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FULL LENGTH ARTICLE

Preparation and evaluation of cationic bolaform surfactants for water-based drilling fluids

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Abstract Three cationic bolaform surfactants with different spacer lengths were prepared from the reaction of two moles of triisopropanolamine with one mole of each of the following 1,4-dibromobutane, 1,5-dibromopentane and 1,6-dibromohexane. The chemical structures of the prepared compounds were confirmed via: FTIR spectroscopy, ^{1}H NMR and elemental microanalysis. The surface activity of these bolaform surfactants was studied. The prepared cationic bolaform surfactants were evaluated as viscosifier additives for water-based drilling fluids. The evaluation includes the study of rheological properties of the formulated mud (apparent viscosity, plastic viscosity and yield point, gel strength and thixotropy), effect of temperature on the rheological properties and also, the study of mineralogical properties of the water-based before and after treatment with the prepared surfactants using: X-ray diffraction (XRD), scanning electron microscope (SEM) and transmission electron microscope (TEM). The results of the evaluation were compared to the water-based mud formulated from commercial grade bentonite.

1. Introduction

It is a matter of common experience in the oil and gas industry that the drilling of oil or gas wells is carried out with the aid of circulating drilling mud or drilling fluids. So, the success of any well drilling operations depends on many factors, the drilling mud must be environmentally friendly and more economical. Drilling fluids have many functions including, removal of cuttings generated by the drill bit from the borehole [1], cooling and lubricating the drill bit [2], preventing blowouts by controlling back pressure [3], and forming a thin, low-permeable filter cake [4]. The drilling fluids can be classified into three main types which are Gas-Based Drilling Fluids (GBDFs), Non Aqueous-Based Drilling Fluids (NABDFs) and Aqueous-Based Drilling Fluids (ABDFs). Water based-mud is considered the best drilling fluid that is more environmentally friendly than oil-based mud and is less expensive than the other synthetic-based drilling fluids. Bentonite clay is the key component of water based mud. Na-montmorillonite (> 80% from bentonite clay) is the main constituent of bentonite. The bentonite clay is used in water based mud due to its ability to form viscoelastic and thixotropic dispersions, these properties enable the drilling fluid to carry cuttings

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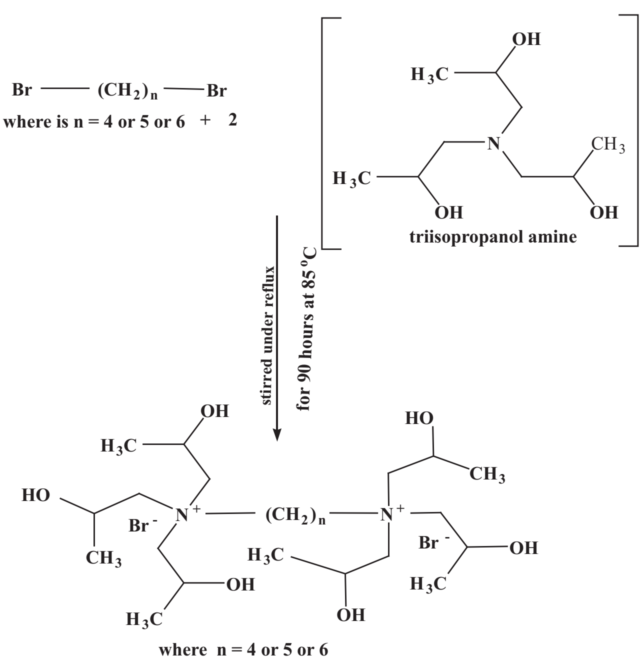
generated by the drill bit from the borehole to the surface and keep the water-based mud components suspended especially during the stoppage of drilling operation. The properties of natural montmorillonite clay can be enhanced or modified by organic modification, due to the substitution of the exchangeable cations in the interlayered area or cation exchange capacity (CEP) [5–9]. The surface modification of the clay minerals can be carried out either by physical adsorption using polymers or by intercalation using surfactant. The activation of bentonite by surfactant occurred for upgrading of the bentonite to meet the API specification and OCMA standard [10,11]. In this study, bolaform surfactants were used to increase the rheological properties of local raw bentonite and to raise its potential use in water-based drilling fluids. Bolaform surfactants are molecules with two polar head groups connected by one or two hydrophobic chains. These compounds have been subjected to much research in the last two decades for their diverse interesting properties. Many efforts were made to design and synthesize bola molecules with different structures and characterize the aggregation behavior of their aqueous solutions [12].

2. Experimental

2.1. Materials

All chemicals that were used throughout this investigation are of analytical grade and used as they are without more purification. Triisopropanolamine (98%, Aldrich), 1,4-dibromobutane (98%, Aldrich), 1,5-dibromopentane (98%, Aldrich), 1,6-dibromohexane (98%, Aldrich), ethanol (98%, Sigma), diethyl ether (98%, Sigma), Egyptian local raw bentonite sample from South-Hamam, Alexandria (AP = 6.5 cp, PV = 2 cp, YP = 9 Ib/100 ft^2, filter loss = 23 ml, CEC = 54 mill equivalents/100 g and pH = 9.23) and Reference mud sample (R) from Halliburton drilling company (AP = 15 cp, PV = 10 cp, YP = 15 lb/100 ft^2, Filter loss = 15 ml and pH = 10.85).



Scheme 1

2.2. Synthesis

The investigated surfactants were prepared by refluxing two moles of triisopropanolamine with one mole from each of 1,4-dibromobutane, 1,5-Dibromopentane and 1,6-dibromohexane in the presence of ethanol as a solvent. The reaction mixture was stirred under reflux for 90 h at 85 °C as shown in Scheme 1. The products were precipitated from the reaction mixture, purified using diethyl ether to obtain, diammonium bromide quaternary salts of different spacers (B_1, B_2 and B_3, with n = 4, 5 or 6) with yields of 85%, 90% and 95%, respectively.

2.3. Analytical equipments

The structures of the synthesized compounds were confirmed via the following equipments:

(1) Proton Nuclear Magnetic Resonance: ^1H NMR spectra of the compounds under investigation were measured in $CDCl_3$ using Varian 300 MHz NMR spectrometer at 20 °C. The measurements were carried out at the National Research Center.
(2) The Fourier Transform Infrared: (ATI Mattson genesis and FTIR spectrophotometer). The measurements were carried out at the Egyptian Petroleum Research Institute (EPRI). All spectra were recorded with 2 cm^{-1} resolution at an angle of incidence 80° relative to the surface normal.
(3) Micro elemental analysis was carried out at the Micro Analytical Center, Faculty of Science, Cairo University.

2.4. Surface properties

Determination of the surface tension of the prepared cationic bolaform surfactants was carried out using a (Kruss-type K6) tensiometer equipped with a Platinum–Iridium DuNouy ring. Double distilled water having a surface tension of 73 mN/m at room temperature was used in the preparation of samples. Measurements were carried out at the Egyptian Petroleum Research Institute (EPRI).

2.5. pH measurements

The pH values were measured for mud batches (ML, MB_1, MB_2, MB_3 and MR) and illustrated in Table 5.

2.6. Yield value and mud density

Bentonite yield was determined according to OCMA (Oil Companies Materials Association) specifications which correspond to 90.0 barrels per ton mud slurry [13].

The density were measured for all mud batches (ML, MB_1, MB_2, MB_3 and MR) by using Fann mud balance model 140 and illustrated in Table 5.