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Article

Effect of Concentration on the Adsorption of Metallic Soaps Shea Butter onto Hematite in Aqueous Media

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Abstract: The effect of concentration on the adsorption of potassium, calcium and aluminum soaps of Shea butter onto hematite in aqueous phase was investigated as a prelude to determine the possible use of these soaps as collector reagents in metal ore beneficiation. The result shows that the most adsorbed of all the soaps with respect to concentration is potassium metal soap of the shea butter oil. The soaps containing potassium adsorbs faster and attains maximum adsorption density at highest concentration followed by the soaps containing calcium. Aluminum soap has the least adsorption with concentration but attains maximum adsorption density at a lower concentration. The level of adsorption of all the adsorbates on the surface of the adsorbent suggests that the potassium soap of shea butter oil in this study show reasonable degree of surface coverage with concentration although at certain concentration, the whole soaps reached maximum adsorption density and shows no effect with increase in concentration.

Keywords: adsorption, concentration, Shea butter soap, temperature, hematite.

1. Introduction

The attachment of molecules to the surface of a solid by adsorption is a broad subject. Adsorption

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science has exhibited great potential in many technological and industrial systems such as the filtration of impurities from liquids or gases, the bonding of reactant molecules to the solid surface of a heterogeneous catalyst, the segregation of surfactant molecules onto the surface of a liquid, and the migration of ions to the surface of a charged electrode. Metallic soaps are understood to refer to the sparingly soluble or insoluble salts of saturated and unsaturated, straight-chain and branched, aliphatic carboxylic acids with 8-22 carbon atoms. They are reaction products of saturated or unsaturated fatty acids (carboxylic acids) with alkaline, alkaline earth or transition metals [1]. Metal soaps are also known as fatty acid salts [2]. Metal soaps are composed of a metal and acid portion supplied as solutions in solvent or oil. They can be represented by the general formula (RCOO)xM, where R is an aliphatic or alicyclic radical and M is a metal with valence x. Soap molecules bear hydrophobic and hydrophilic parts which can be adsorbed selectively on the surface of the desired mineral particles to reduce wetting by water, thereby enhance their flotation. Shea butter oil botanically called Butyrospermum parkii is a soft paste of melted fat with a milky colour in solid form and brownish when melted. It has a characteristic odour. It contains fatty acid triglyceride and a high amount of unsaponifiable matter, which ranges from 2.5% to 15% [3]. This exceptionally rich vegetable extract, contains fatty acids, phytosterol and unsaponifiable matter which stimulate the skin's natural renewal process. The composition of the product depends on several criteria particularly the geographical occurrence, its botanical origin, handling of the seeds and processing e.g. drying time, ripening [4]. Shea butter oil has the following fatty acid composition-palmitic acid (C16) 8.5%, stearic acid (C18) 35.9%, oleic acid (C18) 49.9% and linoleic acid (C18) 5.3% [5]. Extraction and characterization of shea butter oil suggests the potential of the oil for various domestic and industrial applications since the observed parameters of the oil are within values obtained for similar vegetable oils such as avocado pear oil, white melon oil, palm kernel oil, rubber seed oil and castor seed oil [6]. The effect of pH on the adsorption of potassium, calcium and aluminum soaps of shea butter oil onto hematite was studied as a prelude in accessing the suitability of using these soaps as collector reagents in ore flotation. Flotation technique is often employed in the separation of solids of similar densities (between 35 µm and 100 µm) which cannot be separated by gravity using jigging and tabling [7-9].

The objective of this investigation is to determine the effect of pH on the adsorption capacity of potassium, calcium and aluminum soaps of shea butter oil on the surface of hematite and to examine the feasibility of using these soaps as collector reagents for the eventual processing of metal ores through the flotation separation technique. Adsorption and its phenomena have received a lot of attention by several investigators who reported the dependence of the process on factors such as temperature, pressure, effective surface area, pH, concentration, ionic charge, and ionic strength, nature of adsorbate and time [10-19].

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2. Materials and Methods

Ore containing samples of hematite obtained from Itakpe, Nigeria (76.9% iron) were crushed in the laboratory using jaw and roll crushers. Gravimetric method of jigging and tabling was employed in removing siliceous materials, while magnetic separation method was used in separating magnetic materials from the ore sample. Sieve analyses were performed using the British standard sieve plates to obtain sample of hematite – 70 micron. Mineralogical analysis of the ore sample was performed with volumetric and atomic absorption spectrometric (Buck scientific atomic absorption spectrophotometer - model 205A) methods of analyses. Solutions of reagents were prepared with distilled deionised water. Sodium hydroxide and hydrochloric acid solutions were used for pH adjustments. BDH chemical reagents analar grade (of not less than 98% purity) were used in this study. Determination of specific surface area (SSA) was done by the ethylene-glycol-monethyl ether (EGME) method [20].

2.1. Soap Preparation

The 50 g different types of oil (rubber seed oil, castor seed oil and shea butter) was added to each 50 mL of 30% potassium hydroxide, calcium hydroxide and aluminum hydroxide, and 30 mL of ethanol was added into each of the 600 mL beakers, then heated at 90 ^{o}C for 1 h in a water bath with vigorous stirring until creamy-pasty soaps are formed. A 50 mL of hot saturated sodium chloride solution was then added to each of the pasty soaps with vigorous stirring for short period and allowed to cool overnight. The soaps cake formed on the surface of the 'lye' were removed and air dried and stored in plastic containers [21].

2.2. Calibration Studies

The electrical conductance of 25 cm^3 soap (potassium, calcium and aluminum soaps of rubber seed oil, castor seed oil and shea butter) solutions of different concentrations were measured at 29 0C and pH 7.31, using an electronic conductivity meter (model-90 check-mate deluxe field system-corning). From the result, a calibration graph of the soap conductance was plotted against the square root of soap concentrations b ased on the Kohlrausch law equation [22]:

$$\wedge m = \wedge^{\circ} m - KC^{1/2} \quad (1)$$

where $\wedge m$ is the molar conductivity, $\wedge^{\circ} m$ is the limiting molar conductivity, C is the concentration of the solution and K is a constant

3. Result and Discussion

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Adsorption densities at varying metal soap concentrations of shea butter oil are shown in tables 1-3 below. Adsorption densities of the soap increased with increase in metal soaps concentration, for shea butter soap of potassium, calcium and aluminium, the maximum adsorption densities were 0.0029 g/m^2, 0.0028 g/m^2 and 0.0025 g/m^2 respectively. Beyond this value adsorption remain constant and independent of soaps concentration. The explanation is that adsorption densities increase with increase concentration of soaps until a maximum adsorption density is attained at a certain concentration where all adsorption sites must have been occupied by the adsorbates. However, comparing adsorption of the different metal soaps, it is observed that the metal soap of K has the greatest adsorption; the adsorption is also uniform given it a straight plot in fig 1. Ca^{++} metal soap also has a uniform adsorption with concentration and also attains adsorption density maximum at a higher concentration value than Al^{3+} metal soap. This could be explained by the size to charge ratio on the metal. The higher the charge on the metal the lower the adsorption rate with respect to concentration, and the faster the adsorption sites are occupied so is observed that for Al^{3+} and Ca^{++} the adsorption sites were occupied quickly so that maximum adsorption density was attain faster and at a lower concentration value. Once this maximum adsorption density is attained it makes change in concentration to have insignificant effect on the adsorption density.

Table 1: K^+ Shea butter oil soap adsorption density at different concentrations for Hematite

Initial conc. of K^+ shea butter oil soap. g/liter	Equilibrium conductance (µ S/cm)	Equilibrium K^+ shea butter oil soap conc. (g/L)	Soap adsorbed onto hematite per gram	Adsorption density onto hematite surface g soap/m^2
0.2	84	0.0578	0.1422	0.0012
0.4	139	0.1512	0.2488	0.00210
0.6	155	0.3038	0.2962	0.00250
0.8	163	0.4671	0.2329	0.00281
1.0	191	0.6564	0.3436	0.00290
1.2	216	0.8564	0.3436	0.00290
1.4	235	1.0564	0.3436	0.00290

Table 2: Ca^{++} Shea butter oil soap adsorption density at different concentrations for Hematite

Initial conc. of Ca^{++} shea butter oil soap. g/liter	Equilibrium conductance (µ S/cm	Equilibrium Ca^{++} shea butter oil soap conc. (g/L)	Soap adsorbed onto hematite per gram	Adsorption density onto hematite surface g soap/m^2
0.2	75	0.0690	0.1339	0.00113
0.4	128	0.1220	0.2488	0.00210
0.6	152	0.3216	0.2784	0.00235
0.8	178	0.5097	0.2903	0.00245
1.0	200	0.6682	0.3318	0.00280
1.2	228	0.8682	0.3318	0.00280
1.4	252	1.0682	0.3318	0.00280

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Table 3: Al^{3+} Shea butter oil soap adsorption density at different concentrations for Hematite

Initial conc. of Al^{3+} shea butter oil soap. g/liter	Equilibrium conductance (µ S/cm	Equilibrium Al^{3+} shea butter oil soap conc. (g/L)	Soap adsorbed onto hematite per gram	Adsorption density onto hematite surface g soap/m^2
0.2	201	0.1763	0.0237	0.0002
0.4	250	0.2815	0.1185	0.0001
0.6	312	0.4223	0.1777	0.00150
0.8	340	0.5275	0.2725	0.00230
1.0	410	0.7038	0.2962	0.00250
1.2	450	0.9038	0.2962	0.00250
1.4	480	1.1038	0.2962	0.00250

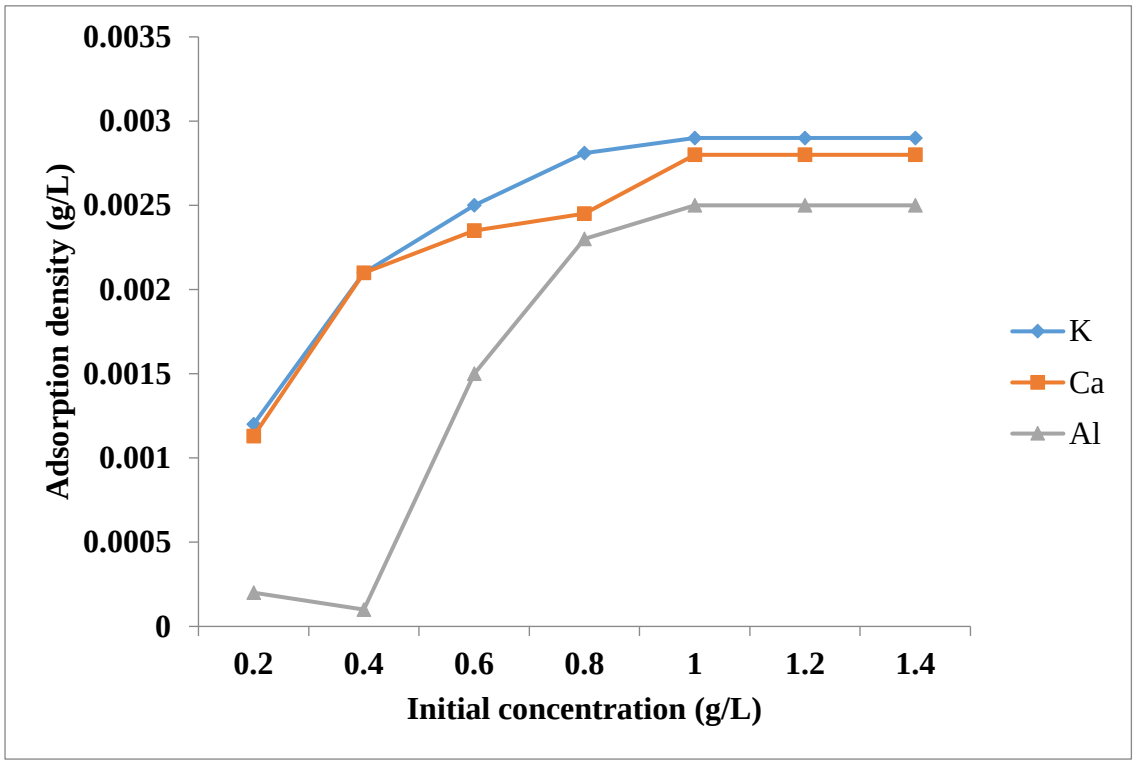

Fig 1: Shows that the adsorption densities for shea butter soaps increase up to a maximum at a concentration of 1g/l for all the soaps of K^+, Ca^{++} and Al^{3+}.

4. Conclusion

From this study it can be concluded that adsorption densities increase with increase concentration of soaps until a maximum adsorption density is attained at a certain concentration where all adsorption sites must have been occupied by the adsorbates. We can therefore conclude that the % of adsorption and by extension the adsorption density is influenced by the predominant size to charge ratio of the ions.

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