The Effect of Temperature upon Foam Fractionation

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Abstract

An experimental investigation is presented of the effect of temp on the foam fractionation of the ethylhexadecyldimethylammonium bromide-water system. Two feed concn, two foam heights, and a temp range of 14-38°C are included. For each fixed set of values of feed concn and of foam height, the greater and lesser coefficients of fractionation are both increasing functions of temp. The effect of a variation in temp on the greater coefficient is more pronounced for more dilute feed solutions, and at greater foam heights. The effect of a temp change on the lesser coefficient is more pronounced for more concn feed solutions and is not related to foam height. At any fixed temp, an increase in feed concn at constant foam height generally decreases the greater coefficient and decreases the lesser coefficient. An increase in foam height at constant feed concn increases both coefficients. The greater and lesser coefficients may be related to temp by power equations with 5% accuracy. The above results may be explained qualitatively on the basis of the response of foam stability and drainage to temp.

Introduction

FOAM FRACTIONATION has been utilized by chemists, biochemists and engineers for the separation of organic and inorganic materials from dilute aqueous solutions. Applications of the process include the separation of enzymes, the transfer of organic solutes which by themselves have little foaming ability, the separation of radioactive metal ions from waste streams and the treatment of secondary sewage effluents for the separation of non-biodegradable organics. Several extensive reviews of the process have appeared in the literature (1,11,12). Recently, a number of studies have been made on the operating and system variables affecting the process. Grieves et al. determined the influence of foam height and foam column diam (7), the influence of surfactant, feed concn, air rate and feed rate (5,6,8), the effect of liquid solution height (7,8) and the effect of feed position (5,8) upon the continuous foam fractionation of anionic and cationic surfactants. Other studies of this nature have been conducted by Kevorkian (9), by Kishimoto (10) and by Brunner and Lemlich (2).

The information available on the influence of temp on the foam process is limited. Grieves and Wood (8) studied variations with temp of the continuous foam fractionation of ethylhexadecyltrimethylammonium bromide solutions, but their temp range was limited to 24-38°C. Kishimoto (10) reported the effect of temp upon the batch foaming of sodium lauryl sulfate solutions, but his temp range was limited to 10-22°C. Bikerman (1) has reviewed a number of investigations concerned with the relation between foam stability and temp; however, none of these studies were concerned with foam fractionation. The overall objective of this investigation is the establishment of the influence of temp upon the greater and lesser coefficients of fractionation for the ethylhexadecyltrimethylammonium bromide-water (EHDA-Br) system. Two feed concn, two foam heights and a broad range of temp are included in the experiments.

Experimental

All of the experiments were conducted in a 10-cm diam, 105 cm high, cylindrical column, made of lucite. High-purity nitrogen was saturated with water, metered with a calibrated rotameter, and passed through twin, 50 μ, fritted-glass diffusers. In each experiment, 2000 ml of the feed solution of EHDA-Br in distilled water were placed in the column. Nitrogen bubbles were dispersed through the solution for a period of 15 min with continuous foam removal at a port located at a selected height above the feed solution level. Feed concn of 87.5 mg/liter (2.31 x 10^{-4} M) and 125 mg/liter (3.30 x 10^{-4} M) were employed, with a nitrogen flow rate of 4950 ml/min (at Standard Temperature and Pressure) used with the 87.5 mg/liter solutions and of 3700 ml/min (STP) used with the 125 mg/liter solutions. Foam was removed at heights of 15.2 cm and of 77.8 cm above the average bulk solution level during the experiments. The temp of the solution and of the foam at the point of foam removal were measured to the nearest 0.5°C throughout each run, and an average operating temp was computed. At the termination of each experiment the residual solution volume was measured and the concn of EHDA-Br...
was determined by a two phase titration technique (3). Random analyses of the collapsed foam were conducted for material balance verification. The analyses were accurate to within \( \pm 1.0 \) mg/liter.

### Results and Discussion

Results of the experiments are presented in Figures 1-4 in which the greater and lesser coefficients of fractionation are related to temp. Temp investigated ranged from 14-54°C. The greater coefficient is defined as \( \frac{y_f}{x_f} \) and the lesser coefficient as \( \frac{x_r}{x_i} \), in which \( x_i \) (mg/liter) is the conen of EHDA-Br in the feed solution, and \( y_f \) and \( x_r \) are the conen in the collapsed foam and residual solution, respectively. For each experiment, the following material balances may be written:

\[
V_i = V_r + V_f \quad [1]
\]

\[
x_i V_i = x_r V_r + y_f V_f \quad [2]
\]

\( V_i, V_r \) and \( V_f \) are the volumes in ml of feed solution, residual solution and collapsed foam, respectively. \( V_i \) was held constant at 2000 ml. For given \( x_i \) and \( V_i, y_f \) may be computed from experimental values of \( x_r \) and \( V_r \), using Equations 1 and 2.

Figure 1 shows the effect of temp on the greater coefficient for 87.5 mg/liter feed solutions, with parameters of foam height (\( H_f \), cm). Figure 2 presents similar relations for 125 mg/liter feed solutions. For each fixed set of values of \( x_i \) and \( H_f \) (i.e., for each curve), an increase in temp always provides an increase in the greater coefficient of fractionation. The effect of a variation in temp, \([ \frac{(x_r/x_i)@t_1}{(x_r/x_i)@t_2} \] \), is most pronounced for \( x_i = 87.5 \) mg/liter and \( H_f = 77.8 \) cm. For constant \( x_i \), the influence of a variation in temp in always greater at the larger foam height, particularly at higher temp. The slopes of the \( y_f/x_f \) vs. temp curves sharply increase at high temp for \( H_f = 77.8 \) cm, while they tend to decrease slightly or become constant for \( H_f = 15.2 \) cm. Comparing results for both feed conen (at constant \( H_f \)), the effect of temp variation is greater for the more dilute feed solutions, but only at \( H_f = 77.8 \) cm. At \( H_f = 15.2 \) cm, the effect is minimal; however some of the response may have been shielded by the higher nitrogen flow rate that was used with the more dilute solutions. It has been shown previously (5) that an increase in gas rate with all other variables held constant provides a less rich foam. Considering both figures, at 15°C \( y_f/x_i \) ranges from 1.41-2.44, while at 48.5°C \( y_f/x_i \) ranges from 2.43-7.21. Thus at higher temp, variations in feed conen and foam height have a more marked influence on the greater coefficient of fractionation.

Figure 3 presents the variation of the lesser coefficient with temp for a foam height of 15.2 cm; the parameters are feed conen. Figure 4 shows similar relations for a foam height of 77.8 cm. For each fixed set of values of \( x_i \) and \( H_f \), an increase in temp always brings about an increase in the lesser coefficient. For any fixed temp, an increase in \( x_i \) decreases \( x_r/x_i \) (at constant \( H_f \)), which is more pronounced.