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Does A Partition or Distribution Coefficient Exist For A Solute That Distributes Between Two *Miscible* Solvents?

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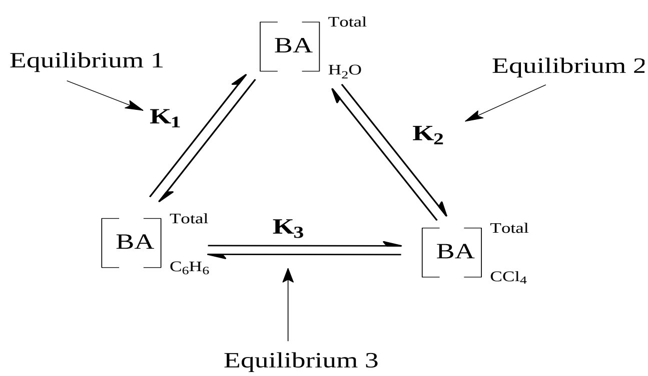
ABSTRACT

It is known that for any solute, the Nernst distribution law is between two solvents which are immiscible[1]. It is a well established fact that partition coefficient is meant for un-dissociated species and distribution coefficient is that for total concentration of the un-dissociated and dissociated solute[2]. At constant temperature a solute can distribute between two immiscible solvents so that the ratio of the amounts or concentrations of the solute in two solvents is constant. For all practical purposes and to avoid any confusion we have used the total concentration of the solute in this article.

Keywords: Nernst distribution law, Distribution coefficient, Partition coefficient.

INTRODUCTION

Our concern is, is there any distribution or partition law of a solute between two solvents which are completely ***miscible***? If so can it be determined? We have taken benzoic acid (BA) as an example.
From the scheme 1 below



Scheme 1

From equilibrium 1

$$\left[\mathrm{BA}\right]^{\mathrm{Total}}_{\mathrm{C_6H_6}} \overset{\mathbf{K_1}}{\rightleftharpoons} \left[\mathrm{BA}\right]^{\mathrm{Total}}_{\mathrm{H_2O}} \quad \ldots\ldots\ldots\ldots(1)$$

BA as an example stands for benzoic acid. Therefore,

$$\mathrm{K_1} = \frac{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{H_2O}}}{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{C_6H_6}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Similarly from equilibrium 2

$$\left[\mathrm{BA}\right]^{\mathrm{Total}}_{\mathrm{H_2O}} \overset{\mathbf{K_2}}{\rightleftharpoons} \left[\mathrm{BA}\right]^{\mathrm{Total}}_{\mathrm{CCl_4}} \quad \ldots\ldots\ldots\ldots(3)$$

Therefore,

$$\mathrm{K_2} = \frac{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{CCl_4}}}{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{H_2O}}} \ldots\ldots\ldots\ldots(4)$$

Hence K_1 and K_2 can be determined for the distribution of benzoic acid between the two pairs of solvents water : benzene and carbon tetrachloride : water in a usual manner in any undergraduate laboratory. The amounts of soluble benzoic acids in water and benzene and in benzene and carbon tetrachloride should be in thermal equilibrium. Then only it is possible to determine the distribution coefficients.

From equations 2 and 4 we get

$$K_1 \text{ X } K_2 = \frac{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{H_2O}}}{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{C_6H_6}}} \text{ X } \frac{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{CCl_4}}}{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{H_2O}}} \ldots\ldots\ldots(5)$$

Therefore

$$K_1 \text{ X } K_2 = \frac{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{CCl_4}}}{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{C_6H_6}}} \ldots\ldots\ldots\ldots(6)$$

If the amounts of BA between benzene and water are in equilibrium and the same between water and carbon tetrachloride, then according to zeroth law of thermodynamics[3] the amounts of benzoic acids in benzene and carbon tetrachloride must be in equilibrium with each other. Then K_3 could be evaluated as shown below. And it should be equal to the ratio of solubilities of benzoic acid in benzene and carbon tetrachloride.

From equilibrium 3

$$\left[\mathrm{BA}\right]^{\mathrm{Total}}_{\mathrm{C_6H_6}} \overset{\mathbf{K_3}}{\rightleftharpoons} \left[\mathrm{BA}\right]^{\mathrm{Total}}_{\mathrm{CCl_4}} \quad \ldots\ldots\ldots(7)$$

Then

$$K_3 = \frac{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{CCl_4}}}{[\mathrm{BA}]^{\mathrm{total}}_{\mathrm{C_6H_6}}} \ldots\ldots\ldots(8)$$

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