MIXING, REACTION AND PRECIPITATION:  
THE BARIUM SULPHATE PRECIPITATION SYSTEM

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Abstract

This paper reviews critically the important studies that have been reported in the literature on the barium sulphate precipitation system with an emphasis on the influence of mixing on the reactive precipitation processes.

1. Introduction

A rational approach to crystallizer description and subsequent design should be based on a solution of relevant conservation equations representing crystal population, mass and energy balances, together with a description of kinetics of rate processes involved and a definition of flow patterns within the vessels. Thus, the performance of a chemical vessel depends not only on the chemical rate processes but also on the physical processes, such as interphase and interparticle mass and heat transfer occurring within a multiphase system, which in turn depend very significantly on the mixing characteristics of the phases involved. Characterization of mixing (macromixing by residence time distribution theory and micromixing, i.e., mixing at molecular scale) from the Lagrangian perspective has provided a unified and elegant treatment for continuous flow systems. Micromixing can influence significantly the overall performance of a crystallizer (Danckwerts, 1958; Becker and Larson, 1969). The kinetic events for crystallization systems are generally non-linear; crystallizers are usually operated at relatively high yields; the residence time distribution (RTD) function is closer to an exponentially decaying type representing a fully backmixed vessel; and the physical nature of the crystallization process allows the practical possibility of segregation. All these factors indicate that micromixing effects may be important in real crystallizers. Process simulation studies concerning the extreme levels of micromixing have clearly demonstrated its enormous effect on the product crystal
size and size distribution (Garside and Tavare, 1984, 1985; Tavare, 1986, 1989). Characterization of intermediate level micromixing or partial segregation for a reactive precipitation (or crystallization) system is therefore essential.

Although the general topic of mixing and mathematical analysis of continuous flow systems is of considerable interest and a variety of micromixing models for a chemical reactor have been proposed by many authors in the chemical reaction engineering literature, only recently published work on reactive precipitation systems is beginning to emerge using the approaches developed mainly in chemical reaction engineering. Some of these micromixing models have been used for reactive precipitation processes (Pohorecki and Baldyga, 1979, 1983, 1985, 1988; Tavare, 1986, 1992, 1993, 1994, 1995b; Fitchett and Tarebell, 1990; Mydlarz et al., 1990; Baldyga, 1993). The bulk of the literature deals with configurations having single inlet and exit streams. When the reactants however enter separately the problem of unpremixed feeds evolves and under these circumstances the micromixing effects have shown to be much more important than those for the case of premixed feeds (Metha and Tarbell, 1983, Tavare, 1995a, Tavare and Borrissova, 1997). Most recent studies appear to deal with batch or semibatch reactive precipitation processes (Kuboi et al., 1986; Pohorecki and Baldyga, 1988; Tosun, 1988; Baldyga et al., 1990; 1995; Tovistiga and Wirges, 1990; Marcant and David, 1991, 1994, Aslund and Rasmuson, 1992; Podgoriska et al., 1993; Iyer and Przbycien, 1994; Wachi and Jones, 1991, Jones et al., 1992). The analysis presented in the past appears to have inadequate physical insight into the interaction of mixing, reaction and subsequent crystallization, but has rather provided a means of evaluating and subsequently predicting the performance for a given crystallizer configuration. In addition, the attempts are being made to integrate computationally fluid dynamic and precipitation processes into commercial CFD codes in order to define both spatial distributions of instantaneous and local values of intensive properties of all species. On many occasions, detailed three dimensional, time dependent direct valid numerical evaluations may not be feasible and other viable approaches may be advocated (Van Leeuwen et al., 1996a, b; Wei and Garside, 1997a, b; Baldyga and Orciugh, 1997). The majority of published work is centred around the barium sulphate precipitation system. The purpose of this work is to review critically the important studies that have been reported in the literature. It is by no means a comprehensive review of all the studies that are reported on the barium sulphate precipitation system covering all the aspects but is restricted to looking at analysis of process simulation and identification studies on this system in different process configurations with a view to provide a better understanding of the influence of mixing on reactive precipitation processes.