-band method proposed by Spedding and co-workers for a fixed bed of ion exchanger (^{17,18}). However, in comparison with the latter it has a number of advantages both from the technological standpoint (possibility of automation, simplicity of control over the course of the process, ease of carrying out feed and product withdrawal) and from the standpoint of increasing the separation effect, since in the proposed method the nonspreading band is divided into two parts and the processes occurring at its front and rear ends are carried out in separate columns. This makes it possible to implement different operating regimes (rates of movement of the phases, solution concentrations) and to change the chemical conditions of the process (composition of the solvent, introduction of a complexing agent) in each of the columns and thereby to make maximum use of the capabilities of the equipment.

The proposed method has the same advantages over carrying out the nonspreading-band method in one countercurrent column with feed at the middle point. To this it should also be added that feeding at the middle point does not ensure uniform motion of the liquid phase, increases bypass flows and thereby decreases the separating capacity of the system (increases the HETP). These disadvantages are eliminated when the process is carried out in two columns.

By the proposed method, on a laboratory installation consisting of two countercurrent columns 25 mm in diameter and 1.5 m high, in which the cation exchanger moved counter to the solution under the action of gravity and was removed by means of an auger, we carried out the separation of various mixtures of alkali-metal cations. For example, in separating a mixture of 0.4 N solutions of lithium and sodium sulfates on KU-2 cation exchanger, at exchanger and solution flow rates of 0.3 ml/min and 1.3 ml/min, respectively, after 20 h in column I a lithium zone was obtained containing less than 10^{-5}% Na, and in column II a sodium zone containing less than 10^{-4}% Li. Further operation of the installation made it possible to obtain products of the indicated purity in amounts of 0.7 g/h Li_2SO_4 and 1.0 g/h Na_2SO_4. The HETP was 0.5 cm.

S. E. Bresler, A. I. Egorov, and B. P. Konstantinov ([19]), for the separation of Li and Na by the nonspreading-band method on a fixed bed of SBS-1 cation exchanger under conditions close to those used in the present work, obtained an HETP equal to 0.25 cm. The larger HETP value obtained by us is explained by the larger, than in the cited work, diameter of the grains of the cation exchanger.

and also by some mixing during the countercurrent motion of the solution and the exchanger.

The proposed method can be applied not only to ion-exchange separation, but also to any sorption separation of mixtures.

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Received
20 IX 1961

References Cited

1. J. R. Higgins, J. E. Roberts, Chem. Eng. Progr. Sympos., Ser. No. 14, 87 (1954).
2. N. K. Hiester, R. C. Phillips, Chem. Eng., 61, 161 (1954).
3. C. W. Hancher, Eng. and Mining J., 160, 80 (1959).
4. R. Porter, Chem. Week, 78, June 9, 74 (1956).
5. J. W. Wilson, J. Am. Chem. Soc., 62, 1583 (1940).
6. D. De Vault, J. Am. Chem. Soc., 65, 532 (1943).
7. A. N. Tikhonov, A. A. Zhukhovitskii, Ya. L. Zabezhlinskii, ZhFKh, 20, 113 (1945).

8. Ya. M. Bikson, ZhFKh, 27, 1530 (1953).
9. S. E. Bresler, DAN, 97, 699 (1954).
10. G. V. Samsonov, DAN, 97, 707 (1954).
11. N. N. Tunitskii, E. P. Cherneva, V. I. Andreev, ZhFKh, 28, 2006 (1954).
12. O. M. Todes, V. V. Rachinskii, ZhFKh, 29, 1591 (1955).
13. V. V. Rachinskii, ZhFKh, 31, 444 (1957).
14. K. A. Golbert, I. A. Myasnikov, in: *Chromatography, Its Theory and Application*, Publishing House of the Academy of Sciences of the USSR, 1960, p. 163.
15. L. S. Aleksandrova, S. Yu. Elovich, K. V. Chmutov, ZhFKh, 33, 627 (1959).
16. V. I. Gorshkov, I. A. Kuznetsov, G. M. Panchenkov, ZhFKh, 36, No. 3 (1962).
17. F. H. Spedding, J. E. Powell, H. J. Svec, J. Am. Chem. Soc., 77, 1393, 6125 (1955).
18. F. H. Spedding, J. E. Powell, Pat. USA, 2889205, 2.06.1959.
19. S. E. Bresler, A. I. Egorov, B. P. Konstantinov, Izv. AN SSSR, OKhN, 1960, No. 11, 1938.

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