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Idealized Mixing Impacts

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DISCLAIMER

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The dispersion of tetraphenylborate in continuous stirred tank reactors plays a significant role in the utility achieved from the tetraphenylborate.[1] Investigating idealized mixing of the materials can illuminate how this dispersion occurs.

Consider the case of a single drop of solution containing tetraphenylborate entering the stirred tank reactor (see Figure 1). This droplet has a specified volume (V), sodium molarity (N) and tetraphenylborate molarity (M). This droplet will then encounter a volume of salt solution of a variable volume (X) but of a fixed sodium molarity (N'). For the sake of illustration, we will assume that this drop of salt solution does not contain any soluble tetraphenylborate. The sodium molarity of this drop equals that of the bulk CSTR. Mixing the two volumes together yields a new equilibrium:

$$V_i = V + X$$

$$N_i = \frac{V * N + X * N'}{V_i}$$

$$M_i = \frac{V * M}{V_i}$$

Fix V as 1 mL. Then, one can solve for X as a function of N_i.

$$X = \frac{N_i - N}{N' - N_i}$$

Substituting for X yields M_i as a function of N_i.

$$M_i = \frac{M}{1 + \left(\frac{N_i - N}{N' - N_i} \right)}$$

This formula provides the tetraphenylborate molarity in mixed droplet, Mi, as a function of the sodium molarity of the mixed droplet. Figure 1 contains a plot of the curve defined by this equation for the following variable values:

M	0.033 M
N	1.2 M
N'	4.7 M

Figure 1 also contains a plot of the sodium tetraphenylborate solubility as a function of sodium molarity. Inspection of this figure indicates that as the solution mixes, the solution will exceed the sodium tetraphenylborate solubility. Note that as the sodium molarity increases from 3.4 M to 4.0 M, the ratio of the solubility to the total molarity decreases and reaches a minimum at a sodium molarity of 4.0. Thus, one can define an utility (U) of the mixing of tetraphenylborate based on this analysis as:

$$U = Min\left(\frac{S(N_i)}{M_i} \right)$$

where $S(N_i)$ is the solubility of tetraphenylborate at sodium molarity N_i. One can then generate a suite of efficiencies based on varying the initial sodium and tetraphenylborate molarity of the tetraphenylborate-laden stream. Figure 2 contains a plot of these efficiencies over a range of inlet stream conditions. Figure 2 indicates that for streams containing higher concentrations of TPB, the utility decreases dramatically.

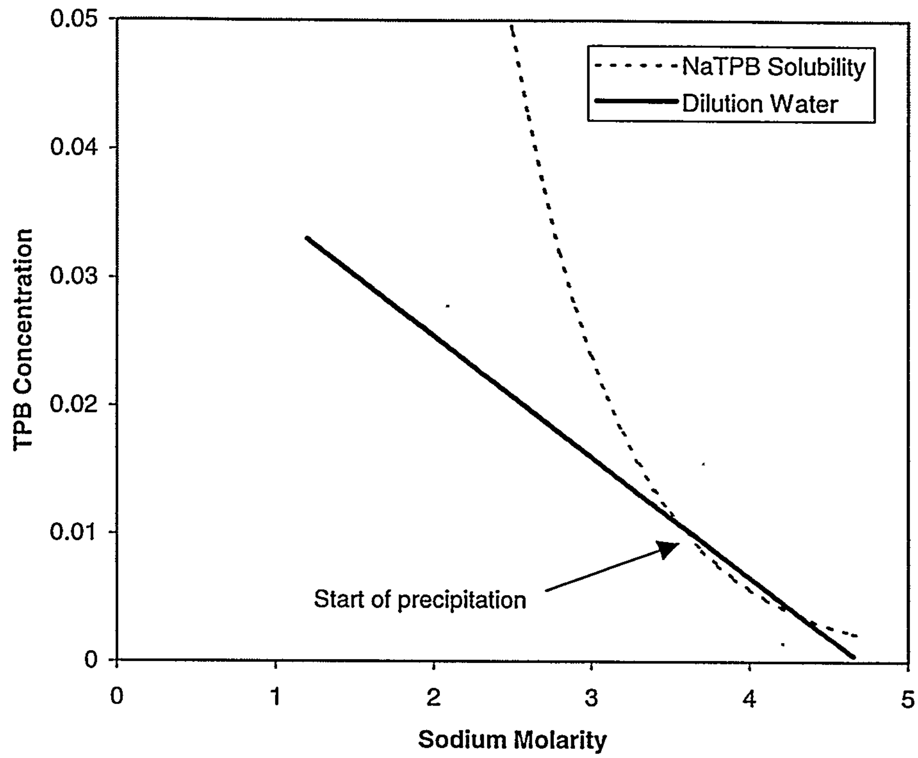

Figure 1. TPB concentration as a function of sodium molarity

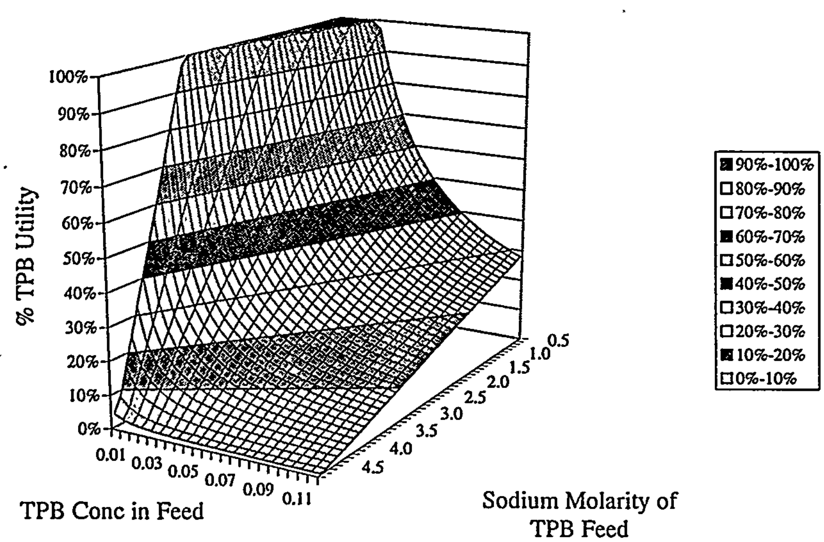

Figure 2A. Tetraphenylborate utility as a function of feed stream TPB and Sodium molarity.

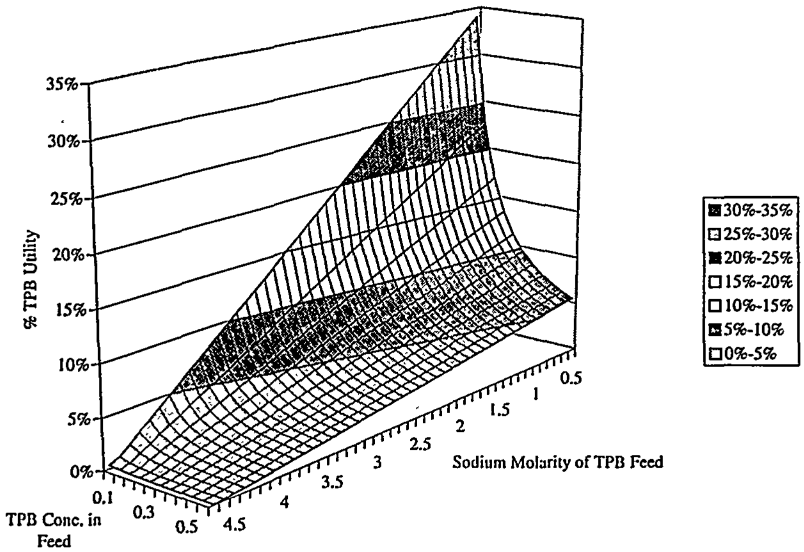

Figure 2B. Tetraphenylborate utility as a function of feed stream TPB and Sodium molarity.

Approvals

9/16/99

R. A. Peterson, Liquid Waste Processing, Author — Date

9/20/99

M.J. Barnes, Liquid Waste Processing, Design Check — Date

9-20-99

S.D. Fink, Manager, Liquid Waste Processing — Date

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[1] M.J. Barnes and R.A. Peterson, "Cesium Removal and Kinetics Equilibrium: Precipitation Kinetics", WSRC-TR-99-00325, September 8, 1999.

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