Continuous and Simultaneous Removal of Anions and Dissolved Oxygen from Water by an Ion Exchange Membrane Cell

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Dissolved oxygen can be removed from anion-free water by an ion-exchange process¹⁾ based on the interaction of dissolved oxygen with a sulfite form of a strongly basic anion exchange resin, according to the equation

$$2R_2SO_3 + O_2 \rightarrow 2R_2SO_4 \qquad (1)$$

On passing the treated solution through the column of the anion exchanger in a sulfite form, the content of dissolved oxygen is reduced below 10 ppb. This process is discontinuous. After exhaustion it is necessary to convert the resin to a sulfite form with a sodium sulfite solution. This process has now been carried out continuously in an electrolytic membrane cell.

Apparatus. A 4-compartment membrane cell (Fig. 1) has been used for experiments. Electric conductivity has been measured with a conductometer Radelkis Budapest. Dissolved oxygen has been estimated by the Töller method,²⁾ with a sensitivity as low as 10 ppb.

Procedure. Sulfite ions are transported under the influence of an applied electric potential from compartment III across membrane AM_1 into packed compartment **II**, and thus particles of resin are continuously converted into the sulfite form. Sulfate ions, resulting from the reaction (1), are transported across membrane AM_2 into anode compartment I. Treated water passes through the packed compartment **II**, and a continuous uptake of dissolved oxygen takes place in this compartment. It has been found that only such an amount of sulfite ions should be transported across membrane AM_1 which can be immediately absorbed by the given amount of resin in compartment **II**. Under these conditions, sulfite and sulfate ions are transported across packed compartment II toward membrane AM_2 preferably within the resin particles and do not remain in the solution.

When a greater number of sulfite ions than can be absorbed by the anion exchanger in compartment II are transported across membrane AM_1, they remain in solution and contaminate the deoxygenated effluent, increasing the electric conductivity of the deoxygenated water (Table 1, Run 1).

TABLE 1. SIMULTANEOUS REMOVAL OF DISSOLVED OXYGEN AND ANIONS FROM WATER

Run No.	SO_3^{2-} inlet concn. (equiv·l^{-1})	SO_3^{2-} flow rate ($l\cdot h^{-1}$)	Current density ($mA\cdot cm^{-2}$)	Effluent electric conductivity (m℧·cm⁻¹)
1	0.025	0.75	7.7	10.0
2	0.025	0.54	7.7	5.5
3	0.025	0.47	7.7	2.5
4	0.011	2.70	2.3	5.5
5	0.011	2.70	2.75	1.8
6	0.011	2.70	4.0	1.3

Dissolved oxygen content of the outlet in all runs below 10 ppb.

Treated solution:

in runs No. 1—5: distilled water (electric conductivity 5.5 m℧·cm⁻¹, flow rate 1.0 $l\cdot h^{-1}$);

in run No. 6: 0.002 N H_2SO_4 solution, flow rate 0.7 $l\cdot h^{-1}$; SO_3^{2-} outlet concentration =0.0092 equiv·l^{-1}

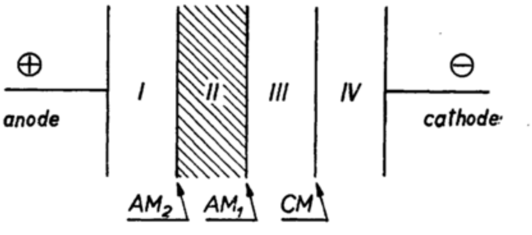

Fig. 1. 4-Compartment cell.

AM_1, AM_2: anion exchange membrane Permaplex A-20

CM: cation exchange membrane Permaplex C-20

Effective membrane area: 125 cm²

Height of packed compartment: 25 cm

Width of packed compartment (distance of membranes): 0.3 cm

Material used: plexiglass

I: anode compartment

II: compartment packed with particles of the strongly basic anion exchange resin Zerolit FF (size 60—80 mesh)

III: SO_3^{2-} solution compartment

IV: cathode compartment

The number of sulfite ions transported across membrane AM_1 has been checked by evaluating the concentration polarisation, which causes a

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1) V. Kadlec and A. Brodský, *Chem. listy*, **58**, 891 (1964).

2) K. Buriánek, *Energetika*, **7**, 21 (1957).

decrease in the transport numbers of the ions of the electrolyte.[3] A concentration polarisation arises under certain conditions (given by the concentration of the sulfite solution, flow rate and current density) on the surface of membranes AM_1 and CM in compartment III. The number of transported sulfite ions is, in this way, kept at the desired level. Contamination of effluent does not appear. Electric conductivity of deoxygenated water remains unchanged (Table 1, Run 2).

A strongly basic anion exchange resin in sulfite form in the column can be used for removing of dissolved oxygen from anion-free water only. Anions, present in the solution, displace, during the working period, sulfite ions into the effluent, causing both a capacity and efficiency decrease.

In the process of continuous removal of dissolved oxygen by the packed bed membrane cell, the presence of anions does not interfere. Resin in the packed membrane cell is continuously and simultaneously converted into sulfite and hydroxide forms and it is capable of the quantitative uptake of both dissolved oxygen and anions from water. By a variation in the conditions on which the concentration polarisation depends, one can vary the ratio of the functional groups converted into hydroxide and sulfite forms. It enables the treatment also of solutions which are rich in anions.

If the concentration of the sulfite solution, while passing through the cell, drops remarkably, the concentration polarisation increases and proceeds nonuniformly, *i. e.,* at the outlet increases more than at the inlet. Owing to this fact, some lower portions of the anion exchanger are converted into the hydroxide form only, and the removal of dissolved oxygen will cease. Therefore, the sulfite solution concentration can be reduced only slightly on passing the cell.

The results, obtained in experiments with distilled water and 0.002 N sulfuric acid solution are given in Table 1. It has been shown possible to reduce the dissolved oxygen content below 10 ppb, and simultaneously to remove all anions present in solution (electrical conductivity of the treated solution at the outlet $\kappa = 1.3\ \mathrm{m℧ \cdot cm^{-1}}$) (Table 1, Run 6).

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[3] T. R. E. Kressman and F. L. Tye, *Discussions Faraday Soc.,* **21**, 185 (1956); N. W. Rosenberg and C. E. Tirrell, *Ind. Eng. Chem.,* **49**, 780 (1957); B. A. Cooke and S. J. van der Walt, *Electrochimica Acta,* **5**, 216 (1961).