

Limiting partition coefficient of salts and its dependence on solute-solute interactions in progressive freeze-concentration

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Progressive freeze-concentration forms only a single ice crystal in the system and is expected to reduce the process cost of freeze concentration substantially as compared with the conventional method of suspension crystallization, in which many small ice crystals are formed in the system. In progressive freeze-concentration, the effective partition constant of a solute between ice and liquid phase, K , is dependent both on the advance rate of ice front, u , and the stirring rate at the ice-liquid interface and has been explained by the concentration polarization model as follows:

$$K = K_0 / [K_0 + (1-K_0)\exp(-u/N^{0.2})] \quad (1)$$

where K_0 is the limiting partition constant and is an important process parameter in progressive freeze-concentration. Equation (1) can be rewritten as:

$$\ln(1/K-1) = \ln(1/K_0-1) - (1/a)u/N^{0.2} \quad (2)$$

By using this equation, the limiting partition coefficient, K_0 , could be obtained from the effective partition coefficient observed under various operating conditions and the linear relationship between $u/N^{0.2}$ and $\ln(1/K-1)$.

For various aqueous solutions containing Blue dextran, glucose, NaCl, KCl, LiCl, CsCl, and Dextran 2000, the limiting partition coefficient, K_0 , was obtained. K_0 was dependent on the concentration of solute and increased with an increase in the solute concentration suggesting that K_0 reflects not only the equilibrium partition at the ice-liquid interface but also some nonequilibrium factors. K_0 was dependent also on the type of solute when compared at the same concentration. Among salts, K_0 increased in the order of $\text{Cs}^+ < \text{K}^+ < \text{Na}^+ < \text{Li}^+$, corresponding to the Hofmeister series. K_0 was affected also by the existence of cosolutes, reflecting the solute-solute interactions in the solution.