The Effect of Ultrasound and Mechanical Stirring on the Ion-Exchange Kinetics

By

K. L. Cheng and Zhenpu Wang*

With 6 Figures

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The extensive fundamental work on ion-exchange has largely been devoted to equilibria and thermodynamics. Relatively little consideration has been given to the kinetics of ion-exchange. The ion-exchange kinetics have been reviewed by Helfferich 1.

In 1970, one of us (KLC) found that the ion-exchange equilibrium reached by the ultrasonic agitation took much longer than that reached by mechanical stirring 2. Recently we continued this study. Little information could be found in the literature concerning the effect of ultrasonic agitation on ion-exchange. Shostak et al. 3 published a short note that both ultrasonic agitation and hand-stirring can accelerate ion-exchange equilibria; the authors reported that ultrasound was more effective than hand-stirring without offering any explanations. In contrast, we report here that mechanical stirring is more effective than ultrasound to accelerate ion-exchange equilibria.

Experimental

Apparatus

Ultrasonator: (1) Fisher Ultrasonic Generator and Cleaner, made by Blackstone Ultrasound Inc., maximum power of ultrasonic output is 100

* On leave from Nanking Institute of Chemical Technology, Nanking, China.

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watts with a power range of 0—100. The frequency of ultrasonic output is 20 ± 2 kilocycles per second. (2) Sonic Dismembrator 300, made by Artek Systems Corporation, maximum power of ultrasonic output is 300 watts. Intermediate tip with a maximum intensity of 60 (intensity range is 0—100) corresponding to 180 watts. The frequency of ultrasonic output is 20 ± 0.4 kilocycles per second.

Yankee Variable Speed Rotator: Made by Clay Adams, with intensity range of 0—10. Maximum revolutions per minute (rpm) for intensity 10 is 300 rpm.

Reagents

Amberlite IR-120 resin, strongly acidic, sulfonated polystyrene type in H form, 20—50 mesh. Dowex 50W-X8 resin, strongly acidic, sulfonated polystyrene type in H form, 20—50 mesh. Dowex 1-X10 resin, strongly basic styrene and quaternary ammonium type in chloride form, 200—400 mesh. Dowex 1-X8 resin, strongly basic styrene and quaternary ammonium type in chloride form, 20—50 mesh.

Procedure

Determination of the distribution coefficient (K_d) of cation exchange between the magnesium ion and the cation exchange resin was carried out by pipeting exactly 25 ml of 0.0250 M MgSO_4 solution into each of 125-ml Erlenmeyer flasks containing a weighed amount of resin. The flasks were stoppered and agitated by either a mechanical rotator or an ultrasonator for various lengths of time at the same intensity or speed, or at various intensities or speed with a specified length of time. The supernatant liquid was rapidly filtered. The magnesium ion remaining in the filtrate was titrated by 0.0200 M ethylenediaminetetraacetate (EDTA) solution at pH 10 using Eriochrome Black T as the indicator. The experiments were done at 20°C.

The determination of distribution coefficient (K_d) between the nitrate ion and the anion exchange resin was carried out in a similar manner, by using an anion exchange resin and 25.00 ml of 0.1000 M or 0.0200 M KNO_3 solution. The chloride ion in the filtrate was titrated with 0.1000 M or 0.0200 M AgNO_3 solution using 5% potassium chromate as the indicator.

Results and Discussion

At the beginning, it was thought, in agreement with Shostak et al., that the ultrasound would be more powerful or effective than a mechanical stirring for accelerating the ion-exchange equi-