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TECHNICAL NOTE

Proposed Operation of Large-Scale Isotachophoresis

BHASKAR K. ARUMUGAM* and PHILLIP C. WANKAT†
SCHOOL OF CHEMICAL ENGINEERING
PURDUE UNIVERSITY
WEST LAFAYETTE, INDIANA 47907-1283, USA

ABSTRACT

The operation of preparative isotachophoresis with either or both the leading and trailing ions replaced by the ions with the highest and lowest mobility in the feed is proposed. The advantages of this procedure are that one does not have to search for appropriate leading and trailing ions, and no additional chemicals need to be added and later recovered from the separation. The familiar steady-state theory for isotachophoresis predicts that the separation will be successful if the bands form. Experiments with the analogous displacement chromatography system were successful.

INTRODUCTION

Isotachophoresis (ITP) was developed as electrophoresis operated in the displacement mode by analogy with displacement chromatography (1). Like displacement chromatography, ITP has considerable unmet potential as a large-scale separation method (2, 3). However, most research in the area has focused on use of ITP as a preconcentration step before analysis by capillary electrophoresis (4–8).

In a recent publication (9) on gas displacement chromatography, we showed experimentally and theoretically that the least strongly absorbed component in the feed can be used as the initial component and the most strongly adsorbed component in the feed can be used as the desorbent. Thus displacement chro-

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* Current address: Eastman Chemical Company, Kingsport, TN, USA.
† To whom correspondence should be addressed.

matography can be performed with components in the feed as presaturant and displacer. In analytical separations this will result in loss of information. However, in large-scale operation this mode of separation is likely to be a major economic advantage since one does not have to search for a proper desorbent and no chemicals not already present need to be added. This last advantage is a major concern in large-scale processing (10).

In this note we use the analogy between ITP and displacement chromatography to propose a similar operating procelure for large-scale ITP. That is, the leading electrolyte can be the fastest moving electrolyte in the feed and the trailing electrolyte can be the slowest moving electrolyte in the feed.

THEORY

Consider a system consisting of a ternary feed containing three anionic species A, B, and C, a leading ion L, and a trailing ion T. The effective mobilities of the ionic species are $\mu_L \geq \mu_A > \mu_B > \mu_C \geq \mu_T$. Complete ionization is assumed, and the effect of background hydrogen and hydroxyl ions is neglected. The counterion q is the same in all zones. Operation is at constant current. At steady state, zones with pure components are formed in the order L, A, B, C, T.

At steady state it is easy to show (1, 2, 11) that

$$\frac{c_i z_i(\mu_i + \mu_{q,i})}{\mu_i} = \frac{c_j z_j(\mu_j + \mu_{q,j})}{\mu_j} \tag{1}$$

The above equation relates concentrations in various zones. Using the analogy between displacement chromatography and isotachophoresis, and the success of operating displacement chromatography without separate least adsorbed and displacing components (9, 11), the following modified method for isotachophoresis is proposed.

- The leading ion is replaced by the ion with the highest mobility already present in the feed, L = A
- The trailing ion is replaced by the ion with the lowest mobility already present in the feed, T = C

If mobilities are pH-dependent, appropriate buffering may be required for the bounding electrolytes.

Everaerts and Verheggen (12) noted that if one of the ions in the sample has an effective mobility equal to that of the leading ion, the conductivity of the leading electrolyte remains unchanged. The conductivity and zone lengths of all other zones are not influenced by this ionic species. So, if species A is the leading ion, Eq. (1) reduces to

$$c_A z_A = c_L z_L \quad \text{or} \quad c_A = c_L \tag{2}$$

The fastest moving ion present in the feed will separate from other components in the feed and form a zone behind the leading zone with the same concentration as in the leading zone. Obviously, this zone cannot be distinguished from the leading zone since both are species A. Similarly, if the trailing ion is replaced by the slowest moving ion in the feed, a single zone of the slowest ion is formed. The concentration in this zone is determined by the concentration of the leading ion, following Eq. (1)

DISCUSSION

Based on the analogy with displacement chromatography, we hypothesize that we can operate isotachophoresis (ITP) by replacing either or both the leading and trailing ions by ions with the highest and lowest mobility in the feed. In each case, concentrations in any zone are determined by the concentration of the leading ion. Experiments with an analogous displacement chromatography system showed that bands developed (9, 10). This leads credence to the proposed operation for ITP. Of course, experimental verification of this proposed operating procedure is needed. One purpose of this note is to encourage ITP experimenters to try this procedure for large-scale applications.

This modification of ITP uses chemicals already present in the feed as the leading and trailing species. In general, the use of a chemical already present in a large-scale process is highly recommended even if the chemical is not the optimum mass separating agent based on its properties alone (10). This procedure has many advantages in large-scale operation such as considerably easier FDA approval. In many applications the increased cost of the ITP (since nonoptimum leading and trailing ions are used) will be more than compensated for by the savings since there is no cost for removal of leading and trailing ions. Thus, this modification should be of considerable interest for many applications of large-scale ITP. If desired, spacers could be used in this operation. Experimental verification is still required, and a model for the transient period that can predict development of the isotachophoretic condition in modified systems will facilitate understanding of the process.

SYMBOLS

c	concentration (equivalents/L)
z	valence
μ	electrophoretic mobility ($m^2/V{\cdot}s$)

Subscripts

A, B, C, *i*, L, T	anions A, B, C, *i*, leading, trailing
q	coion

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