이온교환막에 의한 이온치환 반응을 이용한 젖산나트륨으로부터 젖산 생산

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Production of lactic acid from sodium lactate by electro-ion substitution reaction using ion-exchange membrane

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1. Introduction

A typical ED cell arrangement consists of a series of anion and cation exchange membranes placed in an alternating pattern between an anode and a cathode. However electro-ion substitution reaction can be carried out in a special ED stack in which the ion-exchange membranes are all of the same kind, using either anionic or cationic membranes only. In a stack in which each unit cell has two compartments, protons replace the sodium ions, converting lactate to lactic acid by moving cations under an electric field [1,2,3].

The electrodialysis experiments on the efficient production of lactic acid from sodium lactate by electro-ion substitution reaction was carried out using the Neosepta CMX cation-exchange membrane. The influences of operating parameters, such as current density, and composition of acid compartment solution, on the overall performance of the ED stack were investigated.

2. Experiment

ED stack All experiments were performed by a laboratory scale ED stack, which is made by Plexiglas cells and has four separate

compartments (Fig. 1). A platinized titanium anode and a stainless steel cathode were used. And CMX membranes as cation-exchange membranes and AMX membrane as a anion-exchange membrane (Tokuyama Soda Inc., Japan) were placed in the stack as shown in Fig. 1. The voltage drop across the unit cell was measured by Ag/AgCl electrodes connected to a multimeter (HP 34410A) and the data were saved at every 10 seconds by computer.

ED operation Five tenth normal of Na_2SO_4 (Merk, analytical grade) was used in the electrode compartments and 0.1 N of sodium lactate was circulated in feed compartment. The pH and conductivity of the feed solution were measured as a function of time using pH meter (Orion, Model 250A) and conductivity meter (Cole-Parmer, Model 124). Samples were taken in a predetermined schedule from feed solution, and analysed by ion chromatography (Dionex DX-500, ED 40 conductivity detector, CS 12A column). The flow rate of acid and feed stream were set at 150 mL/min, while the flow rate of electrode solution was 500 mL/min.

3. Results and Discussion

As the constant current density of 10 mA/cm^2 was supplied through the ED stack shown in Fig. 1, the protons in the acid stream were transported to the feed stream and equilibrated with the negatively charged organic species. As the results, lactate molecules were converted to electrically neutral lactic acid, and sodium ions were transported to the next acid compartment to meet the electroneutrality of the feed stream. The conversion efficiency (η_{con}) of the organic salt to the organic acid and the current efficiency (η_I) were calculated by following equations.

$$\eta_{con} = \frac{C^0_{Na} - C^t_{Na}}{C^0_{Na}} \times 100 \quad (1)$$

$$\eta_{con} = \frac{(C^0_{Na} - C^t_{Na}) \cdot V \cdot F}{I \cdot t} \times 100 \quad (2)$$

Fig. 2 shows the conversion and current efficiency as a function of time for the lactic acid. For the current density of 10 mA/cm^2, the conversion efficiency of lactic acid was 96.2 % at 180 min, and the

current efficiency maintained at nearly 100 % for the first 100 min.

The influence of the current densities below and beyond the LCD on the process performances was studied. From the current-voltage curve (not shown here), LCD for the Neosepta CMX membrane was determined as 11.5 mA/cm^2 in 0.1 N sodium lactate solution. Thus the conversion and current efficiency were measured at 10, 15 and 20 mA/cm^2 (Fig. 3). As expected, lower current density required longer operation times. It took about 180, 130 and 100 minutes to obtain 95 % of conversion efficiency at the current density of 10, 15 and 20 mA/cm^2, respectively. The conversion efficiencies were finally about 96 % at all current densities. There was no influence of the current density, even beyond the LCD value, on the conversion efficiency, while the current efficiencies decreased with the increasing current densities.

During the ED operation, the sodium ions transported from feed to the acid compartment are accumulated and can decline the process efficiency. So the effect of the composition of acid compartment solutions on the process performance was also studied. The results of experiments with various compositions of acid solution (the equivalent ratio of H_2SO_4 to Na_2SO_4 were 1:4 and 3:2) at a current density of 10 mA/cm^2 were presented in Fig. 4. After 180 min., the conversion efficiencies for 3:2 and 1:4 mixed solutions were 90.7 and 44.8 %, respectively and the final current efficiencies were 79.6 and 39.3 %, respectively. The high permselectivity of protons compared to sodium ions was observed because the mobility of protons is much higher than that of sodium ions.

4. Acknowledgement

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5. References

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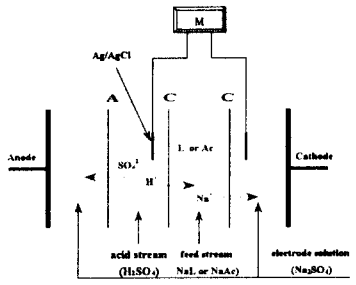

Figure 1. Schematic diagram of electrodialysis cell used in this study. A: AMX, C: CMX membrane, respectively (Tokuyama Soda Inc., Japan).

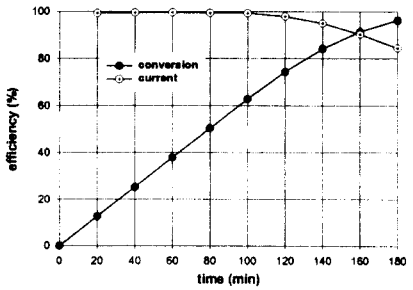

Figure 2. Conversion and current efficiency of 0.1 N sodium lactate solution as a function of time at the current density of 10 mA/cm^2.

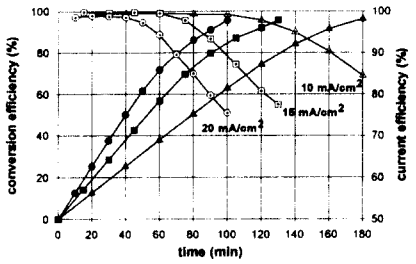

Figure 3. Effect of current density on the conversion and current efficiency in 0.1 N of sodium lactate solution.

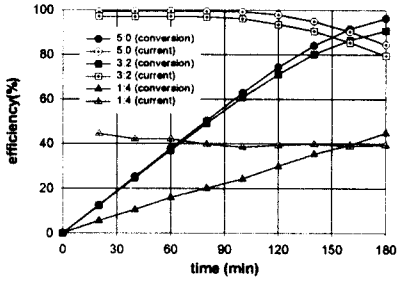

Figure 4. Effect of the composition of acid compartment solution on the conversion and current efficiency of sodium lactate at the current density of 10 mA/cm^2. The solutions were composed of H_2SO_4 and Na_2SO_4, and the total equivalent concentration was 0.5 N.