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# Phase Behavior in EOR Surfactant Flooding

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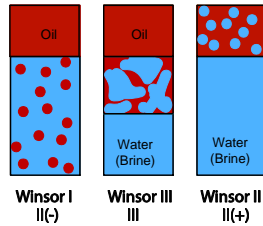
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## Introduction

Worldwide there are an increasing demand for improved enhanced oil recovery techniques as significant amounts of oil is left in the swept zone after primary and secondary recovery techniques are applied. To keep an efficient oil production Enhanced Oil Recovery (EOR) is introduced, where the main target is to displace the crude oil trapped in the reservoir, often due to capillary and viscous forces. Among several techniques, surfactant flooding is one way to apply tertiary oil recovery, which is the injection of water mixed with appropriate surfactants (and co-surfactants) to control the phase behavior properties inside the reservoir.

Surfactant systems are typically considered as the so-called Winsor type systems as pictured. The aim of this process is to lower the interfacial tension (IFT) to ultra low by forming a microemulsion phase as is shown as Winsor III, which will mobilize the crude oil.



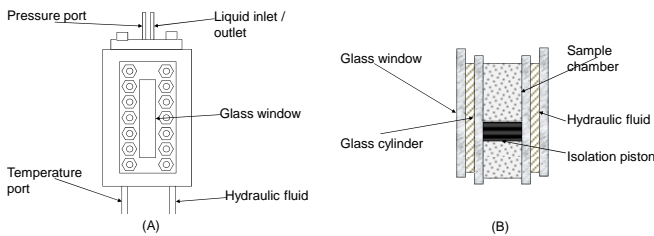
## Facts generally accepted in literature

- An increase in temperature entails an increase in optimal salinity.
- Effect of pressure is debatable.
- Surfactant systems are sensitive to salinity.
- Surfactant compositions in the system are challenged by chromatographic separation.

Surfactant systems are sensitive to the salinity and the temperature, [1]. An increase in temperature increases the optimal salinity and therefore it is a demand that the surfactant systems can resist the present physical reservoir conditions. Note that both high temperatures and pressures will be reservoir conditions.

It is crucial that the Winsor III type system is formed (thus achieving the ultra low IFT when the microemulsion is formed) and as this can be correlated to the salinity, the salinity of the injection water must be designed to match the single reservoir.

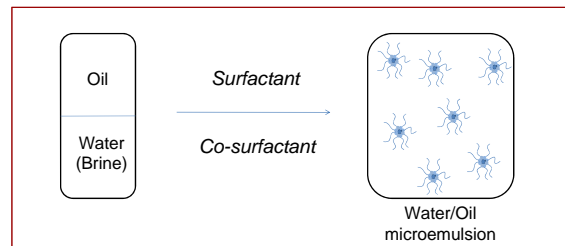
## High Pressure Equipment



This project is concerned about the effect from increased pressures and temperatures on the phase behavior of surfactant systems, hopefully to get a better understanding of the underlying mechanisms. Pressures are varied from 1 to 400 bar at 40 to 60 °C. Experiments are conducted on a DBR JEFRI PVT cell, allowing volume measurements and visual observations when the surfactant systems is equilibrating.

## Emulsions

Formed in mixtures of liquids as droplets either as macroscopic or microscopic size. In surfactant flooding either water/oil or oil/water microemulsions are required, as the microemulsion reduces the IFT between oil and water.

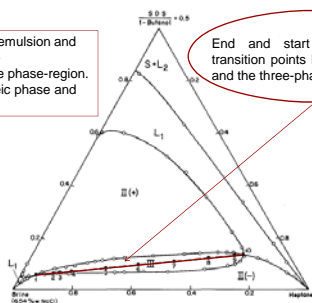


## Experimental Work

### Surfactant system tested

Sodium Dodecyl Sulphate/ 1-Butanol/Heptane/ Water/ NaCl [2].

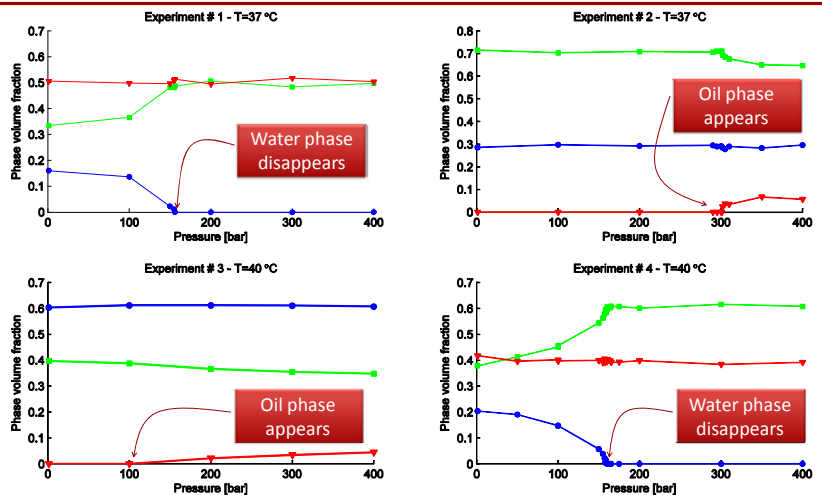
> II(+) is microemulsion and aqueous phase  
 > III is the three phase-region.  
 > II(-) is the oleic phase and microemulsion



The composition of the examined systems who resulted in a change in phase behavior dependent on pressure effect

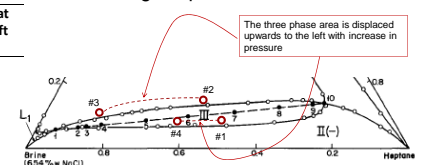
Exp #	Water	SDS	Butanol	Heptane	NaCl
Composition in wt%					
1	0,423	0,023	0,046	0,478	0,030
2	0,441	0,044	0,089	0,396	0,031
3	0,711	0,028	0,055	0,157	0,050
4	0,532	0,022	0,044	0,365	0,037

## Results



### Overview of the shift in number of phases dependent on change in pressure

Experiment No.	Phase shift	Temp. [°C]	Pressure at beginning [Bar]	Pressure at phase shift [Bar]
#1	3 to 2	37	1	156
#2	2 to 3	37	1	302
#3	2 to 3	40	1	100-200
#4	3 to 2	40	1	160



## References

- [1] D.W. Green and G.P. Willhite, 'Enhanced Oil Recovery', SPE Textbook Series, vol 6, 7, (1998)  
 [2] J. Van Nieuwkoop and G. Snoei, Journal of Colloid and Interface Science, (1985), 103, 400-41