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Using emulsion inversion in industrial processes

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Abstract

Emulsion inversion is a complex phenomenon, often perceived as an instability that is essentially uncontrollable, although many industrial processes make use of it. A research effort that started 2 decades ago has provided the two-dimensional and three-dimensional description, the categorization and the theoretical interpretation of the different kinds of emulsion inversion. A clear-cut phenomenological approach is currently available for understanding its characteristics, the factors that influence it and control it, the importance of fine-tuning the emulsification protocol, and the crucial occurrence of organized structures such as liquid crystals or multiple emulsions. The current know-how is used to analyze some industrial processes involving emulsion inversion, e.g. the attainment of a fine nutrient or cosmetic emulsion by temperature or formulation-induced transitional inversion, the preparation of a silicone oil emulsion by catastrophic phase inversion, the manufacture of a viscous polymer latex by combined inversion and the spontaneous but enigmatic inversion of emulsions used in metal working operations such as lathing or lamination.

Keywords: Emulsion inversion; Emulsification protocol; Transitional inversion

1. Introduction: importance of phase behavior

Macroemulsions, which are simply called emulsions, are liquid–liquid dispersions exhibiting certain persistence against phase separation because of the presence of stabilizing agents, usually surfactants, at the interface. In most practical cases they can be categorized as surfactant–oil–water (SOW) systems containing at least three components. Even when there are many more components, it is convenient to assume the SOW ternary for the sake of simplicity and without committing much from the interpretative point of view.

The two main emulsion types, i.e. oil-in-water (O/W) and water-in-oil (W/O) morphologies, involve the presence of two non-miscible phases and are thus associated to two-phase behavior at equilibrium. This is generally the case for double or multiple emulsions as well, in spite of a higher grade of morphology complexity. It is thus of utmost importance to know the physicochemical conditions that are associated with two-phase behavior [1].

Single-phase SOW systems such as microemulsions or liquid crystals would not produce any emulsion upon stirring.

As far as three-phase behavior systems are concerned, they generally contain a surfactant-rich phase, either microemulsion or liquid crystal, in equilibrium with excess oil and excess water, which are essentially pure oil and pure water for inventory purposes. Whenever the formulation is appropriate, the occurrence of a microemulsion or a liquid crystalline mesophase essentially depends upon the degree of disorder. Molecular order and liquid crystal occurrence are favored by surfactant purity, straight chain structure, low temperature and high polar interaction as in ionic systems [2–7].

In such cases disorder can be introduced either by elevating the temperature or by adding a short chain co-surfactant amphiphile such as an alcohol. Systems containing polyethoxylated non-ionic surfactants often produce microemulsions without co-surfactant because of the variety of species produced by the ethoxylation reaction, and the resulting difference in molecular size [6]. In some cases, systems containing ionic surfactants

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