Interaction Of Cationic Collector At Mineral/Water Interface And Its Efficacy On The Beneficiation Of Iron Ores

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ABSTRACT: The adsorption of cationic amine collector on quartz, alumina and hematite was studied with a view to understand the selective separation of quartz from iron ores by flotation. The mechanism of amine adsorption at mineral/water interface was established by FT-IR, zeta-potential measurements and atomic force microscopy (AFM). The amine molecules are adsorbed on quartz surface by electrostatic and hydrogen bonding mechanisms. The AFM data has revealed multi-layers of amine with an average profile height of 32 nm. The conversion of hydrophilic mineral surface to hydrophobic was visualized by contact angle measurements. Good correlation between adsorption, zeta-potential, contact angle and atomic force microscopy was observed. Flotation experiments were conducted to look at the selective removal of quartz from iron ores. The results revealed that the quartz/silicates could be effectively removed from iron ores if liberated in coarse size. The flotation recovery was observed to be drastically affected in the case of finely disseminated low grade ores.

Keywords: Flotation, cationic collector, zeta-potential, Hydrophobicity, FTIR Spectroscopy, Atomic force microscopy, iron ore, quartz, multilayer adsorption.

NTRODUCTION

The utilization of low grade finely disseminated iron ores and the recovery of iron values from tailing ponds is becoming essential due to rapid depletion of high grade reserves. The iron ores in the form of siderite, limonite, goethite, taconite and banded forms of iron are considered as potential resources. The conventional process flow-sheets consisting of washing, jigging, gravity separation and magnetic separation are not adequate to beneficiate such complex ores. The flotation is considered more suitable process to recover iron values from such low grade ores. Depending on the liberation characteristics of the gangue minerals and their volume fraction, different routes namely direct flotation, reverse flotation, selective dispersion and flocculation and flocculation and flotation were devised. The iron bearing minerals are floated using oleic acid/oleate as collector in direct flotation; whereas quartz and silicate minerals are floated using cationic/anionic collector in reverse floatation. Selective flocculation, desliming and cationic flotation was found to be effective in the case of finely disseminated oxidized teconites.

Direct flotation of iron oxides using anionic collectors such as oleic acid, linoleic acid and their combination, petroleum sulfonates were extensively tried in the early days of flotation [1], [2], [3], [4]. The direct flotation is supposed to be attractive in the case of low grade ores such as banded hematite quartzite (BHQ), banded hematite jesper (BHJ) and banded magnetite quartzite (BMQ) where the Fe content varies between 25-35%. In spite of extensive research, perfect separation of hematite from quartz could not be accomplished [5]. Alternatively, flotation of quartz from iron ore was attempted using sodium oleate as collector, starch as depressant for iron minerals and CaO as an activator for quartz flotation (reverse anionic flotation). The presence of siderite ($FeCO_3$) was found to pose severe problems in achieving the desired grade by reverse anionic flotation. To overcome this problem, two stage-flotation was suggested [6] wherein siderate was floated in the first stage using sodium oleate at neutral pH. After siderite separation, the silica was activated and separated using $CaCl_2$ as activator, sodium oleate as collector and starch as depressant. The chemistry behind silica activation was explained by adsorption and zeta-potential measurements [7]. However, both grade and recoveries were found to be seriously affected in the presence of hydrolysable cations like Ca^{2+} and Mg^{2+}. The up-gradation of lean ores by magnetic separation prior to flotation was suggested to enhance the recoveries [8].

The reverse flotation route using cationic collector developed by U.S. Bureau of Mines, was widely practiced in USA and in European countries. Initially, fatty amines were tried as collectors and the same were subsequently replaced by more efficient ether amines. The effectiveness of various ether amines for iron ore beneficiation was reviewed and recommended partial substitution of amine with non polar oils [1]. It was reported that iron ore concentrates assaying less than 1% silica could be obtained from iron ore tailings/rejects with iron recoveries of around 60% [9]. The effect of amine type and pH on quartz flotation was studied and found that the ether di-amine was more effective to float medium and coarse quartz, while ether monoamine is suitable in the case of fine quartz. It was also observed that the flotation of coarse particles is enhanced by the presence of fine particles in the system [10]. Different amine collectors were evaluated on three different samples of magnetite taking coco primary amine acetate as standard for comparison. The oleyl and tallow di-amines were found to display better selectivity compared to other fatty amines. The trimethyl alkylammonium chloride was found to be more selective but less efficient than primary and di-amines [11], [12]. In most of the cases, mono amine and di-amine are blended in certain proportion for thorough separation of silica from iron ore. Mixed anionic and cationic collector scheme was suggested to enhance the hydrophobic character and in turn the floatability [13]. The flotation behavior of quartz in alkaline water was studied and observed that the floatability of quartz decreases with increase in the alkalinity of the process water [14]. Beneficiation of alumina rich Indian iron ore slimes by flotation [15] and removal of specific impurities like alumina, phosphorous in addition to the recent developments in flotation equipment were reviewed and reported [16]. Flotation column was found to be very effective to improve the quality and recovery of iron ore concentrates [17], [18], [19].

The present study was aimed to unravel the mechanism of amine adsorption on hematite, alumina and quartz. The fundamental knowledge thus gained was utilized to arrive at the separation of quartz from low grade ores.

2. EXPERIMENTAL MATERIALS AND METHODS

2.1 Materials:

Pure mineral samples of hematite, quartz and alumina were collected from the iron ore mines of Bellary-Hospet region. Fatty amine collectors were obtained from M/s Somu Organochem pvt ltd., Bangalore and Akzo nobel, Sweden. All the other chemicals used are of analytical grade. The reagent solutions were prepared in double distilled water.

2.2 Chemical analysis:

The chemical composition of various fractions of flotation was carried out by standard procedure [20]. The sample was dissolved in hydrochloric acid and baked for dehydration of silica. It was subsequently filtered and silica was determined by volatilization with hydrofluoric acid. The insoluble residue was fused with sodium carbonate, extracted with hydrochloric acid and added to the main filtrate obtained during first filtration. The solution was made up to a definite volume and reserved for the analysis of Fe and Al_2O_3. From this solution, an aliquot of sample was taken and diluted. The diluted solution of iron is reduced to ferrous state by stannous chloride and titrated with standard potassium dichromate solution in the presence of barium diphenylamine sulphonate indicator. For the determination of alumina, an aliquot of the solution was acidified with hydrochloric acid and 25 ml of EDTA was also added. The pH was adjusted to 5.5 with ammonium hydroxide and hydrochloric acid and the solution was allowed to boil for 15 minutes. After the solution was cooled, 25ml acetic acid -ammonium acetate buffer solution was added followed by few drops of xylenol orange indicator. The solution was titrated using zinc acetate solution. The colour change from lemon yellow to purple indicates the end point. From the difference of titration value, the Al_2O_3 % was determined

2.3 BET Surface area:

The specific surface area and porosity was determined by BET analyzer (Brunauer, Emmett and Teller) Model ASAP 2020 supplied by Micromeritics, USA.

2.4 Contact angle measurement:

Contact angle of the mineral powders was determined by sorption measurement using Kruss Tensiometer, model- K 100. The contact angle of the powder sample was arrived from the

Washburn equation incorporated in the software. When a column of powder bed is in contact with liquid, the pores between the particles act like small capillaries and the rise of liquid is measurable. The capillary constant in the Washburn equation was determined using n-hexane. The mineral sample was evenly packed in the sample tube each time. Measurement was repeated at least 3 times and an average value was reported.

2.5 Zeta potential Measurements:

The zeta potentials were measured using a Zeta Meter 3.0+, Zeta Meter Inc, USA. A suspension of 0.01g/L of mineral (ground to -10µm) was prepared in 1×10^{-3} M KCl electrolyte solutions. After adjusting the pH to the desired value, the suspension was conditioned for half an hour at 25 ° C. The conditioned slurry was transferred in to the electrophoresis cell for measurements. The average value of the zeta potential of the five readings with standard deviation of less than 1 unit was reported as the final value.

2.6 Adsorption Studies:

The cationic surfactant (amine) was estimated by standard colorimetric procedure [21]. Required quantity of the mineral sample was taken in Erlenmeyer flask and known quantity of amine solution (pH adjusted) was added and thoroughly equilibrated at 25 ° C. After equilibration time of half an hour, the concentration of un- adsorbed amine was determined. The amount of amine adsorbed was arrived by subtracting from the initial amine concentration.

2.7 FT-IR Spectroscopy:

The FT-IR spectra of the samples were recorded using Perkin-Elmer spectrophotometer. 10 mg of the dried sample was dispersed in 200 mg of spectroscopic grade KBr and 40 scans were collected for each spectrum at a resolution of +/- 4 cm^{-1}.

2.8 Surface characterization:

Scanning probe microscope, model 5500 series, Agilent Technologies, USA was used for surface characterization. Measurements were made in contact mode using NSC 15 Cantilever and Picoview 1.12.2 software. Silica vafar samples were cut to the size of the sample holder and immersed in the aqueous solutions and subjected to ultrasonication treatment for 30 minutes to remove the adhered slimes. The fresh sample was equilibrated with amine solution for 30 minutes and dried in vacuum desiccators. The dried samples were examined by scanning probe microscope.

2.9 Flotation tests:

Batch scale flotation tests were conducted in D-12 Denver flotation machine. The flotation tests were conducted at 25% solids at an impeller speed of 1200 rpm. The pH was adjusted prior to the addition of depressant, activator and collector. The conditioning time of 3 minutes was maintained for each reagent. The floated fraction and residue was collected separately and analyzed.

3.0 RESULTS AND DISCUSSION

3.1 Adsorption studies: The interaction of collector molecules at mineral/water interface is an important criterion for flotation. Hence the adsorption of fatty amine on hematite, quartz and alumina particles was studied at different pH conditions at an initial amine concentration of 15 ppm. From the results shown in Fig.1, it is apparent that the fatty amine adsorbed on all three minerals but with varying densities. Adsorption on quartz is high ($17x10^{-5}$ g/m^2) compared to hematite and alumina. Low adsorption density of around 5x10^{-5} g/m^2 on alumina and less than 2x10^{-5} g/m^2 on hematite clearly reflects its weak interaction on hematite and alumina. It is also evident that the variation in adsorption density is very marginal in the entire pH range of 4.0-11.0. The mechanism of fatty amine interaction at mineral / water interface can be explained by considering the surface species of the mineral and fatty amine at different pH conditions.

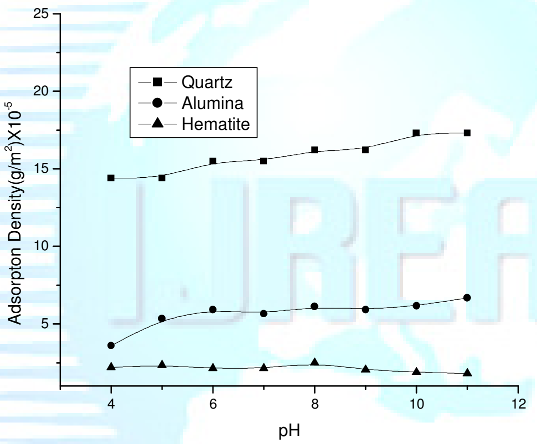


Fig 1: Adsorption behavior of amine on quartz, alumina and silica

From the solution chemistry of amines, it is known that amine exist as ammonium ion ($R\text{-}NH_3^+$) between pH 3.0-10.5. When the quartz particles are in equilibrium with aqueous solution, three different hydroxylated sites are formed depending on the pH of the solution. In acidic pH of below 3.0, the quartz surface is dominated by positive $=SiOH_2^+$ species where as $=SiO^-$ species will be prevelent in the alkaline pH. The quartz surface exhibit neutral character due to $=SiOH$ in the pH range 4.0-8.0. The details of species distribution diagram of quartz and fatty amine are discussed in the previous work [22]. The adsorption of fatty amine in acidic pH can be interpreted due to the following

$$=SiOH{-}{-}{-}H_2N{-}R \rightleftarrows =SiO{-}{-}H_3N^+{-}R \qquad (1)$$

The interaction of molecular amine with silanol can be realized with the hydrogen of amino group bonded to oxygen atom of silanol group. The ammonium group is formed as a result of deprotonation/charge transfer. The above equilibrium between quartz surface and amine can be expected at the interface once the molecular amine appears at the surface corresponding to hemimicelle concentration [23]. The adsorption of positively charged ammonium ion on negatively charged quartz is attributed to electrostatic interaction as represented in equation 2.

$$=SiO^- + R{-}NH_3^+ \longrightarrow SiO^-.\ R{-}NH_3^+ \qquad (2)$$

Thus the adsorption of amine on quartz takes place both by electrostatic and hydrogen bonding mechanisms.

3.2 FTIR Study: The adsorption of fatty amine on quartz, alumina and hematite was also studied by Fourier transform infrared (FTIR) spectroscopy. The FTIR spectra of pure amine, quartz equilibrated with 100 ppm of amine, hematite equilibrated with 100 ppm of amine and alumina equilibrated with 100 ppm of amine are shown in Fig 2. The broad band around 3387 cm^{-1} and 1634 cm^{-1} in the spectrum of amine could be interpreted to N-H stretching and bending vibrations. The sharp and intense bands at 2922 cm^{-1} and 2855 cm^{-1} are assigned to asymmetric and symmetric stretching vibrations of $-CH_2$ group. The medium band at 1461 cm^{-1} may be ascribed to asymmetric bending of $-CH_3$ group and also to scissoring, symmetric bending of $–CH_2$. The low intensity band at 1116 cm^{-1} may be attributed to C-O-C stretching vibrations. The detailed interpretation of various bands related to amine is discussed elsewhere [24]. The broad band around 3432 cm^{-1} and sharp bands at 2923 cm^{-1} and 2852 cm^{-1} are seen in all the spectra recorded after equilibration of minerals with amine solution. The appearance of these bands on mineral samples after equilibration with amine reveals the adsorption of amine on all minerals. The broad band around 1070 cm^{-1} in the spectrum of quartz may be assigned to the Si-O

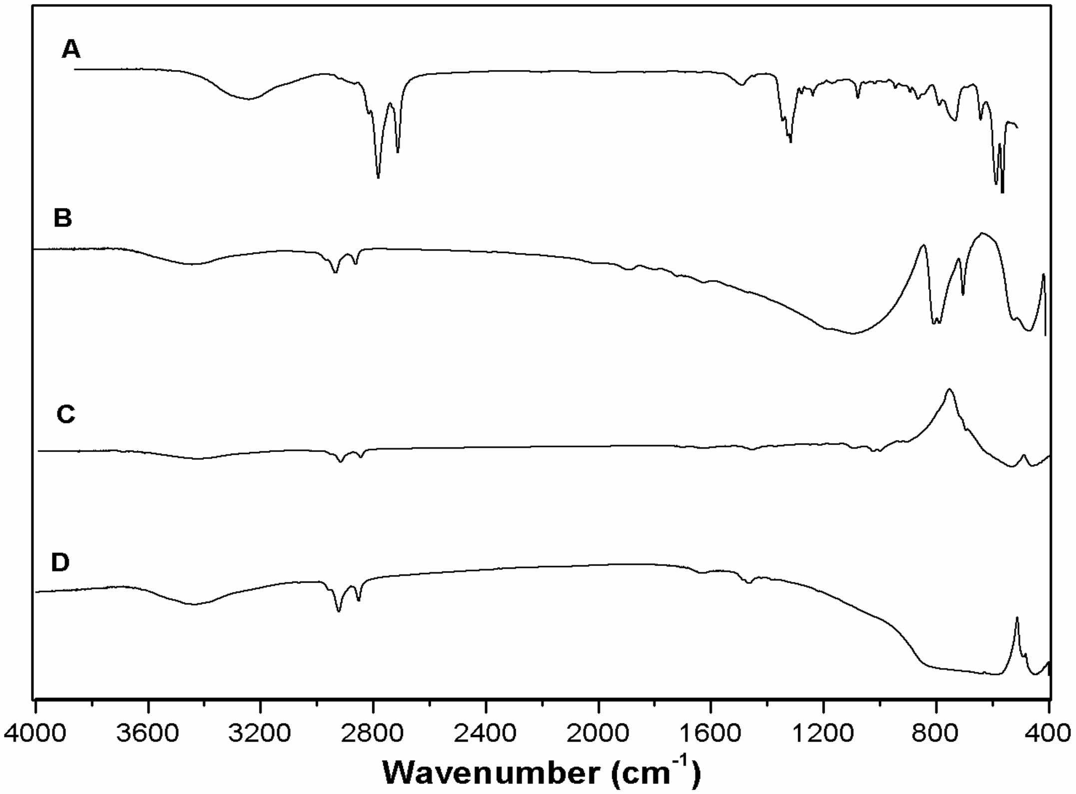


Fig 2: FTIR Spectra of a) pure amine, b) quartz equilibrated with amine, c) hematite equilibrated with amine, d) alumina equilibrated with amine

asymmetric stretching. The high intensity bands at 798 cm^{-1} and 694 cm^{-1} are attributed to Si-O The FTIR spectrum of hematite exhibited strong and intense bands at 540 cm^{-1} and 467 cm^{-1}. These bands are interpreted due to Fe-O stretching vibrations which are characteristic of hematite. The sharp and low intensity bands in the region of 3600-3700 cm^{-1} shows the presence of surface –OH groups. Thus the adsorption of amine is evident on quartz, hematite and alumina.

3.3 Zeta-potential measurements: The zeta potential of pure quartz and quartz in the presence of amine solution were measured with respect to pH and the results are presented in Fig 3. The iso electric point (iep) of quartz observed around pH 2.5 is consistent with the value reported earlier. The zeta potential of quartz was observed to be positive in the presence of fatty amine up to pH 10.0 (Fig.3). The reversal of charge may be accounted to the presence of ammonium ion on quartz surface either bound by hydrogen bonding as represented in equation.1 or adsorption of amine in the second layer with the hydrocarbon tails oriented towards the quartz surface and charged amine head group projecting towards solution.

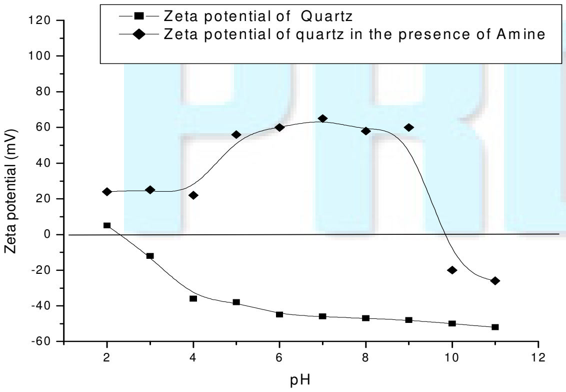
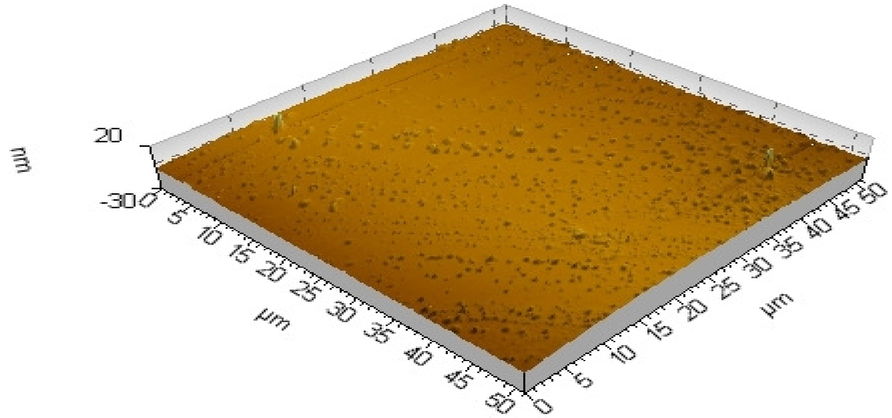


Fig 3: Zeta potential of quartz in the presence and absence of fatty amine

The adsorption mechanism of fatty amine on quartz surface at different concentrations and pH's beyond hemi micelle concentrations was elucidated by FT-IR and quartz crystal microbalance with dissipation techniques [26]. Three types of adsorption mechanisms: (1) single ion adsorption at lower concentration; (2) surface micelle formation at intermediate concentration; and (3) multilayer adsorption due to precipitation of molecular amine at higher concentration. The recent study using quartz crystal microbalance with dissipation has indicated different adsorption processes at pH 6.0 and 9.5. At lower dodecylamine concentrations of 0.07-0.11mM and at pH 6.0, ammonium ion molecules are electrostatically held at the silicate water interface as thin but rigid adsorption layer (physisorption). At pH 9.5, neutral molecules of dodecylamine were co adsorbed with dodecylammonium ions. It may be due to the high concentration of molecular amine at pH 9.5.

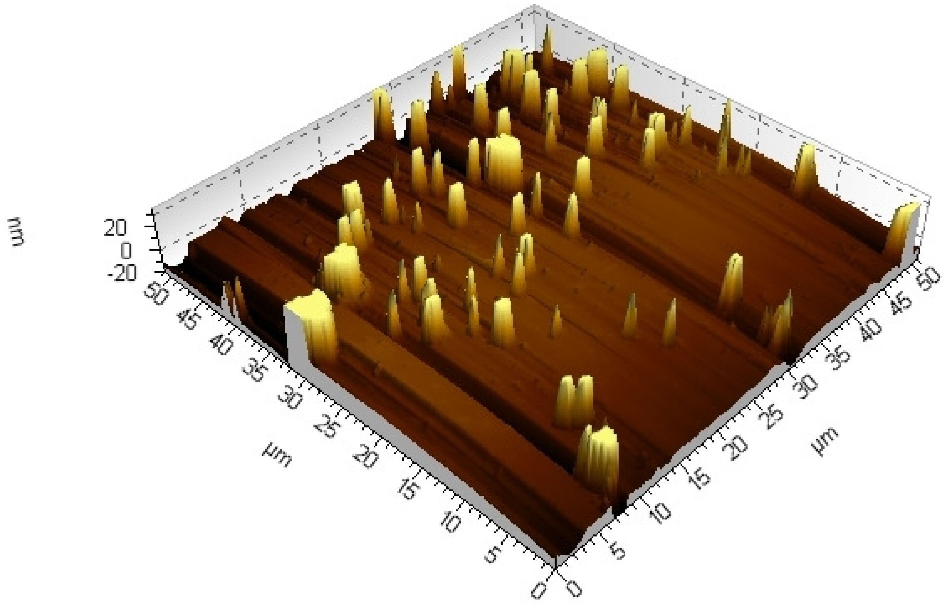
The adsorption of fatty amine on neutral =FeOH and =AlOH sites and also on negatively charged FeO^- and AlO^- can also be explained by the similar mechanisms discussed above.

3.4 Atomic Force Microscopy: The three dimensional (3D) micro-topography of the quartz equilibrated with 1.0 ppm of fatty amine and the corresponding height profile shown in Figs.4a reveals that the surface is uniform with mean height of roughness profile as 1.45 nm. The 3D view of the quartz equilibrated with 100 ppm of amine and its height profile are also shown in Figs 4b. The adsorption of amine is evident from the pillar like structures grown on the quartz surface. The picture also reveals that the adsorption of amine is prominent on the cracks and edges which are considered highly energetic. The average height of adsorbed layer was observed to be 32 nm. If the adsorption is restricted to monolayer, the height profile would have been less than 3 nm. Since the height of adsorbed layer is 32 nm, it could be concluded that the amine is adsorbed as multilayers at high amine concentration of 100 ppm. The multilayers of adsorbates are held together by Van der Waals force associated with hydrocarbon chains. Similar adsorption behavior was observed between octadecylammonium chloride and quartz [27].



Amplitude parameters- Roughness profile	
Maximum peak height (Rp)	2.19 nm
Maximum valley depth (Rv)	0.672 nm
Maximum height (Rz)	2.86 nm
Mean height (Rc)	1.45 nm
Total height (Rt)	2.86 nm
Arithmetic mean deviation (Ra)	0.351 nm
Root mean square (Rq)	0.513 nm
Skewness (Rsk)	2.10
Kurtosis (Rku)	8.15
Material ratio parameters- Roughness profile	
Relative material ratio (Rmr)	100%
Height difference Roughness (rdc)	0.519 nm

Fig 4a: 3D & Roughness profile of quartz surface at low amine concentration (1.0 ppm).



Amplitude parameters- Roughness profile	
Maximum peak height (Rp)	24.2 nm
Maximum valley depth (Rv)	10.7 nm
Maximum height (Rz)	34.9 nm
Mean height (Rc)	31.1 nm
Total height (Rt)	34.9 nm
Arithmetic mean deviation (Ra)	7.81 nm
Root mean square (Rq)	9.22 nm
Skewness (Rsk)	1.03
Kurtosis (Rku)	2.96
Material ratio parameters- Roughness profile	
Relative material ratio (Rmr)	100%
Height difference Roughness (rdc)	15.2

4b: 3D & Roughness profile of quartz surface equilibrated with 100 ppm of amine

From the AFM images of silica surface, the adsorbed amine was seen in the form pillars with multi-layers of amine. The AFM images shown in Fig 4b are consistent with the theory proposed by Novich and Ring [28]. The reason why the amines do not form a close-packed monolayer on silica surface was explained in terms of cross sectional area of the amine and the area around the negative charged oxygen hexgon on the silicate surface [23].

3.5 Flotation studies: Different iron ore samples analyzing 40-65 % of Fe and 3.8-39.0% of silica was obtained from various sources. Each sample was ground to below 45 microns for liberation of values from gangue minerals. Flotation tests were conducted using Sokem 524C as collector. Initially the pH of the mineral slurry was adjusted to 9.0-9.5 using sodium hydroxide and conditioned with starch solution to depress the flotation of iron minerals. Addition of starch was found to be essential as the amine was seen adsorbing on hematite particles. The contact angle measurements of quartz and hematite equilibrated with amine solution of 100 ppm were conducted to know the extent of hydrophobicity. The results presented in Fig 5 reveal that both quartz and hematite particles have became sufficiently hydrophobic after the amine adsorption. The hydrophobic character of quartz particles is slightly higher than the hematite particles.

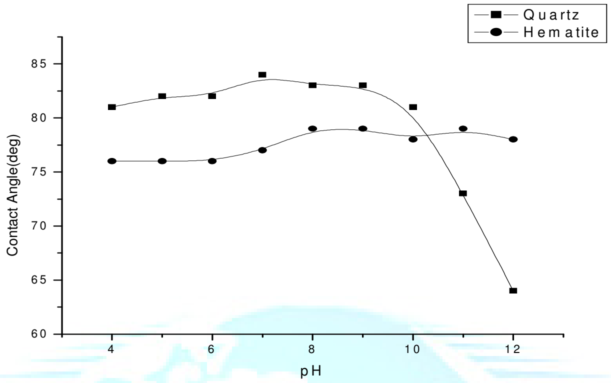


Fig 5: Contact angles of hematite and quartz equilibrated with Sokem 524C solution

Initial Grade and composition				Reagent Consumed (kg/t)	Final Grade and composition				Recovery (%)
Fe%	Fe_2O_3 (%)	SiO_2 (%)	Al_2O_3 (%)		Fe (%)	Fe_2O_3 (%)	SiO_2 (%)	Al_2O_3 %	
40.55	57.98	39.04	1.72	0.60	63.00	93.09	7.04	0.61	31.16
54.44	77.85	6.77	6.7	0.40	58.89	84.21	3.64	5.01	33.36
43.87	62.73	30.87	1.67	0.40	62.45	89.3	1.40	1.32	36.09
61.38	87.77	7.15	1.40	0.40	68.51	97.96	0.85	0.18	41.90
55.15	78.87	17.34	4.4	0.50	62.30	89.10	2.52	1.82	51.25
60.43	86.41	6.88	3.26	0.40	66.37	94.91	2.97	1.94	53.85
55.56	79.45	10.86	2.92	0.40	64.73	92.56	3.16	0.49	54.41
64.37	92.05	3.84	1.59	0.20	66.35	94.88	1.67	1.75	65.66
65.33	93.42	4.82	1.30	0.20	69.0	98.67	1.07	0.22	67.60
59.82	85.54	3.95	3.06	0.60	64.10	91.66	1.85	2.2	69.11
59.93	85.70	6.13	3.25	0.40	64.00	91.52	2.18	2.29	73.5

Table 1: Effect of initial grade on iron recovery

While the contact angle of hematite remains same throughout the pH range of 4.0-12.0, the contact angle of quartz drastically decreases beyond pH 10.0. Flotation studies conducted by earlier researchers have revealed that the 100 % surface coverage of dodecylamine is required for the complete flotation of quartz and hematite at pH 9.8 whereas just 1% surface monolayer is enough at pH 5.0 [29]. But flotation at pH 5.0 is not advisable due to poor dispersion that affects quality of iron ore concentrate. Whereas above pH 9.0, both hematite and quartz particles are negatively charged and well dispersed.

Flotation tests were conducted by adding the amine in stages till the required grade is obtained. The results of the final products were presented in Table 1. It is evident that the concentrates suitable for iron making can be produced even from the low grade ores containing 39% of quartz provided quartz is thoroughly liberated from the iron ore. While the iron ores with low quartz (3-5%) can be easily beneficiated with reasonable yield, the iron recoveries are drastically decreased in the case of low-grade ores containing high quartz. The reagent dosage also increases with quartz content of the feed grade but variation is comparatively less. It is apparent that the final iron recoveries are inversely proportionate to the quartz content in the feed. It was pointed out that the presence of molecular amine in solution is detrimental to hematite flotation. Starch adsorb specifically both on quartz and hematite. However starch adsorbed on quartz will desorb in alkaline medium in the presence of alkylammonium salt [30].

Table 2: Feed samples assay: Fe=47.20%; SiO_2=26.98%; Al_2O_3=1.48%; LOI=2.89%

Conditions: Starch=1kg/t; Slurry pH=9.5-10.0

Amine (kg/t)	% Weight of Sink	Fe %	Fe_2O_3 %	SiO_2 %	Al_2O_3 %	LOI %	Fe Recovery %
Commercial name of amine: Lilaflot-811M							
0.15	85.80	53.8	76.93	17.48	1.93	3.35	97.80
0.20	75.00	59.6	85.23	8.59	2.01	3.78	94.70
0.25	66.90	63.2	90.38	4.33	0.94	4.33	89.58
0.30	63.10	63.06	90.18	3.57	0.84	3.57	84.30
Commercial name of amine: Sokem 524C							
0.10	73.0	60.6	86.66	7.36	0.94	3.62	97.80
0.15	67.1	62.9	89.95	4.04	0.67	3.83	94.70
0.20	67.4	63.4	90.66	3.77	0.59	3.77	89.58

The scenario is found to be different in the case of iron sands where quartz is thoroughly liberated and separated from iron particles at coarse size of 150 microns. Two iron ore samples containing 23% and 27% of quartz were beneficiated using two different amine collectors namely Lilaflot-811M and Sokem 524C and the results are presented in Tables 2-3. The iron ore concentrates assaying above 63% of Fe can be obtained with a recovery of above 85%.

Table 3: Feed Samples Assay Fe=49.80%; SiO_2=23.72%; Al_2O_3=1.38% LOI=2.55%

Conditions: Starch=1kg/t; Slurry pH=9.5-10.0

Amine (kg/t)	% Weight of Sink	Fe %	Fe_2O_3 %	SiO_2 %	Al_2O_3 %	LOI %	Fe Recovery %
Commercial name of amine: Lilaflot-811M							
0.05	87.9	55.1	78.79	16.12	0.89	2.78	98.58
0.10	74.4	61.8	88.37	6.74	0.49	3.23	92.32
0.15	67.8	63.8	91.23	3.55	0.57	3.30	86.86
Commercial name of amine: Sokem 524C							
0.05	76.00	61.40	87.80	7.00	0.52	3.34	93.70
0.10	67.00	64.20	91.81	3.64	0.42	3.66	86.37
0.15	60.40	64.8	92.66	2.15	0.62	2.15	78.59

Thus the iron ores completely liberated are highly responsive to perfect separation where as un-liberated iron silicates are highly complex and less responsive to flotation. Low recovery in the case of slimes could be related to physicochemical factors. Fine particles typically exhibit slow kinetics owing to decreased particle bubble collisions. To improve the overall recovery, magnetic separation was suggested prior to flotation. Adoption of column flotation, Jameson cell, selective flocculation and flotation and improvements in reagent regime were suggested to increase the grade and recovery of iron ores. From the economic point of view, direct anionic flotation of iron minerals should be attractive to process finely disseminated low grade ores and to recover iron values from tailing ponds. Most of the laboratory investigations indicated that the flotation of iron oxides either with anionic (fatty acids) or amphoteric collectors (sarcosinates and sulphosuccinamates) yield concentrates with high silica content. The effectiveness of sodium silicate as depressant for quartz and silicates is poor mainly due to slime coating in iron oxide-oleate system. The potential of hydroximate and other chelating agents as collector has not been explored due to their high cost. The viability of reverse flotation using cationic collector appears to be excellent even in the case where the volume of quartz / silica is high.

SUMMARY AND CONCLUSIONS

The effectiveness of cationic amine collector for the selective separation of quartz from hematite was investigated by adsorption, contact angle, zetapotential measurements and flotation studies. The following conclusions were drawn based on the study.

1) The amine was found to adsorb not only on quartz but also on other minerals like hematite and alumina present in iron ore. The adsorption of cationic amine on quartz was found to proceed both by electrostatic interaction and hydrogen bonding. The positively charged amine molecules were held to negatively charged quartz by electrostatic interaction. The neutral amine molecules are bonded to neutral quartz surface by hydrogen bonding. The adsorption of amine in the second layer with the hydrocarbon tails oriented towards the surface and charged amine head group projecting towards solution was substantiated by zeta-potential measurements.
2) The precipitation of amine as micelle at the quartz/water interface at high amine concentration was confirmed by atomic force microscopy.
3) Iron ore concentrates assaying above 63% Fe can be produced even from the low grade ores containing 38% quartz by reverse flotation using cationic collector. The recovery of iron values was found to vary between 35-70% depending on the % of silica, liberation size and other complexities.
4) The reagent dosage also increases with quartz content of the feed grade but variation is comparatively less.

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