

Full Length Article

Minimum miscibility pressure and interfacial tension measurements for N₂ and CO₂ gases in contact with W/O emulsions for different temperatures and pressures



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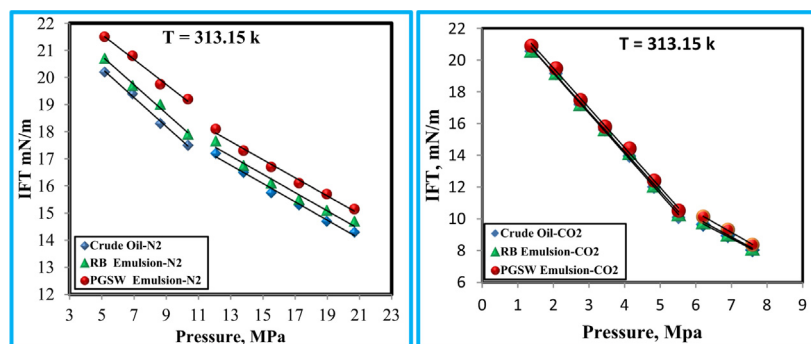
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GRAPHICAL ABSTRACT

In this research, the IFT behavior of the two different specimens of W/O emulsion with distinctive soluble ingredients of water in contact with CO₂ and N₂ was examined. The Minimum Miscibility Pressure (MMP) of the mentioned gases with emulsion specimens were measured and compared with the case of the original crude oil with no water content. This study focuses on the quantity of water in the W/O emulsion specimens and its effects on the IFT and MMP values. The IFT behavior of W/O emulsions was surveyed for two different cases of distinctive water soluble ingredients i.e. sea water and reservoir brine. The tests were performed under high pressure-high temperature (HPHT) condition utilizing Axisymmetric Drop Shape Analysis (ADSA) procedure. The equilibrium IFT between the two distinctive specimens of W/O emulsions with different amounts and composition of dispersed water and two types of gases i.e. CO₂ and N₂ were measured. The outcomes were compared with the behavior of original crude oil i.e. with no water content. The temperature was set in two distinctive values of 313.15 K and 333.15 K, and the pressure changes in the scope of 1 MPa–20.68 MPa. The outcomes manifested that the IFT behavior of the emulsion could be correlated directly with pressure for two distinctive variation rates, categorized in two different regions. Comparing to the original crude oil, in the case of W/O emulsion the equilibrium IFT increases, and this incremental behavior is much significant in the case of N₂-emulsion system. Additionally, the outcomes of IFT versus pressure in the case of N₂-emulsion system manifested that the slope of the first part of the curve decreases with increment in dispersed water content in the crude oil. However, the IFT values versus pressure in the second region were not affected by the water content of the emulsion. Also, Vanishing Interfacial Tension (VIT) technique was used to estimate the MMP of N₂-emulsion systems. According to the outcomes, MMP was increased in the existence of water, and the incremental behavior is significant as the water content was increased. It is worthy to note that the outcomes of the CO₂-emulsion systems manifested that both IFT behavior and MMP values were not changed significantly by water content. Finally in light of the test information gathered in this research, various relationships were proposed to express the IFT and MMP correlations as dependants of pressure at distinctive temperatures.



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ABSTRACT

In this research, the IFT behavior of two different specimens of W/O emulsion with distinctive soluble ingredients of water in contact with CO₂ and N₂ was examined. The Minimum Miscibility Pressure (MMP) of the

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Water-oil emulsion
Minimum miscibility pressure

mentioned gases with emulsion specimens were measured and compared with the case of the original crude oil with no water content. This study focuses on the quantity of water in the W/O emulsion specimens and its effects on IFT and MMP values. The IFT behavior of W/O emulsions was surveyed for two different cases of distinctive water soluble ingredients, i.e. sea water and reservoir brine. The tests were performed under high pressure-high temperature (HPHT) conditions utilizing Axisymmetric Drop Shape Analysis (ADSA) procedure. The equilibrium IFT values between the two distinctive specimens of W/O emulsions with different amounts and compositions of dispersed water and two types of gases, i.e. CO₂ and N₂, were measured. The outcomes were compared with the behavior of original crude oil, i.e. crude oil with no water content. The temperature was set in two distinctive values of 313.15 K and 333.15 K, and the pressure changes in the scope of 1 MPa–20.68 MPa. The outcomes manifested that the IFT behavior of the emulsion could be correlated directly with pressure for two distinctive variation rates, categorized in two different regions. Comparing to the original crude oil, in the case of W/O emulsion the equilibrium IFT increases, and this incremental behavior is much significant in the case of N₂-emulsion system. Additionally, the outcomes of IFT versus pressure, in the case of N₂-emulsion system, manifested that the slope of the first part of the curve decreases with increment in dispersed water content in the crude oil. However, the IFT values versus pressure in the second region were not affected by the water content of the emulsion. Also, Vanishing Interfacial Tension (VIT) technique was used to estimate the MMP of N₂-emulsion systems. According to the outcomes, MMP was increased in the existence of water, and the incremental behavior becomes significant when the water content is increased. It is worthy to note that the outcomes of the CO₂-emulsion systems manifested that both IFT behavior and MMP values were not changed significantly by water content. Finally, in light of the test information gathered in this research, various relationships were proposed to express the IFT and MMP correlations as dependants of pressure at distinctive temperatures.

1. Introduction

The expectation for worldwide increment in energy request would lead to investigation for enhancement of oil recovery through secondary and tertiary EOR processes. The selection and conduction of any secondary and tertiary EOR strategies require comprehensive studies considering possible risks concerning sweep efficiencies, microscopic, volumetric, and formation damage.

These are the premier causes for low recovery during primary and secondary EOR stages in oil reservoirs with asphaltene problem. In addition to the formation damage as a consequent of asphaltene precipitation and deposition, after the secondary water flooding or during water alternative gas (WAG) processes, many of asphaltenic reservoir oils are talented to the emulsification of water in oil, in the reservoir [1–3].

The stability of the W/O emulsion is impressed by temperature and the nature of oil and saline solution [4,5]. Asphaltene precipitation in the vicinity of mobile reservoir brine or injecting water, associated with

the agitation caused by fluid flow through porous medium, causes the emulsification of water in oil in the reservoir [6–9]. In fact, agitation caused by fluid flow through porous medium provides prerequisite shear stress to scatter aqueous phase droplets into oil phase. Therefore, asphaltene molecules, as natural surfactants, can stabilize water in oil emulsions by covering the skin of the scattered droplets of water and prohibit water droplets to get coalesced. It ought to be mentioned that the resin-asphaltene ratio plays a key role in the endurance of the emulsion [6,8,10]. Also, the amount of water in oil emulsion highly depends on the crude oil composition, water salinity, oil production rate, pore structure and oil-water interfacial tension [11]. The injection of sea water and its diluted solutions as the low salinity water injection technique would increase the risk of water in oil emulsification in the reservoir [11,12].

Emulsification significantly affects the reservoir fluid properties such as viscosity, hence the flow ability is changed in the reservoir rock [2,13,14]. Furthermore, the dispersed water droplets in emulsion can reduce the absolute permeability of reservoir rock by obstructing some pathways in porous medium [11,15]. The increase in reservoir fluid viscosity and the decrease in reservoir permeability can lead to serious problems in oil production, in particular, in the reservoirs with asphaltene difficulties pending the EOR processes.

Table 1
Compositional analysis of Ahwaz-Bangestan crude oil.

Specification	Value
Oil gravity at 298 K (kg·m ⁻³)	898
Oil viscosity at 298 K (centipoise)	142
Saturate (mass percent)	68
Aromatic (mass percent)	20
Resin (mass percent)	6.5
Asphaltenes (mass percent)	5.5
CO ₂ (mole percent)	0.03444
N ₂ (mole percent)	0.00068
C ₁ (mole percent)	0.22013
C ₂ (mole percent)	0.2339
C ₃ (mole percent)	0.76431
iC ₄ (mole percent)	0.86928
nC ₄ (mole percent)	1.70179
iC ₅ (mole percent)	1.53056
nC ₅ (mole percent)	2.31041
C ₆ (mole percent)	5.06327
C ₇ (mole percent)	7.24043
C ₈ (mole percent)	7.32006
C ₉ (mole percent)	6.36125
C ₁₀ (mole percent)	4.26918
C ₁₁ (mole percent)	4.64395
C ₁₂ ⁺ (mole percent)	57.65649
C ₁₂ ⁺ Molecular weight	366
C ₁₂ ⁺ density at 298 K (kg·m ⁻³)	953

Table 2
Analysis of Ahwaz-Bangestan Brine (RB).

Salt Type	Concentration (ppm)
NaCl	173349.67
Na ₂ SO ₄	626.39
CaCl ₂	20491.34
MgCl ₂	6169.81
NaHCO ₃	1362.78

Table 3
Analysis of Persian Gulf Sea Water (PGSW).

Ion type	Concentration (ppm)
NaCl	28399.62
KCl	799.996
CaCl ₂	1828.079
MgCl ₂	13729.85
Na ₂ SO ₄	4489.901
NaHCO ₃	99.998

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