Cationic Flotation of Silica From Magnetic Iron-Ore Concentrates

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Abstract

Twelve cationic, amine-salt silica-collectors were evaluated on three samples of magnetic iron-ore concentrate. Coco primary amine acetate was used as the standard of comparison. Lauryl primary amine acetate is somewhat more efficient in collecting silica than the standard, and equally selective. Tallow primary amine acetate is equally selective and somewhat less efficient than the the standard. Coco diamine is more selective and somewhat more efficient than the standard. Oleyl and tallow diamines are more selective and somewhat less efficient than the standard. Trimethyl alkyl ammonium chloride compounds are more selective but less efficient than primary amines and diamines. Selectivity, in general, is inversely proportional to efficiency (silica pulling strength). Strong collectors, in other words, tend to float small amounts of iron along with the silica. Finely ground (90% less than 325 mesh or finer) magnetic concentrates with iron and silica almost completely liberated are highly responsive to upgrading. Concentrates of the same fine mesh size but containing unliberated iron-silicate are less responsive.

Introduction

Cationic flotation, although relatively new in the iron-ore industry, has been used on a large scale for many years in the phosphate, feldspar and beach-sand industries.

Saturated primary amines with chain lengths of 12 and 14 carbon atoms tend to be more efficient than the saturated C_{10}, C_{16} and C_{18} homologs for floating silica from phosphate. Amines that contain monounsaturated C_{18} (oleyl) along with saturated C_{16} and C_{18} carbon chains are almost as efficient as the C_{12} and C_{14} amines for this purpose (1). Mixed alkyl groups of this type occur naturally in tallow. Primary amines with tallow derived alkyl groups therefore have found extensive use in phosphate and feldspar applications. Tallow diamine, as well as tallow primary amine, is used commercially in floating silica from beach-sand. Test data that follow indicate that these same reagents effectively float silica from iron ore.

Ore

Three samples of magnetic iron ore concentrate from the Great Lakes region were used in this study.

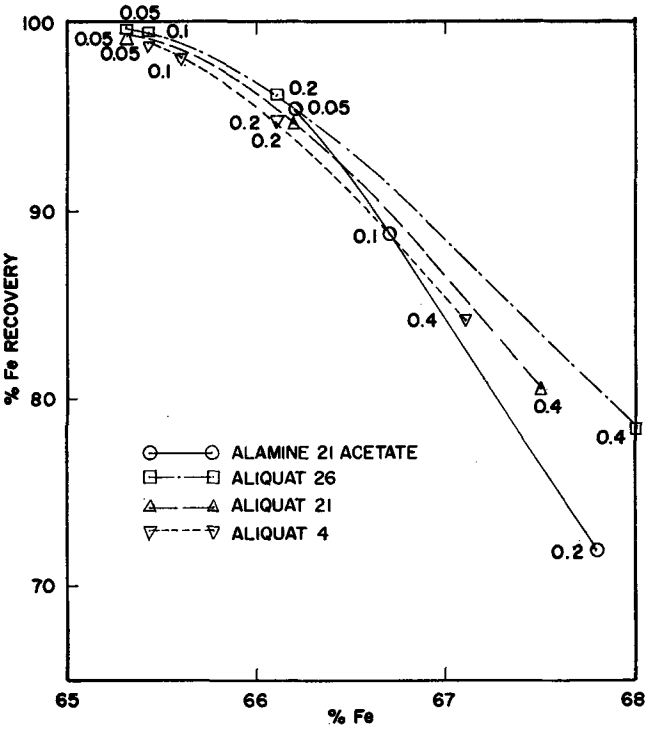

FIG. 1. Grade recovery, ore: 8.0% SiO_2, 65.2% Fe.

Unliberated iron-silicate was present in one of the ores. The iron-silicate was almost completely liberated (or unlocked) in the other two. All of the ore samples were ground to 90% less than 325 mesh or finer.

Flotation Procedure

The magnetic iron ore concentrate was in the form of a wet filter-cake. Each flotation test was run with a 600 g charge (dry wt.) of filter-cake diluted with water to 25% solids in a Fagergren laboratory flotation cell. After the amine had been added and conditioned for 1 min in the flotation cell, one drop of pine oil frother was added and conditioned for 30 sec. After conditioning, the pulp was floated for 5 min with continuous removal of the froth. Flotation was carried out at a natural pH which ranged between 6.8 and 9. The cell product (concentrate) and the froth product (tailing) were filtered, dried and analyzed. The rougher-float only was run.

TABLE I
Chemical Structure[a]-Silica Collectors

Collector	Description	Formula
Alamine 21 acetate	Coco primary amine acetate	$[RNH_3^+][CH_3COO^-]$
Alamine 4 acetate	Lauryl primary amine acetate	$[RNH_3^+][CH_3COO^-]$
Alamine 26 acetate	Tallow primary amine acetate	$[RNH_3^+][CH_3COO^-]$
Diam 21 diacetate	N-coco 1,3 propylene diamine diacetate	$[RNH_2^+(CH_2)_3NH_3^+][2\ CH_3COO^-]$
Diam 26 diacetate	N-tallow 1,3 propylene diamine diacetate	$[RNH_2^+(CH_2)_3NH_3^+][2\ CH_3COO^-]$
Diam 11 diacetate	N-alkyl 1,3 propylene diamine diacetate	$[RNH_2^+(CH_2)_3NH_3^+][2\ CH_3COO^-]$
Aliquat 21	Trimethyl coco ammonium chloride	$[R(CH_3)_3N^+]Cl^-$
Aliquat 4	Trimethyl lauryl ammonium chloride	$[R(CH_3)_3N^+]Cl^-$
Aliquat 26	Trimethyl tallow ammonium chloride	$[R(CH_3)_3N^+]Cl^-$

[a] Coco alkyl: C_8–1%, C_{10}–5%, C_{12}–55%, C_{14}–22%, C_{16}–10%, C_{18} saturated–3%, C_{18} unsaturated–4%. Tallow alkyl: C_{14}–3%, C_{16}–28%, C_{18} saturated–25%, C_{18} unsaturated–44%.

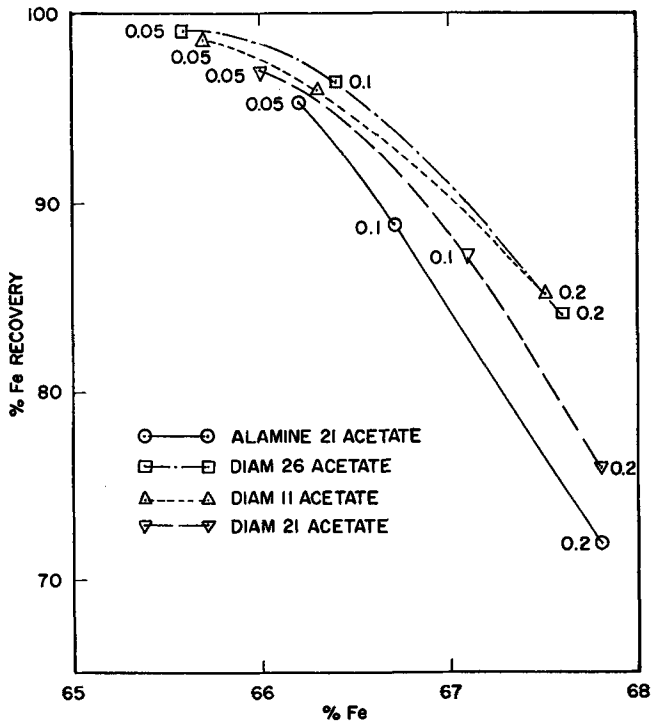

FIG. 2. Grade recovery, ore: 8.0% SiO_2, 65.2% Fe.

Silica Collectors

As described in Table I, alkyl primary amine acetates, N-alkyl-1,3-propylene diamine acetates and trimethyl alkyl ammonium chloride compounds with alkyl groups derived from lauryl, coconut and tallow fatty acids were evaluated as silica collectors. The amines were converted to acetate salts before use to make them soluble in water. The trimethyl alkyl ammonium chlorides are already salts. The trimethyl alkyl ammonium chlorides are 50% solids in isopropanol-water. The other collectors are 100% solids. Coconut and tallow alkyl are defined at the bottom of Table I. Alamine 21, Diam 21 and Aliquat 21 contain coconut alkyl. The corresponding tallow homologs are designated with the number 26. Commercially available (not from General Mills) ether amine acetate (alkyloxypropylamine) and ether diamine monoacetate (alkyloxypropyl-1,3-propylene diamine) were also evaluated. These compounds are made by the cyanoethylation of long chain alkyl alcohol.

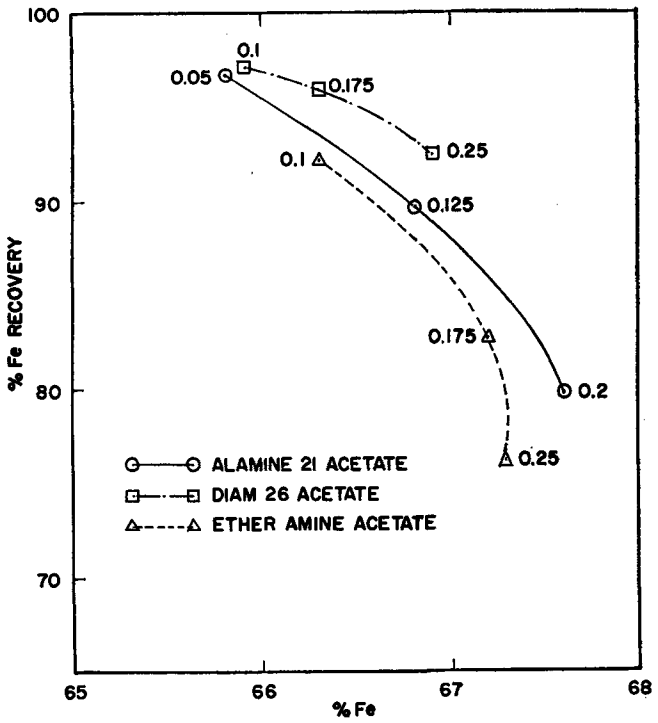

FIG. 3. Grade recovery, ore: 8.0% SiO_2, 65.2% Fe.

TABLE II
Flotation Results

Ore		Collector	Concentrate			
% Fe	% SiO_2		Lb./ Ton	% Fe	% SiO_2	% Rec.
65.2	8.0	Alamine 21 acetate	0.05	66.2	5.7	95.4
			0.10	66.7	5.0	88.9
			0.20	67.8	3.6	71.8
		Aliquat 26	0.05	65.3	6.8	99.7
			0.10	65.4	6.7	99.4
			0.20	66.1	5.8	96.3
			0.40	68.0	3.3	78.4
		Aliquat 21	0.05	65.3	6.8	99.4
			0.10	65.4	6.7	99.2
			0.20	66.2	5.7	94.7
			0.40	67.5	4.2	80.5
		Aliquat 4	0.05	65.4	6.7	99.2
			0.10	65.6	6.4	98.0
			0.20	66.1	5.8	94.8
			0.40	67.1	4.5	84.0
		Diam 26 di-acetate	0.05	65.6	6.4	99.2
			0.10	66.4	5.4	96.5
			0.20	67.6	3.8	84.0
		Diam 11 di-acetate	0.05	65.7	6.3	98.6
			0.10	66.3	5.5	96.0
			0.20	67.5	4.2	85.1
		Diam 21 di-acetate	0.05	66.0	5.9	97.0
			0.10	67.1	4.5	86.2
			0.20	67.8	3.6	75.7
65.2	8.0	Alamine 21 acetate	0.05	65.8	6.2	96.8
			0.125	66.8	4.9	89.7
			0.20	67.6	3.8	79.8
		Diam 26 di-acetate	0.10	65.9	6.0	97.1
			0.175	66.3	5.2	95.9
			0.25	66.9	4.8	92.5
		Ether amine acetate	0.10	66.3	5.1	92.2
			0.175	67.2	4.4	82.9
			0.250	67.3	4.2	76.9
64.3	9.6	Alamine 21 acetate	0.025	68.2	4.3	92.2
			0.05	69.4	3.0	85.9
			0.10	70.5	1.8	70.8
		Alamine 4 acetate	0.025	69.1	3.3	87.8
			0.05	69.9	2.4	79.0
			0.10	70.4	1.7	65.9
		Ether diamine Mono-acetate	0.025	67.3	5.4	95.3
			0.05	69.0	3.4	90.5
			0.10	69.4	3.0	86.9
65.0	8.2	Alamine 21 acetate	0.025	69.3	3.2	88.0
			0.05	69.8	2.7	84.6
			0.10	70.8	1.9	74.3
		Diam 26 mono-acetate	0.05	68.3	4.5	91.7
			0.10	69.3	3.2	88.5
			0.20	70.9	1.6	61.1
		Alamine 26 acetate	0.05	69.4	3.1	86.8
			0.10	70.2	2.1	81.2
			0.20	71.0	1.5	54.2
		Ether amine acetate	0.025	68.4	4.1	92.1
			0.05	69.4	2.9	85.3
			0.10	70.0	2.2	76.7

Results and Discussion

The test results are given in Table II and in grade versus iron-recovery curves (Figs. 1–5). The discussion that follows, although organized on the basis of the grade recovery curves, is based both on the given grade-recovery curve and on the corresponding section of Table II. Flotation concentrates with 5% or less silica are considered satisfactory. Since the grade recovery curves are based on per cent iron in the flotation concentrate and not per cent silica, the per cent iron corresponding to 5% silica is given in the discussion for each ore. Coco primary amine acetate was used as the standard of comparison.

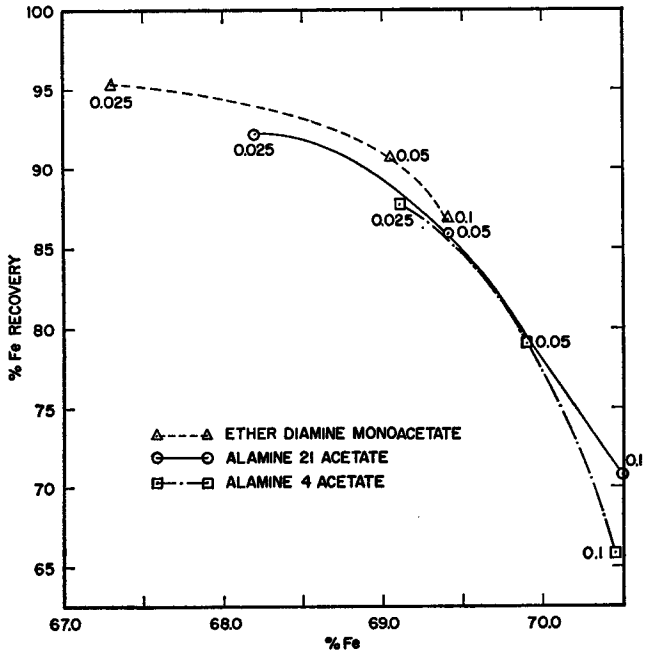

FIG. 4. Grade recovery curves, ore: 9.6% SiO_2, 64.3% Fe.

Grade Recovery, Ore 8.0% Silica, 65.2% Iron (Fig. 1)

The ore used in this group of data contained unliberated iron-silicate. The iron content corresponding to 5% silica is 66.7%. The Aliquat surfactants are 50% solids in water, therefore the pounds per ton should be divided by two when making comparisons with the Alamine 21 Acetate standard (coco primary amine acetate).

Satisfactory grade is achieved with 0.1 lb/ton of the standard. The selectivity of the Aliquat 4 (lauryl quaternary) is for all practical purposes equivalent to that of the standard. The Aliquat 21 (coco quaternary) is somewhat more selective and the Aliquat 26 (tallow quaternary) significantly more selective than the standard. The quaternary ammonium compounds, even after adjustment for solids, are not as efficient as the standard.

Grade Recovery, Ore 8.0% Silica, 65.2% Iron (Fig. 2)

The ore is the same as that in the preceding group. Diam 21 acetate (coco diamine acetate) is more selective than the standard. At the recommended use level (approximately 0.1 lb./ton) it is somewhat more efficient than the standard; at the other concentrations given, efficiency equals that of the standard. Diam 26 acetate and Diam 11 acetate (tallow and oleyl alkyl respectively) are equivalent to each other in selectivity and efficiency. They are more selective than the standard and less efficient.

Grade Recovery, Ore 8.0% Silica, 65.2% Iron (Fig. 3)

This ore is the same as that in the preceding two groups. Diam 26 acetate (tallow alkyl group) is more selective than the standard but only about half as efficient. The ether amine acetate is somewhat less selective than the standard. Efficiency of the ether amine acetate equals that of the standard.

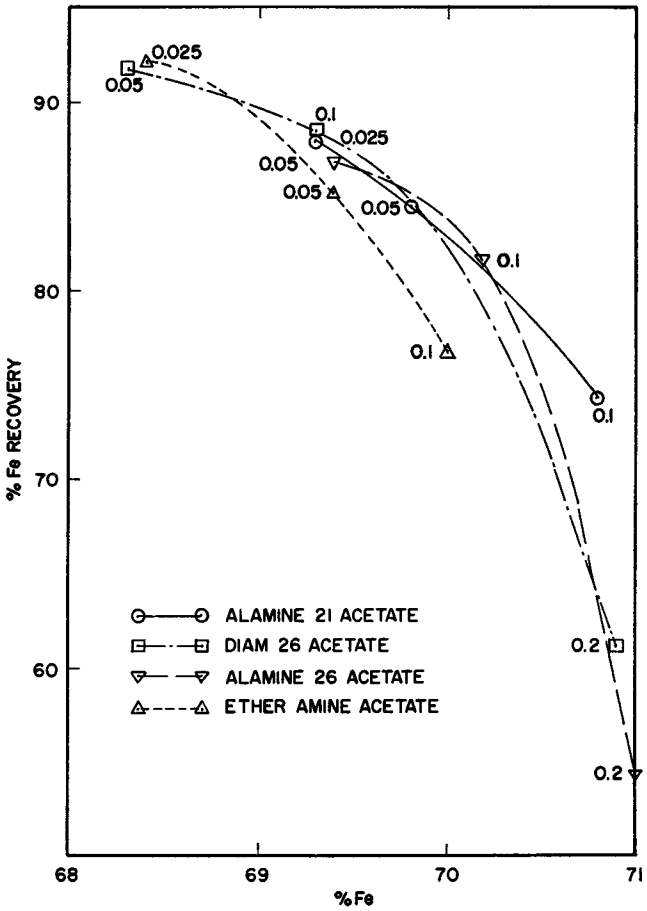

FIG. 5. Grade recovery, ore: 8.2% SiO_2, 65.0% Fe.

Grade Recovery, Ore 9.6% Silica, 64.3% Iron (Fig. 4)

The iron-silicate in this ore is well liberated. Iron content of 67.7% corresponds to 5% silica.

All of the reagents are highly efficient on this well-liberated ore sample. Satisfactory grade can be achieved with less than 0.025 lb./ton of the standard. These results demonstrate the high effectiveness of cationic silica flotation on well-liberated ores. Alamine 4 (lauryl alkyl) is more efficient than the coco amine standard and about equally selective. Ether diamine mono-acetate is somewhat more selective than the standard and less efficient.

Grade Recovery, Ore 8.2% Silica, 65.0% Iron (Fig. 5)

The iron-silicate in this ore sample is also well liberated. The concentration of iron corresponding to 5% silica is 68.0%. Again, as with the preceding ore, all of the reagents performed extremely well. Less than 0.025 lb./ton is needed to achieve satisfactory grade.

Alamine 26 acetate and Diam 26 acetate (alkyl group is tallow in each) equal the standard in selectivity, but are less efficient. The tallow primary amine is more efficient than the tallow diamine. The ether amine acetate is less efficient than the standard and somewhat less selective.

REFERENCES

1. Lentz, T. H., D. E. Terry and H. Wittcoff, Ind. Eng. Chem. *47*, 468 (1955).

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