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ORIGINAL ARTICLE

Effect of Sodium Carbonate on the Cloud Point in Alkyl Ether/Brine Systems: Apparent Relation with Dynamic Interfacial Tension Minimum

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Abstract The effect of Na_2CO_3 on the cloud point in Na_2CO_3/surfactant/brine was investigated using two series of nonionic surfactants, $C_{13}EO_x$ and $C_{17}EO_x$. The cloud point, T_{cp}, was found to decrease linearly with increasing Na_2CO_3 concentration. This was attributed to Na^+ and particularly to CO_3^{2-}salting-out effect. The slope $a = d\text{Tcp}/d[Na_2CO_3]$ became more and more negative as the degree of ethoxylation is increased, suggesting that the higher the number of ethylene oxide (EO) groups the stronger is the cloud point depression for a given increment in $Na^+$and CO_3^{2-}ions in solution. This was also illustrated by the linear variation of $\Delta T_{cp} = T_{cp,0} - T_{cp,[Na2CO3]}$ with the surfactant degree of ethoxylation.

Keywords Enhanced oil recovery · Nonionic surfactant · Soap · Cloud point · Salting-out effect

Introduction

Transient ultralow interfacial tensions in alkali/surfactant/brine/acidic crude oil systems has been associated with the formation of *in situ* surfactant (carboxylate salt) by the reaction of crude oil naphthenic acid components (HA) with alkali [1–4] and its subsequent interactions with added synthetic surfactant. The temporary and permanent lowering of the dynamic interfacial tension in these systems has been investigated over the last 40 years [5–9]. A recent study by Hadji et al. [10] reported on the synergetic effects produced by nonionic synthetic surfactant on the in situ produced surfactant in lowering the dynamic interfacial tension in Na_2CO_3/-surfactant/brine/acidic oil systems. However, it is known that the compatibility of nonionic surfactants with brine is limited by the occurrence of the so-called cloud point, i.e., the temperature at which a clear aqueous micellar solution of nonionic surfactant becomes turbid and ultimately separates into two phases. The lower clear phase is almost micelle-free dilute solution in which the concentration of the surfactants is close to its CMC and the upper phase is a surfactant-rich phase which will be lost by solubilizing in crude oil [11–14].

Na_2CO_3 was shown to be more adequate than NaOH in lowering the crude oil/water interfacial tension (IFT), due to its buffering effect [5]. The first objective of this study was therefore to investigate the effect of Na_2CO_3 on the cloud point of two nonionic ethoxylated surfactants, C_{13}-$(OCH_2CH_2)_xOH$ ($C_{13}EO_x$, $x = 10$, 13, 18) and C_{17}-$(OCH_2CH_2)_xOH$ ($C_{17}EO_x$, $x = 7$, 10 and 13) in brine. In addition, an attempt was made to evaluate the effect of nonionic surfactant structure on the cloud point and its plausible correlation with the occurrence of transient ultralow interfacial tension (IFT_{min}) at the mixed interfacial film in Na_2CO_3/surfactant/oil/brine.

Experimental

Materials

Two series of branched alkyl ethoxylates C_{13}-$(OCH_2$–$CH_2)_x$–OH ($C_{13}EO_x$ with $x = 10$, 13, 18) and C_{17}-$(OCH_2$–

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