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Enhancing Heavy Oil Recovery via the Injection of Malonic Acid based Deep Eutectic Solvents

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Abstract

Increasing demand and decreasing supply of crude oil have spurred efforts towards enhancing heavy oil recovery. Recently, applications of ionic liquids (ILs) for heavy oil recovery and catalytic upgrading have been reported. However, ILs are generally considered too expensive for industrial applications. Moreover, certain types of ILs are non-biodegradable and toxic. An alternative class of ILs called Deep Eutectic Solvents (DESs) have recently been discovered and investigated upon.

A DES generally composed of two or more components that are capable of self-association, to form eutectic mixture with a melting point lower than that of each individual component. DESs are non-toxic, biodegradable, recyclable, non-flammable, environmentally friendly and cheap. Therefore, DESs have found application in fields like extraction/separation, solvent development/reaction medium, and hydrometallurgy. This study investigates the potential of chemical solvents synthesized from DESs to recover the residual heavy oil.

For the first time to our knowledge, the effectiveness of DESs - Choline Chloride: Malonic Acid (1:1) and (1:0.5) molar ratio - in enhancing heavy oil recovery is thoroughly investigated. Measurements of surface tension, interfacial tension, wettability alteration, spontaneous imbibitions, emulsification and formation damage tests were conducted at different temperatures. Heavy oil with 16 ˚API and formation brine from Middle East oil field were used. The core flood experiments were conducted using 200-300 mD Berea sandstone cores. It was found that the solvents produced 7-14% of the residual heavy oil after brine flooding as tertiary recovery stage. The results showed that the two DESs make no emulsion with the heavy oil.

Interfacial tension increased from 8.3 mNm-1 for the oil-brine system to up to 21.9 mNm-1 for oil-DES system. On the other hand, the two DESs altered the wettability of the sandstone rock from strongly oil-wet to neutral-wet conditions. As temperature increases, the interfacial tension and oil recovery increase and wettability becomes more neutral-wet. Hence, wettability alteration is believed to be the main mechanism causing the enhancement in heavy oil recovery. The formation damage test proved that the tested DESs caused no damage to the formation where the absolute permeability before and after injecting the DES's was found the same.