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DONNAN DIALYSIS DESALINATION

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Desalination was effectively carried out with the cell in which a salt solution was separated from hydrochloric acid with a cation-exchange membrane and from sodium hydroxide solution with an anion-exchange membrane. Donnan dialysis occurred in the cell, cations and anions were exchanged with protons and hydroxide ions, and neutralization and desalination proceeded simultaneously.

Ion exchange with ion-exchange resins are an essential process for manufacturing pure water or extra pure water.[1] Ion-exchange resins are very easy to handle but the intermittent regeneration is necessary and the contamination from the resin is a matter of concern. Then, we applied ion-exchange membranes to desalination on the principle of Donnan dialysis.[2] Donnan dialysis is an ion-exchange process through ion-exchange membranes and it has been used for salt enrichment.[3] When a salt solution is separated from hydrochloric acid solution with a cation-exchange membrane and from sodium hydroxide solution with an anion-exchange membrane, cations are exchanged with protons through a cation-exchange membrane, anions are exchanged with hydroxide ions through an anion-exchange membrane, and the salt solution in the cell is desalinated. We will report a preliminary study in this paper.

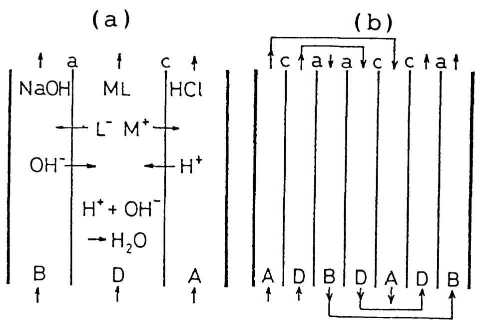

Fig. 1. (a)Donnan-dialysis cell and schematic ion transport and (b)multiple Donnan-dialysis cell. a, anion-exchange membrane; c, cation-exchange membrane; A, compartment of HCl soln.; B, compartment of NaOH soln.; D, desalination compartment.

Figure 1(a) shows a Donnan-dialysis cell and schematic ion transport and Fig. 1(b) shows a multiple Donnan-dialysis cell whose membrane area is 3 fold of that of the cell(a). The cell is similar to the macromosaic cell,[4] the area of an ion-exchange membrane is 11.3 cm^2, and the salt solution of compartment D(50 cm^3), the hydrochloric acid solution of compartment A(1 dm^3), and the sodium hydroxide solution of compartment B(1 dm^3) were cycled from respective reservoirs with tube pumps. The ion-exchange membranes used in this study were Selemion AMV and CMV(Asahi Glass Co. Ltd.). In the dialysis experiment, 2 cm^3 of the solution of compartment D was collected at 30 minutes intervals and the cation concentration was detected with an atomic absorption spectrophotometer.

Figure 2 shows the concentration changes with time in compartment D containing 0.01 mol dm^{-3} potassium chloride solution. In the case of Donnan dialysis using 2 compartments with a cation-exchange membrane, the potassium ion concentration decreased with time but the pH of the salt solution also decreased(pH was 2.4 after 3 hours). In the case of Donnan dialysis using 3 compartments with a cation-exchange membrane and an anion-exchange membrane, the salt concentration decreased rapidly with time, while the pH of the solution changed little(pH was 4.2 after 3 hours).

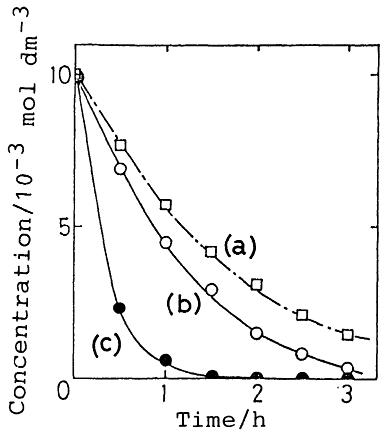

Fig. 2. Concentration change with time.
(a), Donnan dialysis using 2 compartments; (b), Donnan dialysis using 3 compartments; (c), Donnan dialysis with multiple cell;
HCl concn., 0.1 mol dm^{-3};
NaOH concn., 0.1 mol dm^{-3}.

In the process, Donnan equilibrium existed across a membrane as

$$[M^+]_A/[M^+]_D = [H^+]_A/[H^+]_D \qquad (1)$$

$$[L^-]_B/[L^-]_D = [OH^-]_B/[OH^-]_D \qquad (2)$$

where M^+ and L^- show a monovalent cation and a monovalent anion, respectively, and A, B, and D are symbols of the compartments. When the volume of the acid solution is equal to that of the base solution(V cm^3) and $[H^+]_A = [OH^-]_B$, $[M^+]_A = [L^-]_B$ and $[M^+]_D = [L^-]_D$. The material balance for the metal ion is as

$$[M^+]_A \times V + [M^+]_D \times V_0 = C_0 \times V_0 \qquad (3)$$

where V_0 and C_0 show the volume and the initial concentration of the salt solution. From Eqs. 1 and 3,

$$[M^+]_D = C_0V_0/([H^+]_A/[H^+]_D \times V + V_0) \qquad (4)$$

When the amount of migrated protons is equal to that of the hydroxide ions, the concentrations of protons and hydroxide ions become 10^{-7} mol dm^{-3} in compartment D. Then, the final salt concentration in compartment D is calculated to be 5×10^{-10} mol dm^{-3} in the case of Fig. 2(b). The leak of co-ions through an ion-exchange membrane and the difference between the transport rate of protons and that of hydroxide ions should be considered in the actual system. Figure 2 also shows the result of the multiple Donnan-dialysis cell. The desalination rate increased remarkably because of the large membrane area and the concentration of potassium ion in the compartment D was 0.06 ppm and its pH was 7.0 after 3 hours.

Donnan-dialysis desalination is a continuous process substituting for the process with ion-exchange resins and is effective for manufacturing pure water.

References

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