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NOTE

The Resolution and the Effect of the Phases Volume Ratio on It in Countercurrent Distribution

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Summary

This note describes the effect of the phases volume ratio on the resolution and the minimum required number of transfers in countercurrent distribution. It is shown that the resolution or the minimum transfer number can be optimized by a correct choice of the phases volume ratio.

Recently Grushka (*1*) has shown that the plate, resolution, and peak capacity concepts can be used in countercurrent distribution (CCD). The purpose of this note is to further elaborate on the resolution equation and to investigate the role of the volume ratio of the organic and aqueous phases on the resolution and on the number of transfer required for a given resolution.

In our previous work (*1*) the following expression for the resolution (Rs), in the case where the partition coefficients of the two solute are close in magnitude was developed:

$$Rs = \frac{(N_2)^{1/2}}{4}\left(\frac{p_2 - p_1}{p_2}\right) \tag{1}$$

where p is the fraction of the solute in the upper phase and the subscript identifies the solutes, and N is the number of plates. Using the definition of p and defining a relative migration, α, as K_2/K_1, Eq. (1) can be rewritten as

$$Rs = \frac{(N_2)^{1/2}}{4}\left(\frac{\alpha - 1}{\alpha}\right)(1 - p_1) \tag{2}$$

This equation is the exact analog of the commonly used resolution expression in chromatography (*2*). In both methods the resolution depends on the efficiency $(N)^{1/2}$ of the system, on the selectivity $(\alpha - 1)/\alpha$, and on the migration rate of one of the solutes $(1 - p_1)$. The ramifications of this equation are adequately described elsewhere (*1*).

The discussion in our previous work (*1*), as well as here, assumed equal phases volume. Although the common mode of operation involves equal volumes, it is not necessarily the best procedure. The apparent partition coefficients depend on the ratio of the upper (mobile) to lower (stationary) phase volume. Consequently, the rigorous expression for the resolution is (from Eq. 11 of Ref. *1*)

$$Rs = n\left(\frac{VK_2}{1 + VK_2} - \frac{VK_1}{1 + VK_1}\right) \Big/ 2(n)^{1/2}\left[\frac{(VK_2)^{1/2}}{1 + VK_2} + \frac{(VK_1)^{1/2}}{1 + VK_1}\right] \tag{3}$$

where n is the number of transfers and V is the ratio of the upper phase volume to the lower phase volume. It is of practical importance to investigate the effect of V on the resolution. Equation (3) can be rearranged to give

$$Rs = \frac{1}{2(nV)^{1/2}}\left[\frac{K_2(1 + VK_1) - K_1(1 + VK_2)}{(K_2)^{1/2}(1 + VK_1) + (K_1)^{1/2}(1 + VK_2)}\right] \tag{4}$$

Differentiating Eq. (4) with respect to the volume ratio V and setting the resulant equation equal to zero shows that the resolution is maximized when V is

$$V = 1/(K_1K_2)^{1/2} \tag{5}$$

This is in agreement with the Bush-Densen relation (*3*), which was derived, for the case of a single extraction, using semiempirical arguments. In our opinion, the above discussion is the simplest, and yet theoretically sound, derivation of the Bush-Densen relation. To our knowledge, this relationship was not previously derived in connection with CCD. Wolf (4) has also discussed the effect of the phases volume and indicated that by changing V one can change markedly the resolution between the components in the mixture.

Perhaps more important is the effect of the volume ratio on the minimum number of transfers required to yield a resolution of unity. Intuitively, one expects that the phases volume ratio which maximized the resolution should also minimize the required transfer number. The required number of transfers in the case where $V = 1$ was found to be (1 and references therein)

$$n_{req} = 4\left[\frac{(K_1)^{1/2}(K_2+1) + (K_2)^{1/2}(K_1+1)}{K_2 - K_1}\right]^2 \tag{6}$$

If we now introduce the volume ratio V in Eq. (6) and rearrange, we get:

$$n_{req} = 4\left[\frac{V[K_2(K_1)^{1/2} + K_1(K_2)^{1/2}] + (K_1)^{1/2} + (K_2)^{1/2}}{V(K_2 - K_1)}\right]^2 \tag{7}$$

Simple differentiation of Eq. (7) with respect to V shows that indeed the phase volume ratio given by Eq. (5) minimizes the number of transfers required to achieve a resolution of unity. This effect of the volume phases ratio on n_{req} was also mentioned by Wolf. He states that the required number of transfers will be minimized when the product of the apparent distribution ratios of the two solute is unity. Equation (7) allows a simple verification of this statement. The practical implications of this quantitative treatment of the effect of the phases volume ratio are, we feel, obvious.

REFERENCES

1. E. Grushka, *Separ. Sci.*, *6*, 331 (1971).
2. L. Karger, *J. Gas Chromatogr.*, *5*, 161 (1967).
3. M. T. Bush and P. M. Densen, *Anal. Chem.*, *20*, 121 (1948).
4. F. J. Wolf, *Separation Methods in Organic Chemistry and Biochemistry*, Academic, New York, 1969, pp. 18–19 and 91–93.

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