일반강연 A-10

# 전기투석에서의 농축액의 농도에 따른 효율 변화

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# Effects of the concentration of C-solution on the electrodislysis performance

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## 1. Introduction

Electrodialysis has been widely used for desalination, for concentrating a solution, for the separation of amino acids and for the recovery of electrolytes. As a biotechnological process, electrodialysis is very effective at concentrating electrolytes and proteins [1]. With a high concentration of recovered solutes through electrodialysis, the cost for the following processes, crystallization and drying, may be reduced.

It has been reported, however, that there's a limitation to the degree of concentration of C-solution due to a increased water transport as the concentration of C-solution increases. In addition to the water transport problem, a low current efficiency with a high concentration of the C-solution could be a serious hindrance in the application of electrodialysis since it would then require a greater operating cost.

In this research, the effect the concentration of the C-solution had on the current efficiency, energy consumption and the final concentration during electrodialysis using NaCl with various membrane pairs was studied.

## 2. Theory

Current efficiency is determined by the membranes selectivity. For the ion exchange membrane, the concentration of co-ions which decrease the selectivity of a membrane could be described by a donnan equilibrium (Eq. 1) between the C-solution and the membrane phase [2].

$$(C^C)^2 = C^m_{counter-ion}(C^m_{co-ion} + C^m_{fixed-charge}) \quad (1)$$

$$P^m - P^c = A\,C^m_{fixed-charge} \quad (2)$$

$C^C$ concentration of C-solution

$C^m_{counter-ion}$ concentration of counter-ion in membrane phase

$C^m_{co-ion}$ concentration of co-ion in membrane phase

$C^m_{fixed-charge}$ concentration of fixed-charge in membrane phase

$P^C$= pressure of C-solution

$P^m$= pressure in membrane phase

$A$ constant

The concentration of the co-ion in the membrane phase increases if the concentration of C-solution also increases. This trend can then explain the decrease seen in the current efficiency when the concentration of C-solution increases because the membrane can not block the transport of the co-ions from the C-solution to the D-solution effectively.

The water content in the ion exchange membrane is the main factor determining the degree to which water is transported through the membrane since it is this water to which the ions passing through the membrane complex with and pull through. The osmotic pressure depends solely on the capacity of a membrane (Eq. 2). Therefore, the membranes with a high capacity tend to have a large amount of water transported through them.

## 3. Experimental

For the characterization of the ion exchange membranes, AM1-CM1 and AMX-CMX pairs (NEOSEPTA) and an AMV-CMV pair (Asahi Glass Co.) were used. The water content of each membrane was measured after the membrane was equilibrated with a NaCl solution. The electric resistance of a membrane was measured using a 2321 LCZ meter (NF electronic instruments) and a clip cell [3]. The capacity of the cation exchange membranes was determined using a 0.01 M NaOH solution [4]. The capacity of the anion exchange membranes was obtained by analyzing the $Cl^-$ concentration in the membrane [5] using an IonPac AS14 column (DIONEX).

With the initial concentration of D-solution (1M, 2L) remaining constant, the initial concentration of C-solution (1L) was changed from 1M to 5M in the performance of electrodialysis. The operating time was 60 min for each experiment.

## 4. Results and Discussion

Table 1 shows the properties of membranes. The current efficiency decreased when the initial concentration of C-solution was increased because the concentration of co-ion in the membrane increased. The current efficiency varied, however, depending on the capacity of the cell-pair. Due to the lowest capacity, the AMX-CMX pair had the lowest slope of all the curves (Fig. 1). The energy consumption decreased at an intermediate concentration because the decrement of the electric resistance was higher than that of current efficiency. Energy consumption, however, increased when the initial concentration of C-solution was increased further because the current efficiency decreased more rapidly than the electrical resistance (Fig. 2). The water transport increased according to the concentration of C-solution and it accounted for the effect of the osmosis (Fig. 3). The water transported in each membrane pair was proportional to the water content of the membrane and it determined the final concentration of C-solution.

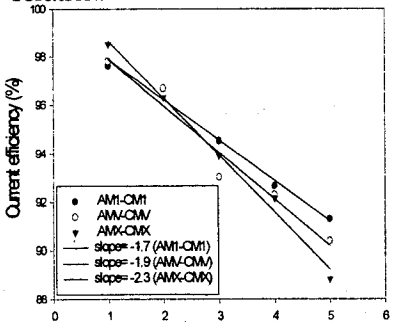


Fig. 1. Current efficiency as a function of the initial concentration of C-solution

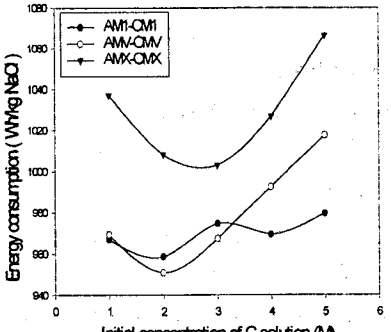


Fig. 2. Energy consumption as a function of the initial concentration of C-solution

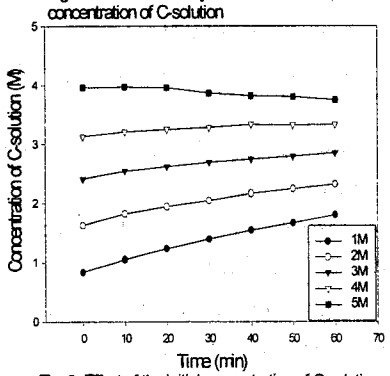


Fig. 3. Effect of the initial concentration of C-solution on the concentration profile; AM1-CM1 pair

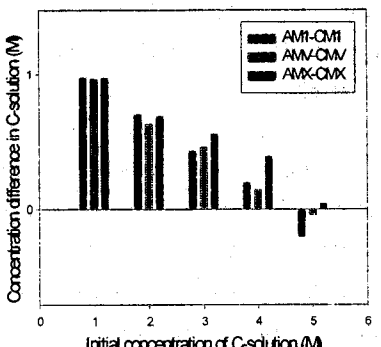


Fig. 4. Effect of the membrane pair on the concentration of C-solution; operating time = 60 min

Table 1. Properties of membranes

| properties \ membrane | AM1 | AMV | AMX | CM1 | CMV | CMX |
|---|---|---|---|---|---|---|
| capacity (meq/g dry membrane) | 1.9 | 2.0 | 1.4 | 2.5 | 2.4 | 2.1 |
| electric resistance ($\Omega$-cm$^2$); 1M NaCl | 2.0 | 2.4 | 3.6 | 1.7 | 2.4 | 3.3 |
| water content (%); 1M NaCl | 20.6 | 20.0 | 16.6 | 31.3 | 27.9 | 22.5 |

In the case of the AMX-CMX pair, even at the highest concentration of C-solution, a further increase in the concentration was noticeable (Fig. 4).

## 5. Conclusion

The effects of the C-solution concentration were examined through the performance of electrodialysis with various membrane pairs. These were compared with the characteristics of the membranes. (1) Water transport increased with an increase in the concentration of C-solution and determined the final concentration. (2) Energy consumption was a function of the electrical resistance of the membrane and current efficiency. (3) The performance was closely related to the properties of the membrane.

## Acknowledgement

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