

Adsorption mechanism of guar gum at solid–liquid interfaces

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Abstract

Guar gum, a polysaccharide, is now widely used in many industrial areas such as pharmaceuticals, cosmetics, textiles, food and mineral industries. One important application is its use as a depressant for talceous gangue minerals in the flotation of nickel and platinum bearing ores. However, the mechanisms of gum adsorption on solids are not clearly established. In this work, adsorption of guar gum at the solid–liquid interfaces is investigated using spectroscopic and allied techniques. Guar gum adsorption on talc was found to be not affected significantly by changes in solution conditions such as pH and ionic strength, ruling out electrostatic force as the controlling factor. Electrokinetic studies showed that guar gum decreased the negative zeta potential of talc but did not reverse the charge. No desorption was observed, which suggests strong binding of this polymer on solid surfaces. Fluorescence spectroscopy studies conducted to investigate the role of hydrophobic bonding using pyrene and dansyl probes showed no evidence of the formation of hydrophobic domains at talc–aqueous interface. Urea, a hydrogen bond breaker, reduced the adsorption of guar on talc to the same extent as that for guar/alumina system, in which hydrogen bond plays an important role. All of the above results suggest that one of the main driving forces for guar adsorption on talc is hydrogen bonding rather than electrostatic or hydrophobic force.

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1. Introduction

Talc is a layered hydrous magnesium silicate in which the layers are held together by van der Waals bonds. During grinding, two different surfaces are formed. Basal cleavage planes are formed by rupture of van der Waals bonds. Because the resulting planes contain no broken Si–O and Mg–O bonds, the surface is neutral and hydrophobic. However, the edges of the mineral sheets contain broken Si–O and Mg–O bonds and, consequently, charged species and the edges thus exhibit hydrophilic properties.

Guar gum is a natural nonionic polysaccharide with an average molecular weight of 100,000–2,000,000. The repeating unit of guar gum is shown in Fig. 1. Each unit contains nine OH groups. These OH groups are available for hydrogen bonding of the guar gum molecule to mineral surfaces (Mackenzie, 1980).

In the flotation of platinum bearing ores, guar gum is often used as a depressant for talceous gangue minerals. In spite of a large number of studies conducted in the past, the mechanism of adsorption of guar gum on talc is not yet well-understood. Mackenzie et al. (1986), Pugh (1989), Healy (1974), Rath and Subramanian (1997) and Rath et al. (1997) proposed that the mechanisms governing the adsorption of polymers on mineral surfaces include hydrophobic interaction, hydrogen bonding, chemical and electrostatic interactions. However the reasons for the selectivity of the adsorption of depressants on minerals has not been accounted for Steenberg (1982), Steenberg and Harris (1984) and Jenkins and Ralston (1998) proposed that the adsorption of guar gum on talc occurs mainly at the basal planes via hydrophobic force. In contrast, Rath et al. (1995) proposed that the adsorption of guar occurs through hydrogen bonding on talc edges.

The objective of the present study was to clarify the mechanistic aspects of the interactions between guar gum and talc using a combination of spectroscopic, electrostatic and adsorption measurements.

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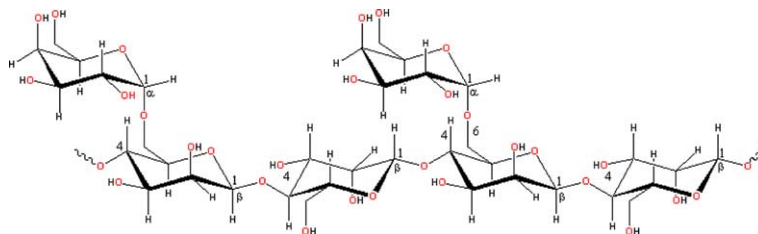


Fig. 1. The monomeric structure of guar gum.

2. Experimental

2.1. Materials

Talc sample of 150–300 microns size used for the present tests was obtained from Cytec Industries. The nitrogen BET surface area measured using a Coulter Omnisorb 100 was 2.61 m²/g after further grinding. X-ray diffraction (XRD) analysis indicated that it was a very pure sample with only a small amount of tremolite (Ca₂Mg₅(Si₄O₁₁)₂F₂). Alumina (AKP50, surface area: 10.9 m²/g) obtained from Sumitomo Chemical Co. was also used in this work.

Unmodified guar gum and dansyl-labeled Guar gum were obtained from Cytec Industries. GPC analysis showed that the weight average molecular weight of guar is 1,450,000 and the number average molecular weight is 961,000. All guar gum stock solutions were prepared by quickly adding 0.045 g of gum powder into 45 ml of vigorously stirred water and further stirring for 30 min. The solution was refrigerated overnight to ensure complete hydration or dissolution of guar gum and then filtered through filter paper (Whatman #4) to remove any undissolved impurities.

2.2. Experiments

2.2.1. Adsorption measurements

The suspensions of talc, with ionic strength adjusted to the desired level using KCl at 10% solid loading, were ultrasonicated for 30 min and then stirred magnetically for 2 h after the pH was adjusted to the desired value using HCl and KOH. Guar gum stock solution was then added to the talc suspension and left for overnight conditioning. The suspensions were then centrifuged and the supernatants pipetted out for determination of guar concentration by Total Organic Carbon Analyzer. The adsorption density of guar gum on talc was calculated from the data for initial and residual guar gum concentrations.

2.2.2. Desorption

Polymer desorption experiment is carried out following the adsorption experiment in a similar manner. The rule of mass conservation is used to calculate the dilution ratio and the residual polymer concentration

after each dilution procedure. Polymer concentration after desorption procedures is determined by Total Organic Carbon analysis and compared with the concentration calculated from the dilution ratio to obtain data on the desorption of adsorbed polymers.

2.2.3. Colorimetric method

A colorimetric method described by Dubois et al. (1956) was used in experiments wherein other organic additives, such as urea, were used. Eighty percent phenol and 5 ml 98% sulfuric acid were added to 2 ml of supernatant obtained after centrifugation. After 4 h of color development under warm conditions. UV absorbance was measured at a wavelength of 487.5 nm. Adsorption density of guar on talc (or alumina) was calculated from the difference in absorbance.

2.2.4. Electrokinetic measurements

Small amounts of talc was added to desired amounts of 10⁻³ M KNO₃ solution and ultrasonicated for 30 min, magnetically stirred for 2 h and the pH adjusted to the desired value using HCl and KOH. Finally, the guar gum stock solution was added and left for overnight conditioning. The zeta potential was then measured using a Zeta meter.

2.2.5. Fluorescence studies

Suspensions of talc at 10% solid loading were ultrasonicated for 30 min and mixed for 2 h with a magnetic stirrer. Guar gum stock solution with saturated pyrene in it or dansyl-labeled guar gum was then added to the talc suspension. The vials containing the suspensions were quickly wrapped with aluminum foil to keep the light away and left to condition overnight. Finally, the hydrophobicity of the supernatant and the solid were analyzed separately via a LS-1 fluorescence spectrophotometer (Photon Technology International).

3. Results and discussion

3.1. Electrokinetic studies

It is evident from the electrokinetic data shown in Fig. 2 that the surface of talc is negatively charged and the isoelectric point is located around pH 2.5. Above pH

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