calcium laurate apparently is formed much in preference to basic calcium laurate, with the resultant lack of any basic aqueous complex in solution.

ACKNOWLEDGMENT

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SELECTIVE FLOTATION OF IRON OXIDE

by M. C. Fuerstenau, J. D. Miller, and G. Gutierrez

The response of pure goethite and two natural iron ores to flotation with potassium octyl hydroxamate is presented. The ores contained 12.5% and 39.7% iron; concentrates containing 69.5% and 61.5% iron, respectively, were obtained with additions of 0.4 lb/ton hydroxamate.

Selective flotation of iron oxides from associated gangue minerals has proven difficult in the past with standard collectors, such as sulfonates and fatty acids. As a result, recent work has been directed toward silica flotation with calcium activation after the iron oxide surfaces have been blinded with certain starches.[1, 2] The results obtained with this technique are encouraging. This method, however, involves depressing a mineral that would normally float under the conditions employed. A preferable method would involve floating the iron oxide because quartz is naturally depressed until activated. Earlier work involved this approach, but in view of the results obtained, collectors that exhibit greater specificity for iron are needed.

During an investigation of chrysocolla flotation with potassium octyl hydroxamate, a metal chelate former, it was observed that pyrite floated well with low additions of collector.[3] This phenomenon suggests that hydroxamate has a rather strong affinity for iron, and that other iron-bearing minerals should also respond to flotation with octyl hydroxamate. The object of this paper is to determine this response.

The experimental work was divided into areas, the first of which involved microflotation experiments with pure goethite with an apparatus described previously.[4] Goethite was selected because of the ease

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of obtaining pure samples and also because the flotation characteristics of the various iron oxides have been shown to be similar.[5] The following technique was used:

1) 2.5 g of 100 × 200-mesh goethite were added to a specified amount of conductivity water,

2) the pH of the solution was adjusted to a predetermined value,

3) a given amount of hydroxamate solution was added to yield the desired molarity,

4) two drops of a solution containing 20 parts water to one part n-amyl alcohol by volume were added as frother,

5) the system was conditioned for 3 min,

6) the pH was measured, termed flotation pH,

7) 100 cc of nitrogen were passed through the cell at a flow rate of 120 cc per min, and

8) the pH was re-measured.

Flotation recovery is presented as a function of pH in Fig. 1. When 1×10^{-4} mole per liter octyl hydroxamate was added, a maximum recovery of 55% was obtained at pH 8.6. With 3×10^{-4} mole per liter, complete flotation was effected from about pH 5 to pH 10.

The second general area of investigation involved the flotation of two natural ores; the first, a low-grade spiral tailings containing 12.5% iron as hematite and magnetite, and the second, a red earthy hematitic ore containing 39.7% iron. Screen analyses of these ores are given in Tables I and II.

The following flotation technique was employed:

1) 500 g of ore were added to 2.3 liters of tap water,

2) a desired amount of collector and two drops of M.I.B.C. were added,

3) the pulp was conditioned for 3 min at the natural pH of the system (pH 7.7),

4) the rougher concentrate was collected until the froth was depleted,

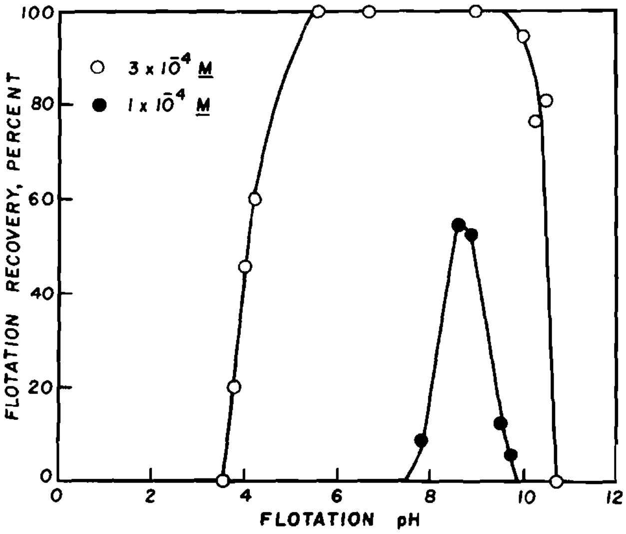

Fig. 1 — Relationship between flotation recovery of goethite and pH with two levels of addition of octyl hydroxamate at 23°C.

Table I. Screen Analysis of the Spiral Tailings

Size, Mesh	Cumulative Pct Finer
35	100.0
48	90.9
65	81.2
100	65.7
200	36.5
325	12.7

Table II. Screen Analysis of the High-Grade Hematitic Ore

Size, Mesh	Cumulative Pct Finer
65	100.0
100	97.0
150	94.0
200	88.4
325	71.2

5) the rougher concentrate was cleaned with no conditioning with only the addition of frother (two drops M.I.B.C.) in some stages and with small additions of collector in others.

Note that the pulps were not deslimed prior to flotation.

The first experiment was conducted with spiral tailings with 0.2 lb per ton hydroxamate. Since the rougher recovery was only about 50%, no attempt was made to clean this concentrate.

The results obtained with 0.3, 0.4, and 0.5 lb per ton are given in Tables III, IV, and V.

Several observations can be drawn from these data: 1) 0.2 lb per ton hydroxamate was not sufficient to produce acceptable recoveries, 2) rougher flotation recoveries of 85.9%, 90.6%, and 92.4% were obtained with 0.3, 0.4, and 0.5 lb per ton hydroxamate, respectively, 3) cleaner flotation recoveries of about 60% were obtained when 0.3 and 0.4 lb per ton hydroxamate were added in the rougher step, and the final concentrate grades were excellent, and 4) a satisfactory concentrate grade was not obtained with three cleaning stages when 0.5 lb per ton hydroxamate was added. An additional cleaning stage would probably have resulted in a grade of 61% iron or better, however.

Experiments were also run on a higher grade ore, and the results obtained with an addition of 0.4 lb per ton hydroxamate are presented in Table VI.

As shown, about 65% of the total iron reported to the final concentrate at a grade of 61.5% iron. The grade of the final concentrate could probably have been improved if additional cleaner flotation steps had been employed.

In order to evaluate more fully the effectiveness of

Table III. Experimental Results Obtained with Spiral Tailings with 0.3 Lb Per Ton Octyl Hydroxamate at pH 7.7 and 23°C.

Product	Wt, %	Fe, %	Fe Units	Fe Distribution, %
Rougher Tail	78.3	2.3	1.8	14.1
Cleaner Tail 1	7.5	24.0	1.8	14.1
Cleaner Tail 2*	2.8	50.2	1.4	11.0
Cleaner Tail 3*	1.4	56.6	0.8	6.2
Final Concentrate	10.0	69.5	7.0	54.6
	100.0		12.8	100.0

*0.05 lb per ton hydroxamate added to cleaner step.

Table IV. Experimental Results Obtained with Spiral Tailings with 0.4 Lb Per Ton Octyl Hydroxamate at pH 7.7 and 23°C.

Product	Wt, %	Fe, %	Fe Units	Fe Distribution, %
Rougher Tail	66.6	1.8	1.2	9.1
Cleaner Tail 1	14.6	7.9	1.2	9.1
Cleaner Tail 2	5.0	33.6	1.7	13.0
Cleaner Tail 3*	1.8	43.8	0.8	6.1
Final Concentrate	12.0	68.4	8.2	62.7
	100.0		13.1	100.0

*0.05 lb/ton hydroxamate added to cleaner step.

Table V. Experimental Results Obtained with Spiral Tailings with 0.5 Lb Per Ton Octyl Hydroxamate at pH 7.7 and 23°C.

Product	Wt, %	Fe, %	Fe Units	Fe Distribution, %
Rougher Tail	44.8	2.1	0.9	7.2
Cleaner Tail 1	21.3	2.4	0.5	4.0
Cleaner Tail 2	12.8	9.1	1.2	9.6
Cleaner Tail 3	7.2	25.7	1.8	14.4
Final Concentrate	13.9	58.0	8.1	64.8
	100.0		12.5	100.0

Table VI. Experimental Results Obtained with High-Grade Hematitic Ore with 0.4 Lb Per Ton Octyl Hydroxamate at pH 7.7 and 23°C.

Product	Wt, %	Fe, %	Fe Units	Fe Distribution, %
Rougher Tail	24.0	23.8	5.7	13.7
Cleaner Tail 1	15.8	25.2	4.0	9.6
Cleaner Tail 2	9.5	28.8	2.8	6.8
Cleaner Tail 3	7.8	33.5	2.6	6.3
Final Concentrate	42.9	61.5	26.4	63.6
	100.0		41.5	100.0

hydroxamate as a collector for iron oxide minerals, a comparison of the results obtained with hydroxamate to those obtained with fatty acids is required. First, the selective flotation of hematite from earthy ores has proven difficult with either fatty acids or sulfonates. In this study a concentrate containing 61.5% was obtained from such an ore with a modest addition of hydroxamate.

Secondly, the spiral tailings used in this study are presently concentrated commercially with about 1.25 lb per ton fatty acid, 0.6 lb per ton sodium fluoride, and 1.1 lb per ton sulfuric acid. Further, the pulp is conditioned at about 70% solids prior to flotation. With this reagent schedule and technique, about 60% of the iron is recovered in the final concentrate at a grade of about 61% iron. The superiority of hydroxamate as a collector for iron oxide as compared to fatty acid is then evidenced by the final concentrate grades obtained. In addition, there is no need for conditioning at high pulp density when hydroxamate is used.

In comparing reagent costs in hydroxamate versus fatty acid flotation, one manufacturer has quoted a price of 70¢ per lb for hydroxamate.[6] It seems reasonable to assume, however, that this reagent can be manufactured for about 50¢ per lb if produced in sufficient quantity. Then, for an addition of 0.4 lb per ton hydroxamate, reagent cost will be 20¢ to 28¢ per ton of feed excluding the cost of frother.

Assuming that the cost of fatty acid is 20¢ per lb, sodium fluoride 15¢ per lb, and sulfuric acid 1.5¢ per lb, reagent cost would be approximately 36¢ per ton of feed with the reagent schedule described above. On this basis, hydroxamate flotation also has an economic advantage over conventional fatty acid flotation for this ore.

From a theoretical point of view, the results shown in Fig. 1 appear to corroborate the mechanism of collector adsorption suggested previously with chrysocolla. That is, flotation of copper silicate was obtained above pH 5 which is the pH range in which Cu^{++} hydrolyzes to $CuOH^+$ and $Cu(OH)_{2(s)}$.[3] From the results obtained with goethite, the presence of hydroxyl ion on the mineral surface is also apparently necessary, since flotation was obtained only in the pH range in which hydrolysis of ferric iron occurs.[7,8] Fig. 2 shows the two sites obtained when iron oxide is fractured.

Above about pH 3, the iron ion of Site B should hydrolyze to $FeOH^{++}$ or to some other hydrolyzed species. Adsorption of hydroxamate ion might then occur by normal chelation in the manner shown in Fig. 3.

System depression observed at low values of pH with 3×10^{-4} mole per liter hydroxamate may be due to insufficient OH^- on the surface or to the hydrolysis of hydroxamate ion to hydroxamic acid.[3]

The lack of flotation at pH 11 with this same collector addition can probably be attributed to the stability of ferric hydroxide relative to ferric hydroxamate.

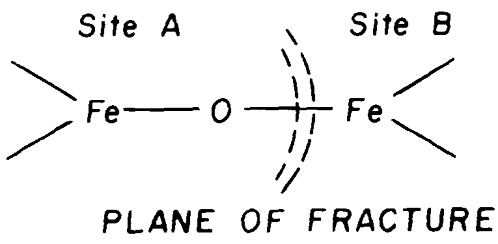

Fig. 2 – Sites obtained when iron oxide is fractured.

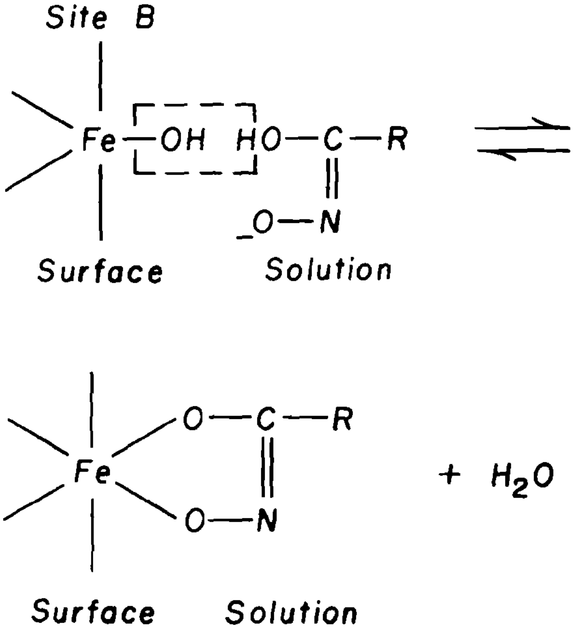

Fig. 3 – Adsorption of hydroxamate ion occurring by normal chelation.

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DISCUSSION

TEMPERATURE AND HUMIDITY IN ELECTRICAL SEPARATION OF OXIDE MINERALS

by G. A. Parks, B. K. Jindal, and J. H. Anderson, Jr.

Transactions of SME, December 1966, p. 451; AIME Transactions, 1966, vol. 235

H. Leslie Bullock *(Engineering Consultant, Oak Park, Ill.)* – In reading over the paper, I find that I have no quarrel with the thoroughness of investigation of the points studied, but I am forced to question the selection of oxides from oxides as the subject of the investigation, the inclusion of silica gel as an example, and to question the validity of some of the conclusions.

Separation of oxides from oxide, in minerals where the liberation of values is possible by grinding, are comparatively rare. Most oxides are only slightly soluble and the action of carbon dioxide or other acid forming ingredient in the air must be added to humidity to produce surface action. Silica gel is a very special synthetic substance in which the adsorption is determined by total surface, pore dimensions and *temperature*. Quartz is our most prevalent oxide and its action in electrostatic separation is far more sensitive to its three thermal transition points than to humidity.