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Scale and corrosion inhibition performance of the newly synthesized anionic surfactant in desalination plants: Experimental, and theoretical investigations

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ABSTRACT

Ring opening reaction was used to prepare novel anionic surfactant as $CaSO_4.2H_2O$ scale and mild steel (MS) corrosion inhibitor. The prepared surfactant was designed as Hexa-anionic surfactant, and named; Sodium (2Z,16Z)-8,11-bis((Z)-3-carboxylatoacryloyl)-5,14-bis(2-((4dodecylphenyl)sulfonamido)ethyl)-4,15-dioxo-5,8,11,14-tetraazaoctadeca-2,16-dienedioate. The Hexa-anionic surfactant was characterized by FTIR, and ^{1}HNMR. Platinum ring method was used to study surface active properties of the investigated surfactant. The anti-scale property of Hexa-anionic surfactant was evaluated according to a static test method. Scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy dispersive X-ray (EDX), and X-ray diffraction (XRD) were used to examine $CaSO_4{\cdot}2H_2O$ crystal morphology. The high anti-scale performance of Hexa-anionic surfactant was related to its chelating, adsorption, and dispersion abilities. The scale inhibition (*SI*%) reached the maximum 100% at concentration 7 ppm. Also, the inhibition performance of the insight surfactant for MS corrosion in synthetic water was tested by electrochemical impedance spectroscopy (EIS), and potentiodynamic polarization (PDP) techniques, accompanied with surface analysis techniques. The obtained results indicated a good corrosion mitigation action of the investigated surfactant. SEM, and EDX show the formation of Hexa-anionic surfactant's adsorbed layer on the MS surface. The adsorption of Hexa-anionic surfactant at MS followed Langmuir adsorption isotherm. Quantum calculations confirmed the experimental data.

1. Introduction

Water is widely used in circulating cooling systems to remove unwanted heat in industrial processes such as oil-gas and electricity. Fe-alloys are the main construction materials in these industrial fields [1,2]. Corrosion and inorganic mineral scale deposits phenomena are considered as the major inseparable problems occurred in industrial fields. These problems lead to a great economic predicaments. Corrosion of equipment parts undergoes due to the interaction with the dissolved oxygen and aggressive chloride ions (Cl^-). This leads to damage and short the service life of the equipment. Scale deposition formed due to the of calcium, sulfate and carbonate ions in water and due to the temperature and pressure increase lead to rise the concentration of these ions up to supersaturation level, and finally scale crystal formed. Once the first layer of scale formed, further deposition layers will be continuously formed and become denser and thicker. So, the inorganic mineral deposition can block pore throats in the near-well, causing it malfunction and narrow the internal diameter of the pipeline and retard the fluid flow. Scale formation also, decreases the cooling efficiency of circulating water system [3]. One of the successful ways to prevent or mitigate the corrosion and scale problems is to use the organic inhibitors [4,5]. Organophosphorus compounds are widely used in water treatment due to their highly corrosion and scale inhibition efficiency, but, these compounds are restricted due to their environmental pollution [6–8]. Intensive scientific efforts have been done to prepare non-toxic, eco-friendly, economic and easy produced organic inhibitor compounds. Among of these compounds PASA, PAA for example [9–14]. A new class of compound that can be used as corrosion and scale resistant is the surface active materials. Surfactants have been widely used in oil and gas industrial processes. One of the largest applications for surfactants is the mitigation of the corrosion problem in the petroleum processing to reduce the loss of oil and metal deterioration, respectively [15,16]. Generally, the best corrosion and scale inhibitor compounds containing phosphate, sulfonate and carboxylate groups, so, the synthesis of the anionic surfactant was inspired from this view. So that this work aim to synthesize a newly anionic

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surfactant containing; Ar-SO_2-, -NH-CH_2-, and -COO^- groups to evaluate, discuss and understand the mechanism of its anti-corrosion and anti-scale abilities experimentally and theoretically.

2. Experimental

2.1. The chemical synthesis

The anionic surfactants are prepared as follow: N,N′-(3,6,9,12-tetraazatetradecane-1,14-diyl)bis(4-dodecylbenzenesulfonamide) prepared before [17] was reacted with maleic anhydride (molar ratio 1:4) in the presence of toluene as a solvent at 80 °C for 6 h. After that, the mixture quenched with NaOH. After that, the solvents were removed, and the anionic surfactants remain as solid yellow crystals. The anionic surfactant obtained was designated as Hexa-anionic surfactant. The synthesis of the Hexa-anionic surfactant represented in Scheme 1. The chemical structures of the synthesized compound was characterized by FTIR spectra using ATI Mattsonm Infinity series™, Bench top961 controlled by Win First™ V2.01 software, and ^{1}HNMRwas measured in DMSO-d6 by Avance III 400 MHz ^{1}HNMR Bruker High performance Digital FT-NMR spectrometer.

2.2. Surface tension measurements

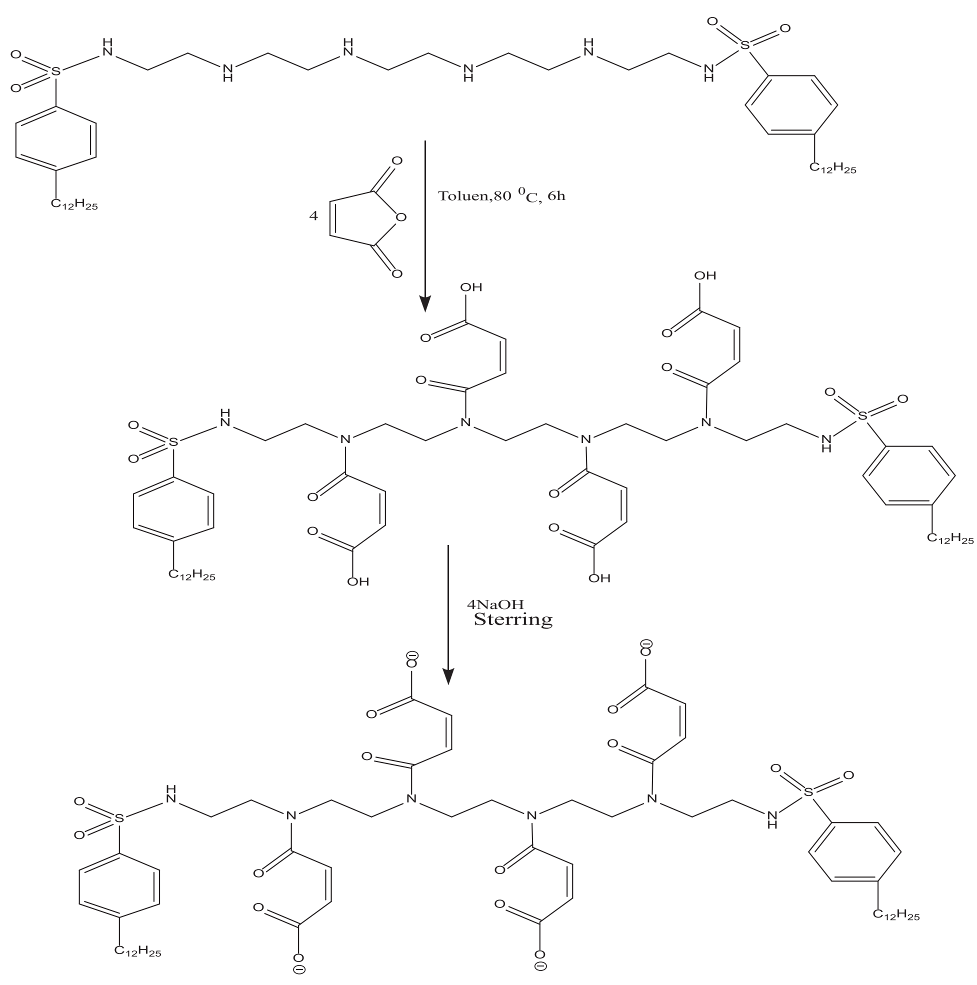
Surface tension measurements for the freshly prepared solutions of the synthesized anionic surfactants were carried out by the platinum ring method using a Kruss-K6 tensiometer at 25 °C. The Kruss-K6 tensiometer was calibrated by measuring the surface tension of pure water before measurement. The prepared solutions were left for 5 min to attain the equilibrium state at the solution surface, then the readings were taken three times to obtain the average value [18,19].

2.3. Scale inspection test

Scale inhibition efficiency of Hexa-anionic surfactant as $CaSO_4$ scale inhibitor was tested as reported in detail in standard test method NACE, TM (037-2007) [20]. The scale inhibition efficiency (*SI*%) is calculated from the following equation

$$SI\% = \frac{(Ca_2 - Ca_1)}{(Ca_i - Ca_1)}x100 \quad (1)$$

where,Ca_2 is calcium ion concentration for the mixed brine treated with the inhibitor after precipitation test.Ca_1 is calcium ion concentration in the blank mixed brine solution after precipitation test.Ca_i is the calcium ion concentration in the blank mixed brine solution before precipitation test.



(2Z,16Z)-8,11-bis((Z)-3-carboxylatoacryloyl)-5,14-bis(2-((4-dodecylphenyl)sulfonamido)ethyl)-4,15-dioxo-5,8,11,14-tetraazaoctadeca-2,16-dienedioate

Scheme 1. The synthesis of Hexa-anionic surfactant.