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Synthesis, Introduction and Study of the Rheological Properties of a Novel Polymeric Surfactant and Its Effect on Interfacial Tension in Different Salinity

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INTRODUCTION

Chemical methods for enhanced oil recovery include the injection of chemicals such as polymers, surfactants and alkaline to the reservoir which are used for transferring the trapped oils. In some cases, these substances are also injected simultaneously into the reservoir [1-5]. In this method, surfactants are used to reduce the interfacial tension between water and oil and also to change the wettability of the reservoir rock, meanwhile the polymers are used to increase the viscosity of the injected water, thereby reducing the water mobility and becoming close to the oil mobility [5,6]. Alkaline also react with organic acids available in petroleum and produce a natural surfactant which has a function almost similar to the surfactant [1].

The mechanism of polymers on enhanced oil recovery is based on the reduction of mobility ratio of water and oil. Specifically, when the polymer is added to the water as a displacement fluid, it leads to an increase in the viscosity of the injected water and mobility of the water become close or equal to the mobility of the oil which is the displaced phase, as the result, the mobility ratio of water to oil equals to 1 or higher. As it is known, the viscosity has an inverse ratio with mobility so that with increasing the viscosity, the mobility decreases. This operation leads to an increase in the sweeping coefficient of the oil which results in enhanced oil recovery while preventing the fingering phenomenon to happen. Some of the important features of the polymers used for this purpose include high molecular weight, suitable resistance to mechanical degradation (shear rate), high salt tolerance, sufficient thermal resistance, and also complete water solubility [7].

EXPERIMENTAL PROCEDURE

CHEMICAL MATERIALS

The materials used in this study include acrylamide with a purity degree of 98%, polyvinylpyrrolidone, sodium chloride, potassium sulfate, magnesium chloride, sodium hydroxide, acrylic acid, a zwitterion [2- (Methacryloyloxy) ethyl] dimethyl - (3-sulfopropyl) ammonium hydroxide with a purity degree of 95% which were provided from Sigma Aldrich company. Ethanol and methanol with the experimental purity were provided from Merck Company. Formation water, core and crude oil were provided from one of the reservoirs located in the southwest of Iran.

METHODS

SYNTHESIS OF SODIUM ACRYLATE

Sodium acrylate was synthesized by sodium hydroxide and acrylic acid in a 1:1 ratio at temperature between 2° and 5 °C, and in the presence of nitrogen, then acrylic acid was gradually added to the system. After 30 minutes, nitrogen was removed and methanol evaporated until dried completely and a white powder was created. Chloroform was used to purify the product. After the sample was dried, an FTIR test was performed which was in accordance with the reference test by Sigma Aldrich.

POLYMERS RHEOLOGY

To measure viscosity and shear rate with controlled stress, Brookfield DVT-III apparatus was used in different conditions. Viscosity at 30 °C and shear rate range for viscosity in the fixed shear rate in the range between 1 (S-1) and 400 (S-1) were selected.

To test the resistance of HPAM and HMZPAM at 2500 to 90000 mg/l, NaCl, $MgCl_2$, $CaCl_2$ were selected and solubilized separately with each polymer sample at the constant concentration of 2000 (mg/l). Then the viscosity of polymer solutions at 30°C was obtained.

INTERFACIAL TENSION

One of the widely used methods for measuring interfacial tension (IFT) between liquid-liquid and gas-liquid under the conditions of high pressure and temperature and also for determining the contact angle is pendant drop technique. In the current study, the interfacial tension measuring apparatus IFT 600 used which is manufactured by technology company of Atiyeh Poyandegan Xsir Arak. The catalysts were activated at 610 °C. It was carried out in a flow of N2 (100 ml min^{-1}) for 60 min.

RESULTS AND DISCUSSION. FTIR OF THE SYNTHESIZED POLYMERS

In Figure 1, the FTIR spectrum for HPAM synthesized in the laboratory is shown. As shown, absorption peaks at the range of 3401.61(cm^{-1}) and 3195.6 (cm^{-1}) represent the presence of [N-H], peak at 2940.65 (cm-1) indicates the presence of [C-H3], peak at 1671.81(cm^{-1}) indicates the presence of [C = O] and peaks at 1405.32 (cm^{-1}) and 1329 (cm^{-1}) and 1122.54 (cm^{-1}) indicate the presence of [C-N] in the composition.

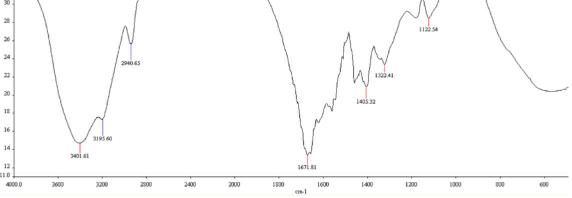


Figure 1: FTIR spectrum for HPAM polymer.

In Figure 2, the FTIR spectrum for synthesized HMZPAM in the laboratory is shown. As seen in the figure, absorption peaks at 3422.94 (cm^{-1}) and 3235.60 (cm^{-1}) indicate the presence of [N-H], peak at 2930.51 (cm^{-1}) represents [CH3], peaks at 2366.71 (cm^{-1}) and 2343.44 (cm^{-1}) indicate the presence of quaternary nitrogen [N + - (R) 4], peak at 1654.78 represents [-C=O-C-], peaks at 1405.32 (cm^{-1}), 1329 (cm-1) and 1122.54 (cm^{-1}) indicate the presence of [CN], peak at 95/1050.95 (cm^{-1}) represents [S=O] and peak 625.75 (cm^{-1}) represents [C-S] in the composition [8-9].

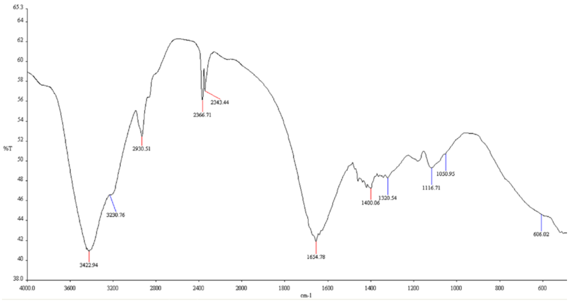
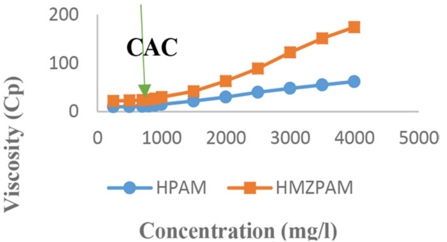


Figure 2: FTIR spectrum for HMZPAM polymer.

APPARENT VISCOSITY OF HMZPAM AND HPAM

Apparent viscosity which is one of the important properties of polymeric solutions was evaluated for both polymers at 30 ° C (temperature room) and in the presence of 10000 (mg/l) of sodium chloride. For this purpose, the viscosity of two solutions was chosen at concentrations of 250 to 4000 mg/l and solubilized in deionized water. The results show that with the increase in the concentration at constant temperature, the apparent viscosity increases which were shown in Figure 3.



Fiure 3: Apparent viscosity of HPAM and HMZPAM polymers in the presence of 10000 (mg/l) of sodium chloride at 30 °C.

On the other hand, the effect of HMZPAM on viscosity is higher than HPAM. The presence of hydrophobic groups in the HMZPAM structure and its accumulation reduces the inter-molecular distance in the structure of the polymer resulting in more molecular contacts. This factor increases the volume of the molecular network so that the increase in the number of these networks will lead to a significant increase in viscosity in comparison with the HPAM solution. In addition, as shown in the following figure, the critical accumulation concentration (CAC) for both polymers is about 800 milligrams per liter [10].

CONCLUSIONS

1. With increasing polymer concentration in the solution, the viscosity increases and HMZPAM provides more viscosity than HPAM.
2. The presence of salts in the polymeric solution led to a significant decrease in the viscosity of HPAM while two-valance salts further decreased the viscosity.
3. The presence of salt in HMZPAM solution led to a reduction in viscosity up to a concentration of 20000 (mg/l) and at concentrations higher this, the presence of salt led to a significant increase in viscosity, and also two-valance salts have a lower effect on viscosity than one-valance cation.
4. Salt resistance of HMZPAM is much higher than that of HPAM.
5. Shear rate led to a decrease in the viscosity of the polymeric solution and HMZPAM indicated a higher stress resistance.
6. HMZPAM further decreased the interfacial tension of polymeric solution and crude oil in comparison with HPAM, and also the presence of salt increased the ability of the polymer in decreasing IFT.

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