

# Qualitative and Quantitative Studies on the Phase Behaviour of Mutual Solvents

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## Introduction and Research Significance

Scale inhibitor squeeze treatments comprise of five stages, namely: a pre-flush stage, a main treatment stage, an over-flush stage, a shut-in stage and, finally, a back-production stage. In contrast to all the attention that the main treatment stage has received in the research community, much less work has been carried out to understand and to develop the pre-flush stage.

A mutual solvent (MS; simple non-ionic amphiphile) may be injected into the formation during the pre-flush stage. Understanding the phase behaviour of MS in the context of squeeze treatments will pave the way for modelling their propagation, ultimately enabling more informed squeeze designs.

In this poster, the results from selected qualitative and quantitative phase behaviour studies are presented. The results offer an insight into MS phase behaviour activities at FAST.

## Brine Salinity Studies

In systems of oil + brine + MS, the MS is salted-out of the brine with increasing salinity. As a result of this, increasing the salinity increases the insolubility of the MS in the brine (e.g. see Figure 1; salinity increases from 1a to 1c). Before the MS becomes completely insoluble with the brine (Figure 1c), a three phase region will form over wide [MS] (Figure 1b). Each phase in this region will be rich in one of the respective main constituents of the system.

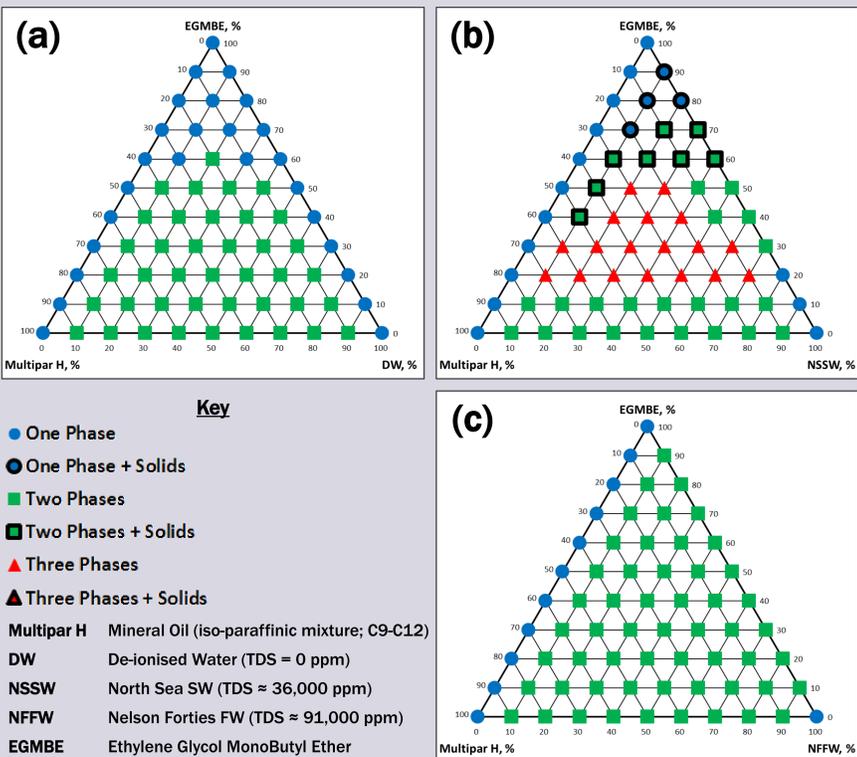


Figure 1 Influence of salinity on oil + brine + MS phase behaviour.

## Brine Chemistry Studies

In a sulphate-rich brine (Figure 2a), precipitation occurs over wide [MS], while in a sulphate-free brine (Figure 2b), precipitation is limited to high [MS] concentrations indicating a sulphate problem.

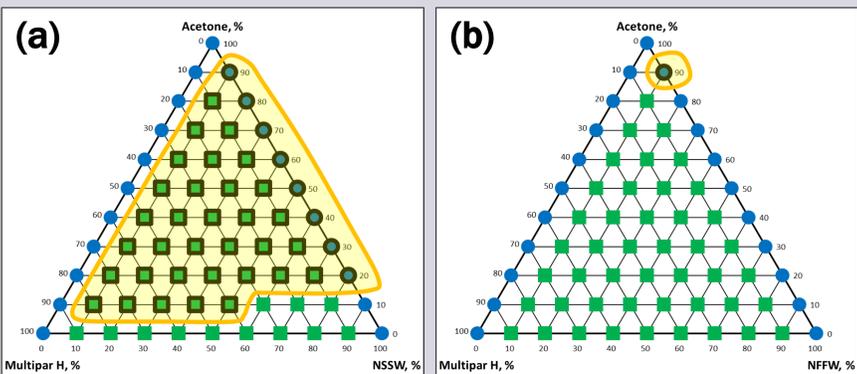


Figure 2 Influence of brine chemistry on precipitation in a system of oil + brine + MS.

The precipitates in a sulphate-rich system tend to be dominated by  $\text{Na}_2\text{SO}_4$  and  $\text{CaSO}_4$  with traces of other sulphate salts (Figure 3a). In a sulphate-free system, the salts are almost entirely  $\text{NaCl}$  with traces of other chloride salts (Figure 3b).

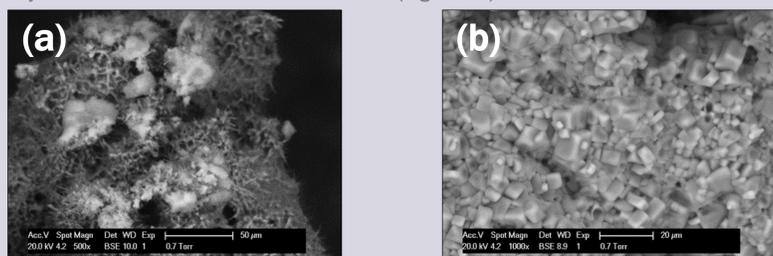


Figure 3 ESEM of the precipitates: (a) sulphate-rich system; (b) sulphate-free system.

## Mutual Solvent Blends

Blending multiple MS enables targeting specific phase behaviour. With reference to Figure 1b as a base case, an example is provided in Figure 4. In a system of mineral oil + NSSW + EGMBE, the MS is partially insoluble in the brine and forms an expansive three phase region (Figure 1b). Blending 10% v/v MEG with the EGMBE eliminates the partial insolubility with the brine (Figure 4a). Increasing the [MEG] further in the blend (e.g. to 20% v/v) enables a shrinking of the three phase region at low [oil] (Figure 4b).

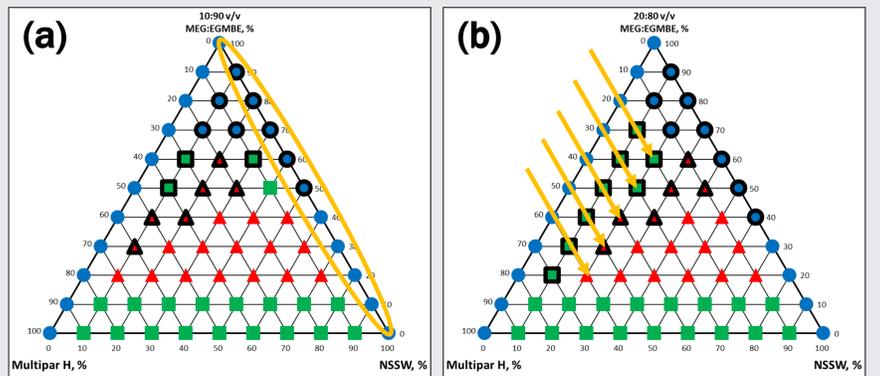


Figure 4 Blending mutual solvents to target a specific phase behaviour.

## Quasi-Ternary Phase Behaviour

Quasi-ternary phase behaviour has been observed for a system of oil + brine + MS. This was demonstrated for various MS even at very high brine salinities. Only mineral oil has been investigated thus far. The main implication of this is the constant composition of each respective phase in the three phase region. A piece of evidence highlighting the quasi-ternary phase behaviour is provided in Figure 5 as an example.

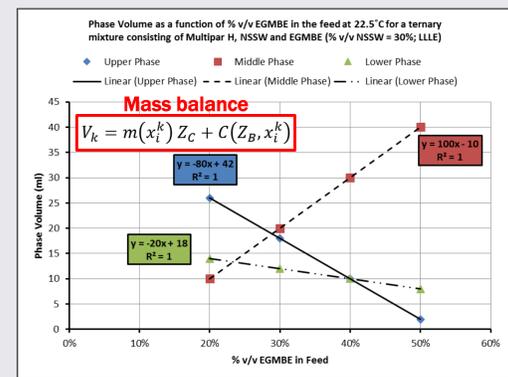


Figure 5 Phase volumes as a function of the feed [EGMBE] at constant feed [NSSW]: Linear correlations are consistent with mass balances in suggesting quasi-ternary behaviour.

## Phase Behaviour Modelling

The quasi-ternary system property was used to devise a semi-empirical model for the quantitative modelling of the phase behaviour in oil + brine + MS systems. Preliminary results highlight the ability of this model to map the three phase region accurately, and its excellent ability to predict phase volumes in this region (Figure 6a). The model can also predict phase separations in the two phase region very well (Figure 6b).

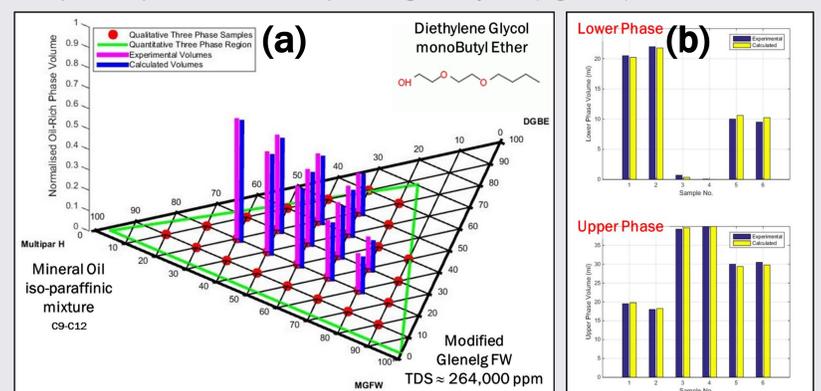


Figure 6 Semi-empirically modelling the phase behaviour in oil + brine + MS systems.

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