Effect of osmosis on spontaneous imbibition of fracturing fluid in shale oil formation

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MS13 - Fluids in Nanoporous Media

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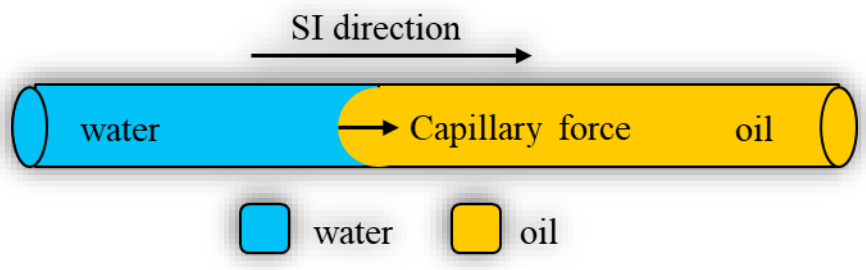
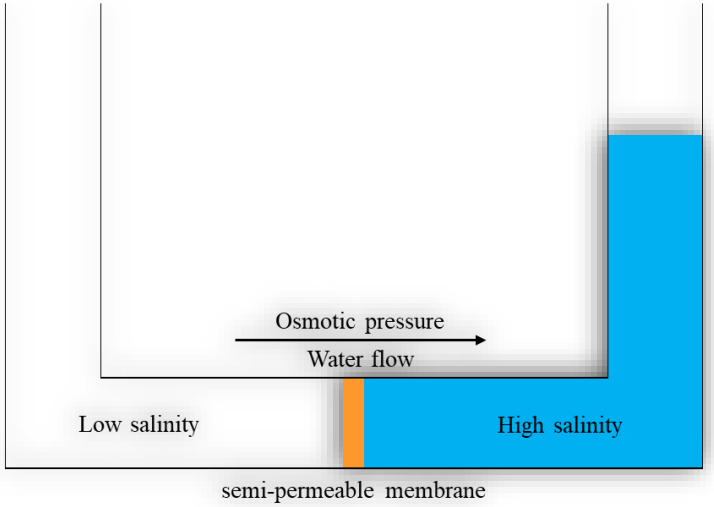
Introduction

1) Spontaneous imbibition (SI) refers to the process that wettable fluid displaces non-wettable fluid out of the pores in matrix without external pressure.



2) Capillary force is the driving force of SI.

3) In addition, osmotic pressure is a significant determinant in the imbibition of fracturing fluid in shale reservoir.



Introduction

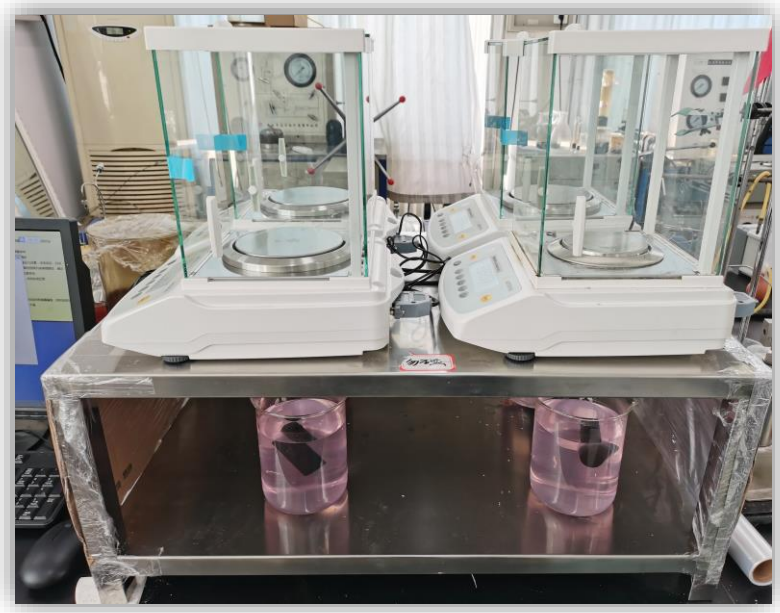
1) Studies of SI of shale involving osmosis focus mostly on the effect of osmotic pressure on production, but few analyze the comprehensive influence mechanism of osmosis and capillarity during imbibition.

2) Current experimental research on osmosis in SI focuses primarily on the external water phase inhalation process, but rarely examines the water-oil two-phase replacement process.

3) Previous SI experiments of shale oil reservoir do not consider the existence of initial formation water in pores.

Methodology

In this paper, using NMR (nuclear magnetic resonance) testing and balance measurement, we developed an SI experimental method of shale oil reservoir considering the presence of initial formation water, and the osmosis mechanism in SI is studied in-depth.



Imbibition experimental apparatus

Low-field NMR instrument.

Results and discussion

Imbibition recovery of fracturing fluid

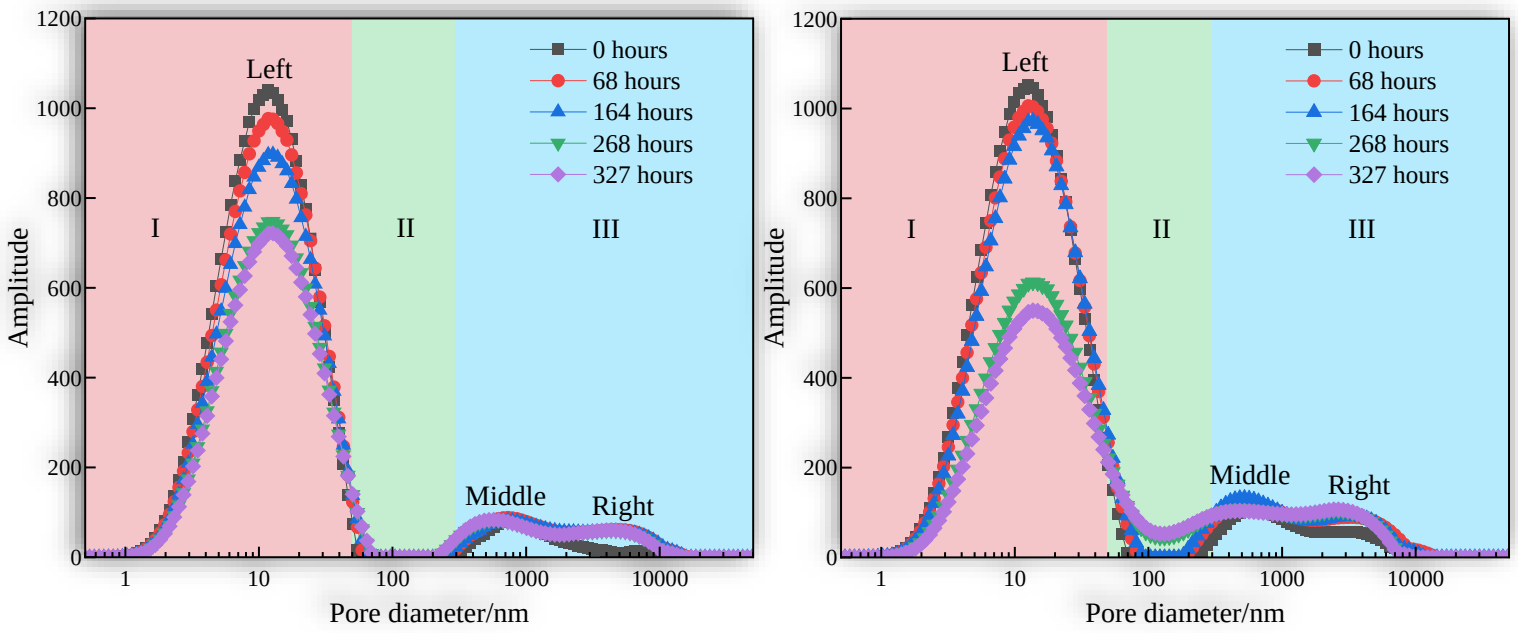
The imbibition recovery ratio can be calculated by the T_2 spectrum area before and after imbibition.

$$E = \frac{S_0 - S}{S_0}$$

Where E is the recovery ratio, S_0 is T_2 spectrum area before SI, and S is T_2 spectrum area after SI.

The imbibition recovery ratio of sample L is 32.18%, which is higher than 21.45% of sample F.

The reason for this is that the "newly formed pores or microfractures" improve oil-water flow capacity.



(a) sample F. (b) sample L.

NMR T_2 spectra of fracturing fluid SI.

Results and discussion

InterPore2022

Drainage of high-salinity fluid SI

decline stage

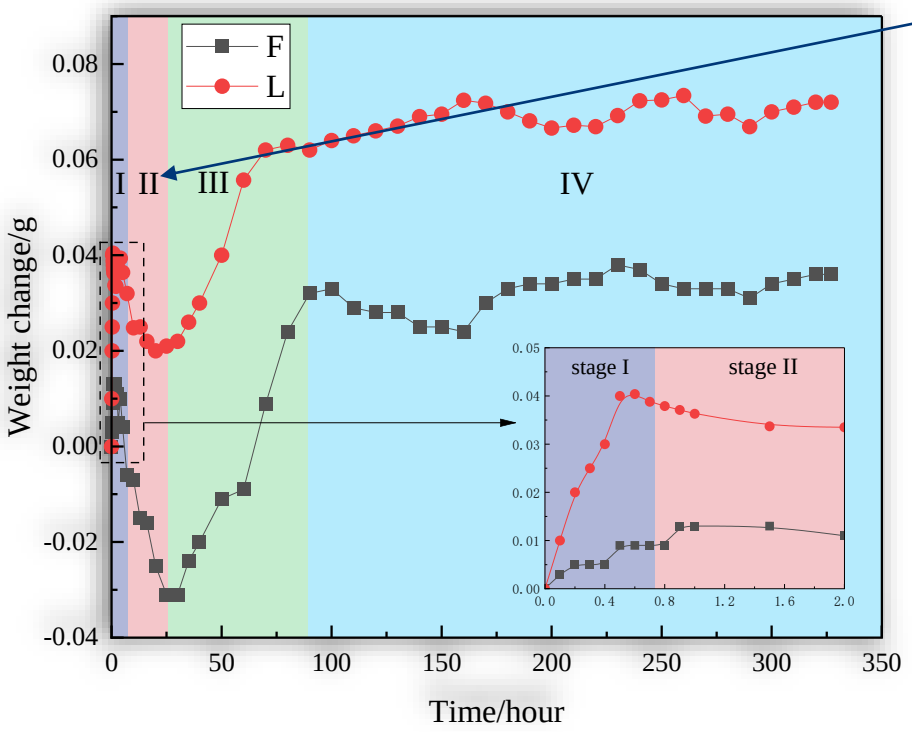
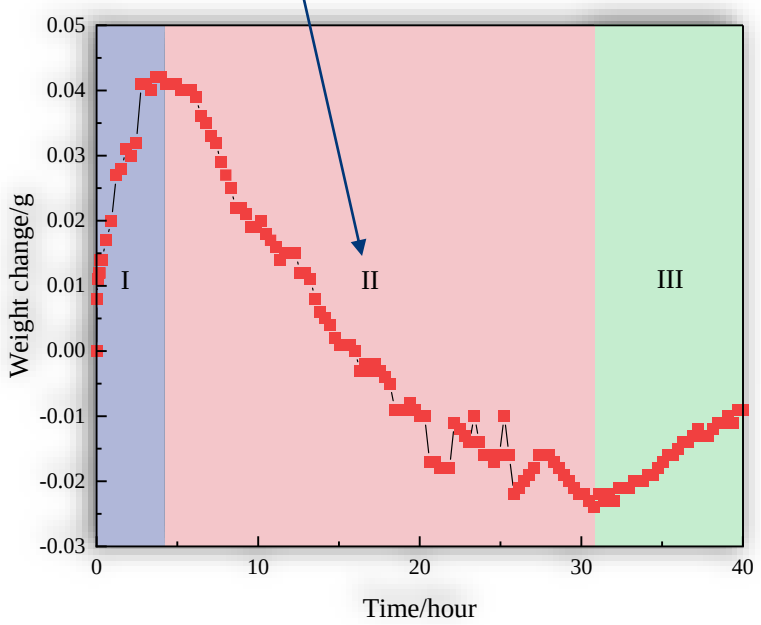
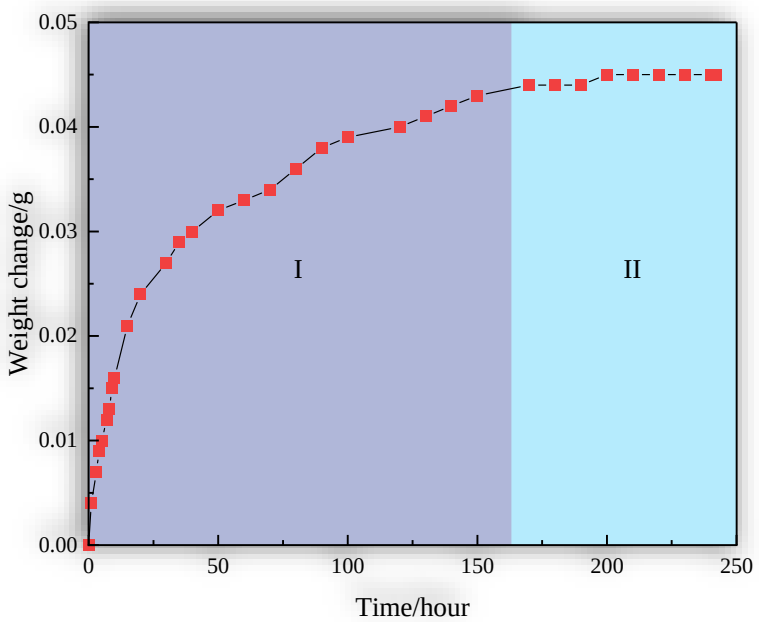


Fig. 1 SI of high-salinity slick water (18wt.% $MnCl_2 \cdot 4H_2O$), $S_w \neq 0$.



(a) $S_w \neq 0$.

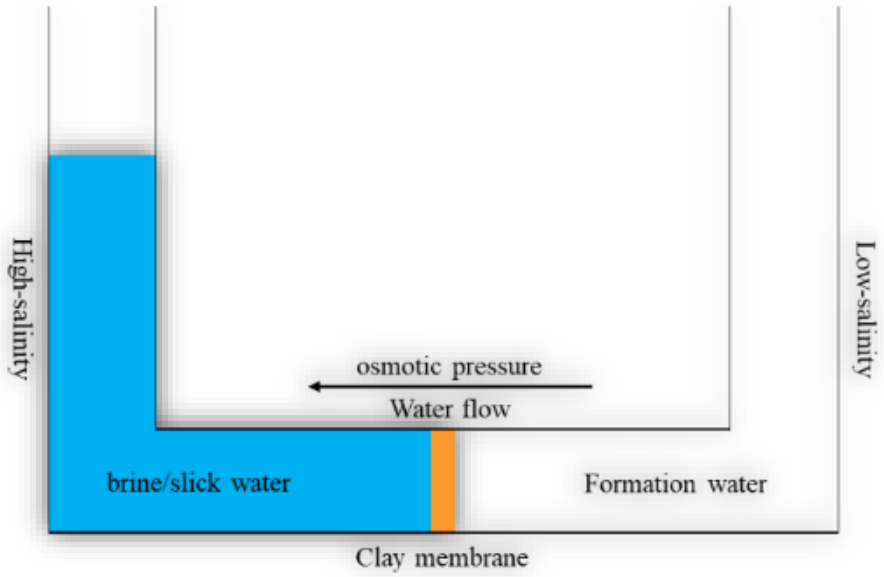


(b) $S_w = 0$.

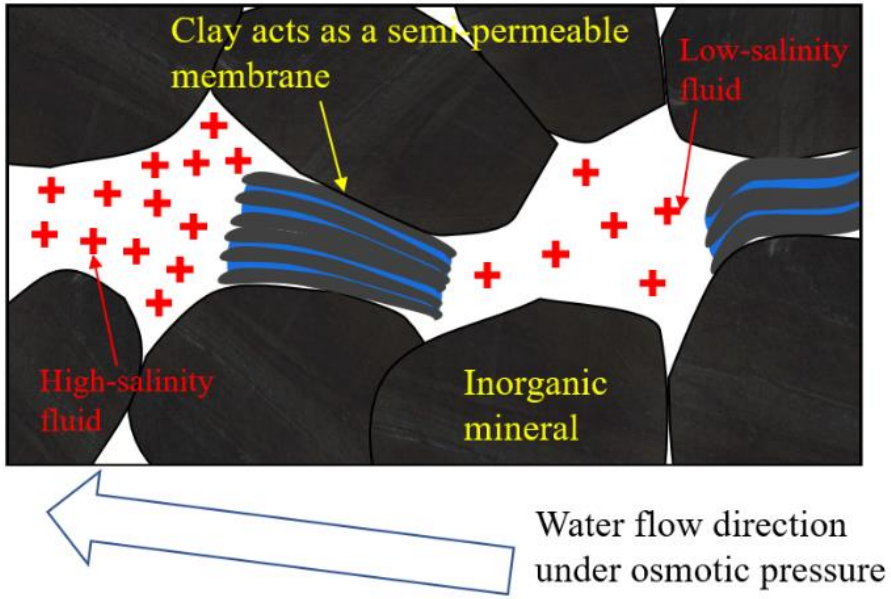
Fig. 2 SI of high-salinity brine (24wt.% KCl).

Results and discussion

Drainage of high-salinity fluid SI



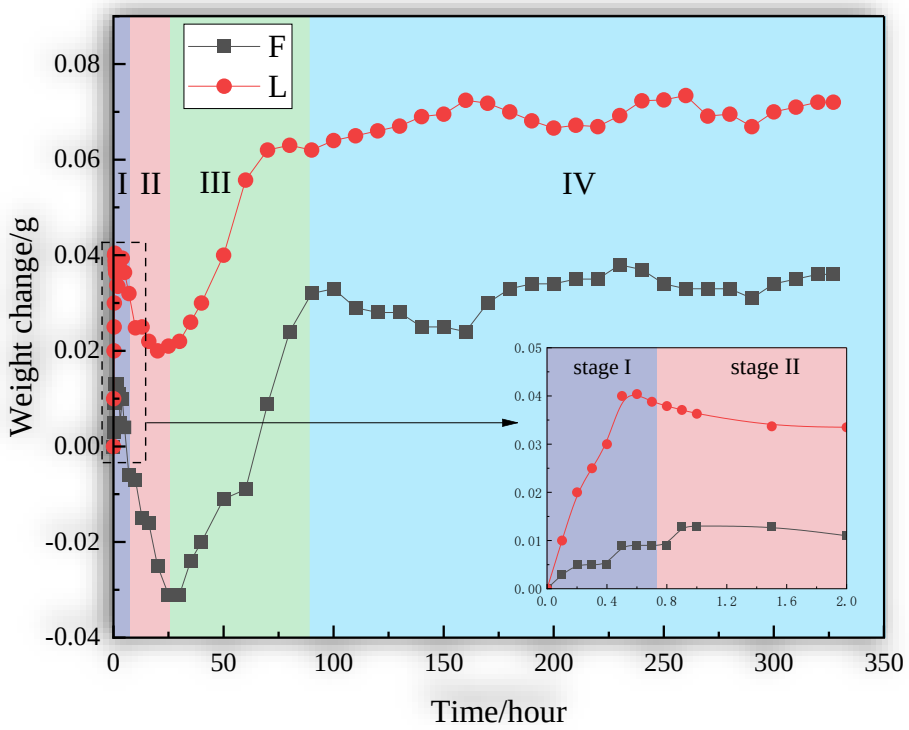
Schematic diagram of **osmotic pressure** in high-salinity fluid SI.



Effect of **osmotic pressure** on external higher salinity fluids.

Results and discussion

Drainage of high-salinity fluid SI

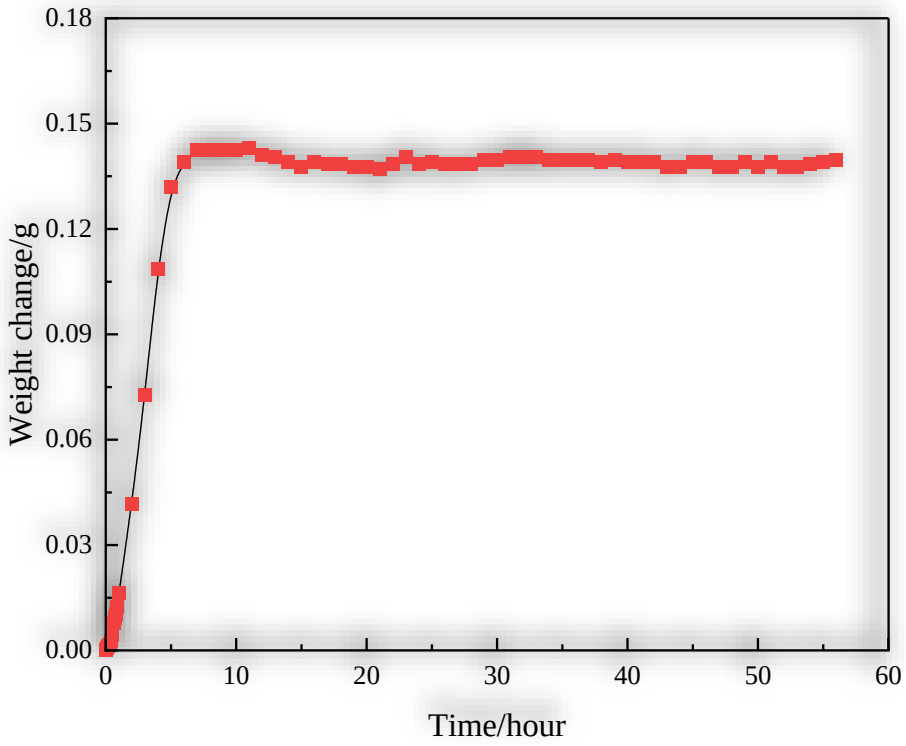


when $S_w \neq 0$, high-salinity fluid imbibition can be divided into four stages:
initial imbibition stage (stage I),
drainage stage (stage II),
secondary imbibition stage (stage III),
stationary stage (stage IV).

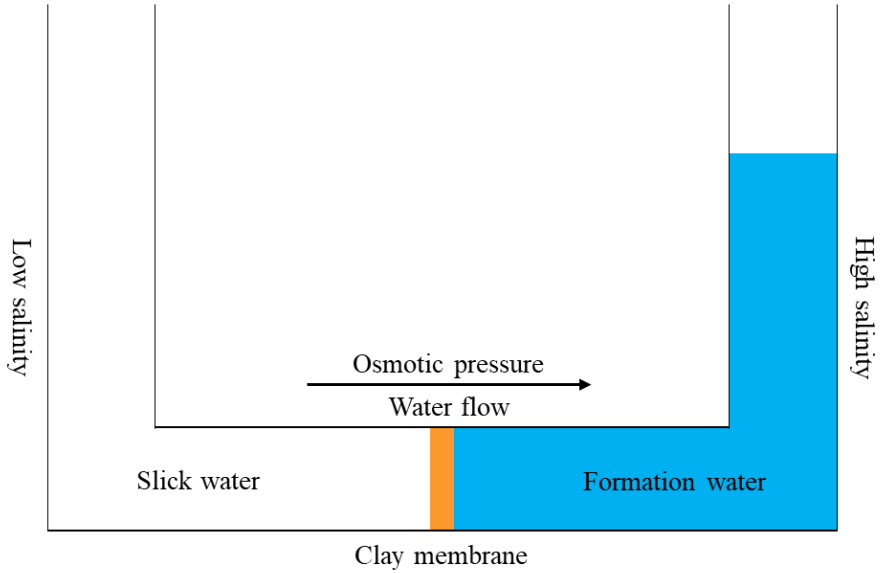
SI of high-salinity slick water (18wt.% $MnCl_2 \cdot 4H_2O$), $S_w \neq 0$.

Results and discussion

Osmosis-enhanced SI of low-salinity fluid



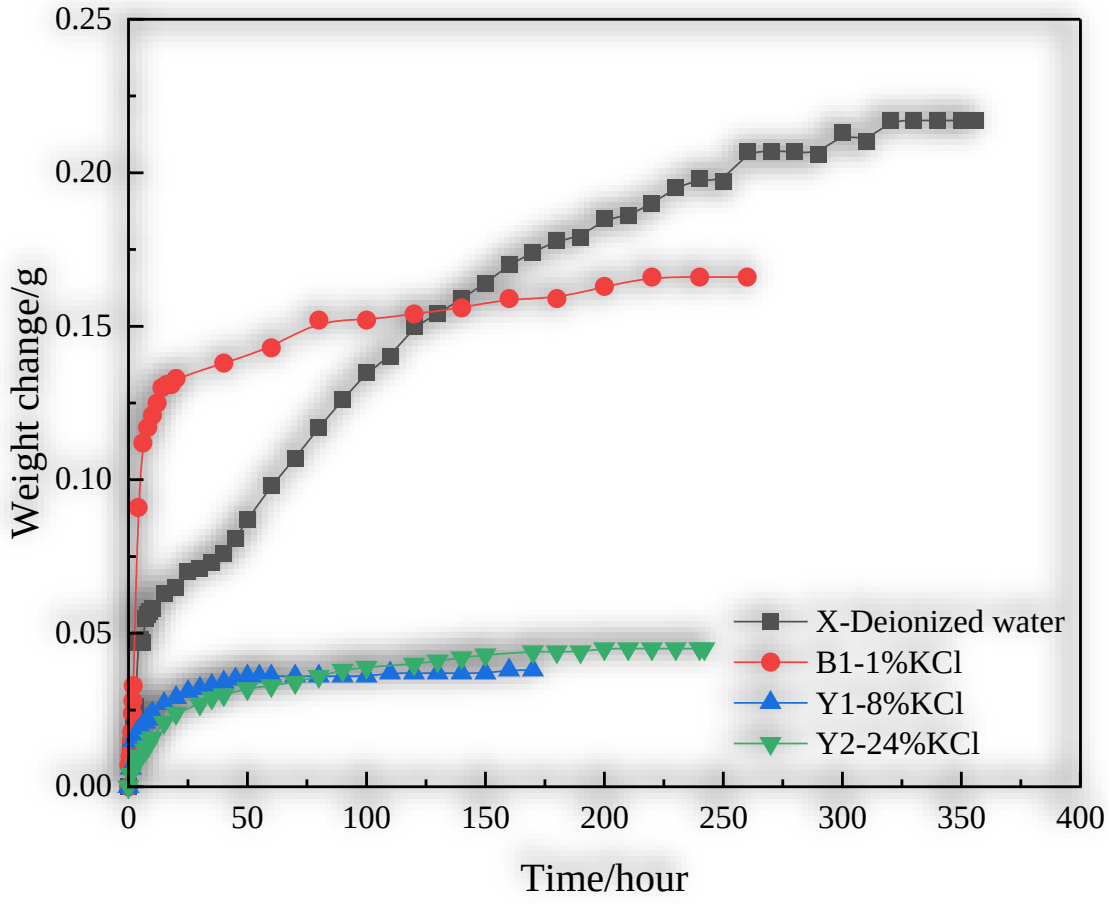
SI of low-salinity slick water (0.1wt.% KCl), $S_w \neq 0$.



Schematic diagram of osmotic pressure in low-salinity fluid SI.

Results and discussion

Osmosis-enhanced SI of low-salinity fluid



SI of brine with different salinities, S_w=0.

the SI experiment of shale samples with S_w of 0,

low-salinity fluid can still play the role of "osmosis-enhanced SI".

Conclusions

(1) During the SI of fracturing fluid, “newly formed pores or microfractures " can act as channel for oil migration, facilitating the replacement of shale oil in smaller pores.

(2) When $S_w \neq 0$, high-salinity fluid SI can be divided into four stages. The salinity difference between the external fluid and the formation water leads to the drainage stage, which is dominated by osmosis. When $S_w=0$, there is no drainage stage.

(3) When $S_w \neq 0$, low-salinity fluid SI can be called "osmosis-enhanced SI". When $S_w=0$, with the increase of S_w during SI, low-salinity fluid can still play the role of "osmosis-enhanced SI".

Thank You / Questions

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