# THE INFLUENCE OF ISOPROPYL ALCOHOL CONCENTRATION ON THE CHANGE OF PHASE BEHAVIOR IN THE MIXTURE OF OIL - SURFACTANT - ISO PROPYL ALCOHOL – FORMATION WATER

by

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## I. INTRODUCTION

Surfactant is surface active agent chemical that has two types of properties; lyophobic (like water) and hydrophobic (like oil). One of enhanced oil recovery methods that is used to improve oil recovery factor, is surfactant flooding. Oil and water are two separated phases and have high interfacial tension value (around 30-40 dyne/cm). Addition of surfactant solution at certain concentration into the mixture of oil-surfactant-formation water will change the phase behavior. In this case, four types possibilities of emulsion formed, these are:

- Upper phase;
- Middle phase (microemulsion);
- Lower phase;
- Macroemulsion.

According to Prince, L.M (*Theory and Practice of Microemulsions*), change of phase behavior in the oil-surfactant-formation water mixture is influenced by several factors, one of them is concentration of alcohol. The main focus of this research is to study influence of isopropyl alcohol (IPA) concentration on phase behavior in the oil-surfactant-IPA-formation water mixture.

## II. SCOPE OF RESEARCH

Scope of research is to study the influence of isopropyl alcohol (IPA) concentration on phase behavior in the oil- surfactant-IPA-formation water mixture. Concentration of isopropyl alcohol used in this research is in range of 0.00 to 1.00 % and type of surfactant is a liquid amphotheric surfactant. An amphotheric may contain both anionic group and nonpolar group.

## III. SPECIFICATIONS

Liquid amphotheric surfactant is an easily pumpable liquid that is completely miscible with fresh water and most brines.

| | |
|---|---|
| Activity | 43 wt % |
| Viscosity | 15.1cps |
| Average molecular weight | 336 |
| Insoluble | 0 % |
| Freezing point | < 14 °F |
| Boiling point | 100 °F |
| Specific gravity | 1.107 |
| pH | 7.30. |

## IV. PHASE BEHAVIOR

Mixture oil-surfactant-IPA- formation water can result in emulsion, which consists of four main phases; these are as follows:

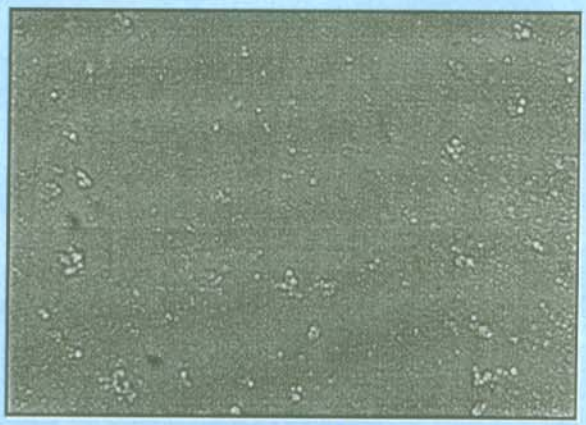

**Figure 1**
**Upper phase emulsion**

- Upper phase.

  Oil-surfactant-IPA-formation water are mixed, then is formed upper phase, emulsion is in oil phase. For example of upper phase emulsion can be seen in Figure 1.

- Middle phase

  Mixture of oil-surfactant-IPA- formation water forms middle phase, which means emulsion in middle phase, called microemulsion. For example of middle phase is shown in Figure 2.

- Lower phase.

  Lower phase occurs in the system of oil-surfactant-IPA-formation water mixture. Emulsion exists in water phase. For example of lower phase emulsion is indicated in Figure 3.

- Macroemulsion

  The form of macroemulsion in the system of oil-surfactant-IPA-formation water can be seen in Figure 4.

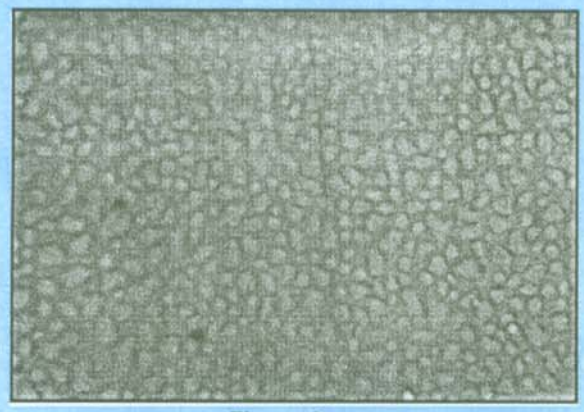

**Figure 2**
**Middle phase emulsion (microemulsion)**

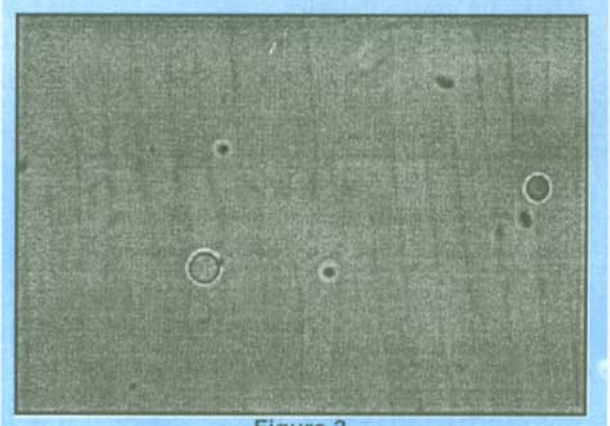

**Figure 3**
**Lower phase emulsion**

Requirements of surfactant that can be used in enhanced oil recovery (EOR) are as follows:

a. Low interfacial tension (IFT) between oil and microemulsion,
b. Low interfacial tension (IFT) between water and microemulsion,
c. In the range of salinity limit,
d. Stable or resistance on temperature.

Factors that influence phase transition from lower phase to middle phase or to upper phase or macroemulsion in system of oil-surfactant-IPA-formation water mixture are as follows:

a. Increasing salinity,
b. Decreasing alkane carbon number (oil),
c. Increasing alcohol concentration (C4, C5, C6),
d. Decreasing temperature,
e. Increasing surfactant concentration,
f. Increasing brine/oil ratio,
g. Increasing surfactant/oil ratio,
h. Increasing molecular weight of surfactant.

## V. MATERIAL STRUCTURES SIZE

The appearance of scattered light is used to identify emulsions and to roughly measure size of material structure droplets. The results of measurements test is presented in Table 1 below.

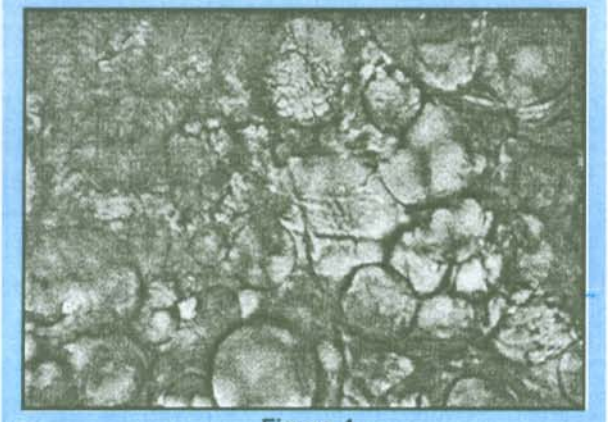

**Figure 4**
**Macroemulsion**

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Table 1
Visual guide for estimating aggregate size

| Material structures | Diameter (A) | Appearance to naked eye |
|---|---|---|
| Water molecules | 2.7 | Transparent |
| Soap micelles | 35 - 75 | Transparent |
| Micellar solutions | 50 - 150 | Transparent and translucent |
| Resolvable units (microscopically) | 1000 - 2000 | Translucent when dispersed |
| Macroemulsions | 2000 - 100,000 | Opaque, milky |
| Resolvable units (visually) | 500,000 | Discrete aggregates |

Table 2
The results of phase behavoiur tests
oil - surfactant - 0.00 % IPA - formation water

| Conscentration | | Phase behaviour | | | Remarks |
|---|---|---|---|---|---|
| | | Volume | | | |
| Surfactant (%) weight | Cosurfactant (%) weight | Water (cc) | Emulsion (cc) | Oil (cc) | |
| 0.10 | 0.00 | 5.25 | 0.00 | 4.61 | Macroemulsion |
| 0.20 | 0.00 | 5.25 | 0.00 | 4.61 | Macroemulsion |
| 0.30 | 0.00 | 5.11 | 0.00 | 4.32 | Macroemulsion |
| 0.40 | 0.00 | 5.76 | 0.00 | 3.75 | Macroemulsion |
| 0.50 | 0.00 | 5.25 | 0.00 | 4.47 | Macroemulsion |

Table 6.2
Phase behavoiur test oil - surfactant - 0.10 % IPA - formation water

| Conscentration | | Phase behaviour | | | Remarks |
|---|---|---|---|---|---|
| | | Volume | | | |
| Surfactant (%) weight | Cosurfactant (%) weight | Water (cc) | Emulsion (cc) | Oil (cc) | |
| 0.10 | 0.10 | 5.25 | 0.00 | 4.61 | Macroemulsion |
| 0.20 | 0.10 | 4.89 | 0.00 | 4.47 | Macroemulsion |
| 0.30 | 0.10 | 5.11 | 0.00 | 4.47 | Macroemulsion |
| 0.40 | 0.10 | 5.11 | 0.00 | 4.54 | Macroemulsion |
| 0.50 | 0.10 | 5.11 | 0.00 | 4.61 | Macroemulsion |

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This table above indicates that diameter of macroemulsions is much higher than micellar solutions diameter.

## VI. RESULTS OF TEST AND DISCUSSION

Based on the phase behavior laboratory tests for enhanced oil recovery need can be divided into 8 parts:

### A. *Oil-amphotheric surfactant-0.00 % IPA - formation water mixture*

In phase behavior tests for the mixture mentioned in Section 6.1, concentration of isopropyl alcohol used is 0.00 % and concentration of surfactant solution in range of 0.10-0.50 %. The results of tests are tabulated in Table 2 and macro emulsions occurred at all test conditions.

### B. *Oil-amphoteric surfactant-0.10 % IPA-formation water mixture*

In phase behavior tests for the mixture mentioned in Section 6.2, concentration of isopropyl alcohol used is 0.10 % and concentration of surfactant solution in range of 0.10-0.50 %. The results of tests are presented in Table 3 and macro emulsions occurred at all test conditions.

**Table 4**
**phase behavoiur test**
**oil - surfactant - 0.20 % IPA - formation water**

| Conscentration | | Phase behaviour | | | Remarks |
|---|---|---|---|---|---|
| | | Volume | | | |
| Surfactant (%) weight | Cosurfactant (%) weight | Water (cc) | Emulsion (cc) | Oil (cc) | |
| 0.10 | 0.20 | 5.25 | 0.00 | 4.61 | Macroemulsion |
| 0.20 | 0.20 | 5.25 | 0.00 | 4.61 | Macroemulsion |
| 0.30 | 0.20 | 5.11 | 0.00 | 4.61 | Macroemulsion |
| 0.40 | 0.20 | 5.25 | 0.00 | 4.61 | Macroemulsion |
| 0.50 | 0.20 | 5.25 | 0.00 | 4.61 | Macroemulsion |

**Table 5**
**Phase behavoiur test**
**oil - surfactant - 0.30 % IPA - formation water**

| Conscentration | | Phase behaviour | | | Remarks |
|---|---|---|---|---|---|
| | | Volume | | | |
| Surfactant (%) weight | Cosurfactant (%) weight | Water (cc) | Emulsion (cc) | Oil (cc) | |
| 0.10 | 0.30 | 5.18 | 0.00 | 4.61 | Macroemulsion |
| 0.20 | 0.30 | 5.18 | 0.00 | 4.61 | Macroemulsion |
| 0.30 | 0.30 | 5.11 | 0.00 | 4.61 | Macroemulsion |
| 0.40 | 0.30 | 5.11 | 0.00 | 4.61 | Macroemulsion |
| 0.50 | 0.30 | 5.11 | 0.00 | 4.61 | Macroemulsion |

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Table 6
Phase behavoiur test oil - surfactant - 0.40 % IPA - formation water

| Conscentration | | Phase Behaviour | | | Remarks |
|---|---|---|---|---|---|
| | | Volume | | | |
| Surfactant (%) weight | Cosurfactant (%) weight | Water (cc) | Emulsion (cc) | Oil (cc) | |
| 0.10 | 0.40 | 5.25 | 0.00 | 4.47 | Macroemulsion |
| 0.20 | 0.40 | 5.18 | 0.00 | 4.47 | Macroemulsion |
| 0.30 | 0.40 | 5.11 | 0.00 | 4.54 | Macroemulsion |
| 0.40 | 0.40 | 4.89 | 0.00 | 4.61 | Macroemulsion |
| 0.50 | 0.40 | 4.89 | 0.00 | 4.61 | Macroemulsion |

Table 7
Phase behavoiur test oil - surfactant - 0.50 % IPA - formation water

| Conscentration | | Phase Behaviour | | | Remarks |
|---|---|---|---|---|---|
| | | Volume | | | |
| Surfactant (%) weight | Cosurfactant (%) weight | Water (cc) | Emulsion (cc) | Oil (cc) | |
| 0.60 | 0.50 | 5.11 | 0.00 | 4.68 | Lower Phase Emulsion |
| 0.80 | 0.50 | 5.11 | 0.00 | 4.61 | Lower Phase Emulsion |
| 1.00 | 0.50 | 5.11 | 0.00 | 4.61 | Lower Phase Emulsion |

C. *Oil-amphoteric surfactant-0.20 % IPA- formation water mixture*

In phase behavior tests for the mixture mentioned in Section 6.3, concentration of isopropyl alcohol used is 0.20 % and concentration of surfactant solution in range of 0.10-0.50 %. The results of tests show the formed macroemulsions at all test conditions (see Table 4).

D. *Oil-amphoteric surfactant-0.30 % IPA-formation water mixture*

In phase behavior tests for the mixture mentioned in Section 6.4, concentration of isopropyl alcohol used is 0.30 % and concentration of surfactant solution in range of 0.10-0.50 %. The results of tests are the occurrence of macroemulsions at all test conditions (see Table 5).

E. *Oil-amphoteric surfactant-0.40% IPA-formation water mixture*

In phase behavior tests for the mixture mentioned in Section 6.5, concentration of isopropyl alcohol used is 0.40 % and concentration of surfactant solution in range of 0.10-0.50 %. The results of tests are macroemulsions formed at all test conditions (tabulated in Table 6).

F. *Oil-amphoteric surfactant-0.50 % IPA- formation water mixture*

In phase behavior tests for the mixture mentioned in Section 6.6, concentration of isopropyl

alcohol used is 0.50 % and concentration of surfactant solution in range of 0.10-0.50 %. The results of tests show change of phase behaviour totally. In this mixture, *lower phase emulsions* are formed at all test conditions, *not in macroemulsion* anymore (presented in Table 7).

**G. *Oil-amphoteric surfactant-0.75 % IPA -formation water mixture***

In phase behavior tests for the mixture mentioned in Section 6.7, concentration of isopropyl alcohol used is 0.75 % and concentration of surfactant solution in range of 0.60-1.00 %. The results of tests results in *lower phase emulsions* at all test conditions (shown in Table 8).

**H. *Oil-amphoteric surfactant-1.00 % IPA-formation water mixture***

In phase behavior tests for the mixture mentioned in Section 6.8, concentration of isopropyl alcohol used is 1.00 % and concentration of surfactant solution in range of 0.60-1.00 %. The results of tests are the occurrence of *lower phase emulsions* at all test conditions (shown in Table 9).

The results of behavior test from Table 6.1 to Table 6 don't show change of phase behaviour, although concentration of isopropyl alcohol is added from 0.10 to 0.40 %. However, concentration of isopropyl alcohol at 0.50 % indicates critical point, which the occurrence of phase behavior change, namely: *the formed lower phase emulsion*, not macroemulsion (Table 7). The results of behavior test in Table 8 and Table – 6.8 are lower phase emulsions formed.

## VII. CONCLUSIONS

As a result of work undertaken, the following conclusions can be made.

1. The results of phase behavior test in the mixture

**Table 8**
**Phase behavoiur test oil - surfactant - 0.75 % IPA - formation water**

| Conscentration | | Phase behaviour | | | Remarks |
|---|---|---|---|---|---|
| | | Volume | | | |
| Surfactant (%) weight | Cosurfactant (%) weight | Water (cc) | Emulsion (cc) | Oil (cc) | |
| 0.60 | 0.75 | 5.11 | 0.00 | 4.75 | Lower Phase Emulsion |
| 0.80 | 0.75 | 5.18 | 0.00 | 4.75 | Lower Phase Emulsion |
| 1.00 | 0.75 | 5.26 | 0.00 | 4.68 | Lower Phase Emulsion |

**Table 9**
**phase behavoiur test oil - surfactant - 1.00 % ipa - Formation Water**

| Conscentration | | Phase behaviour | | | Remarks |
|---|---|---|---|---|---|
| | | Volume | | | |
| Surfactant (%) weight | Cosurfactant (%) weight | Water (cc) | Emulsion (cc) | Oil (cc) | |
| 0.60 | 1.00 | 5.18 | 0.00 | 4.75 | Lower Phase Emulsion |
| 0.80 | 1.00 | 5.18 | 0.00 | 4.75 | Lower Phase Emulsion |
| 1.00 | 1.00 | 5.18 | 0.00 | 4.75 | Lower Phase Emulsion |

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of oil-surfactant-isopropyl alcohol-formation water are influenced concentration of alcohol (isopropyl alcohol).

2. Concentration of isopropyl alcohol from 0.00 to 0.40 % results in the macroemulsion phase in the mixture of oil-surfactant-isopropyl alcohol- formation water.
3. At concentration of isopropyl alcohol 0.50 %, the occurrence of phase behavior change. The results of test show lower phase emulsion formed, not macroemulsion anymore.
4. Lowe phase emulsions are formed at concentration of isopropyl alcohol from 0.60 to 1.00 % in the mixture of oil- surfactant-isopropyl alcohol-formation water.
5. Performance of lower phase emulsion is totally different from macroemulsion (Figure 3 is compared to Figure 4). Theoritically, size of micellar solution is 50-150 A, while macroemulsion is 2000-100,000 A.

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