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FLOTATION OF ORES

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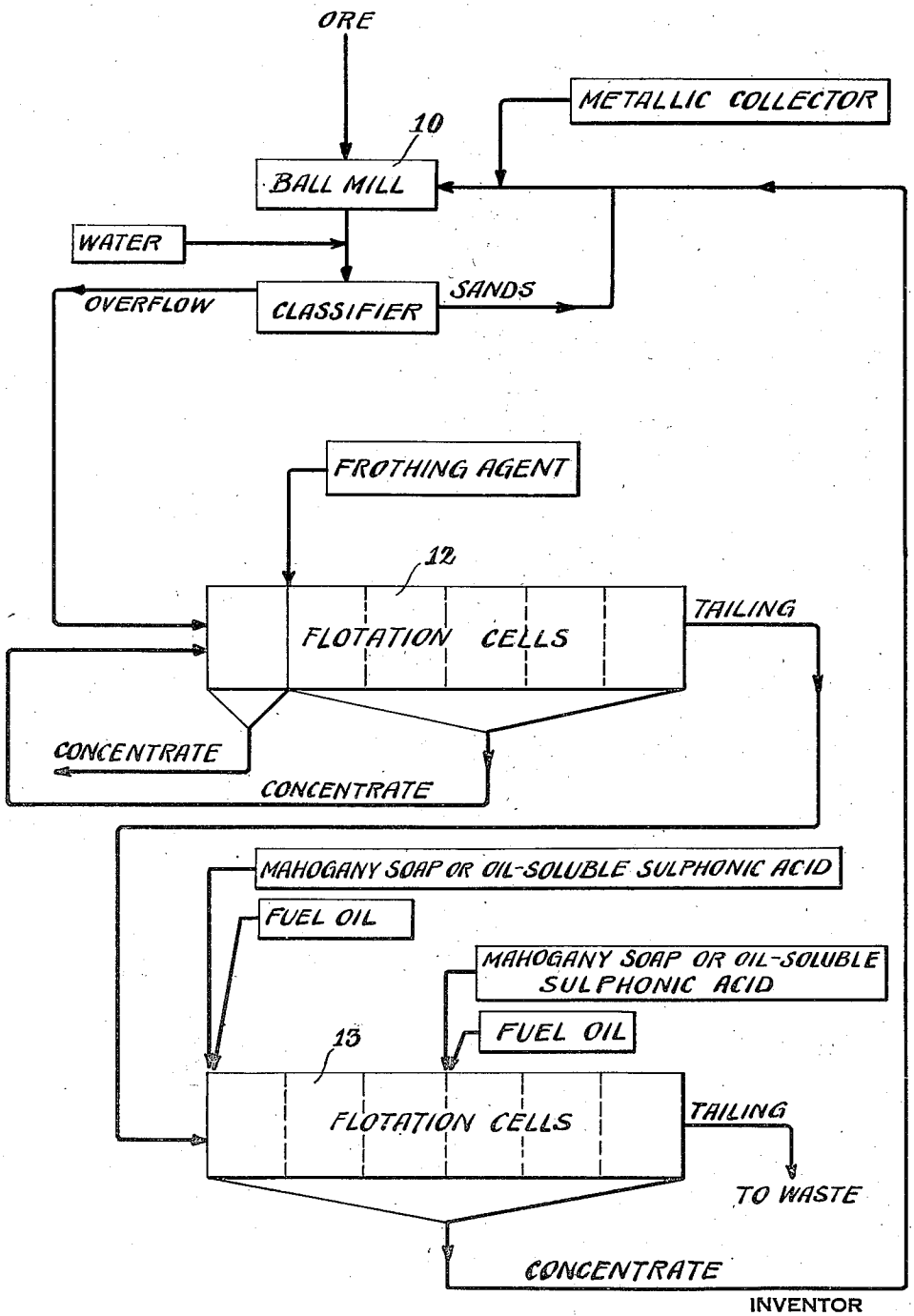

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FLOTATION OF ORES

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This invention relates to the froth flotation of ores and has particular reference to novel flotation agents and to processes for treating ores to more economically recover value bearing minerals therefrom.

Among the major problems that have confronted the froth flotation industry are the poor flotability of the stained or oxidized sulfide ores; the refractory nature of slimes to flotation; and the necessity of very finely comminuting the ore in order to make possible a satisfactory recovery of the valuable material.

In order to commercially float oxidized metallic minerals it has been necessary, heretofore, to use large quantities of the more powerful sulfide collectors, or sulfidizers and sulfide collectors, or fatty acids, such as, for example, oleic acid or derivatives thereof.

Among the disadvantages of using such reagents or combination of reagents is the necessity of using large quantities of these materials which, in most cases, are expensive and thus render the flotation process more costly than is justified by the value of the material recovered.

Usually flotation processes are rendered more complicated by the presence of slimes, inasmuch as slimes are refractory in all flotation operations. They are particularly refractory in nonmetallic flotation so that they are often discarded, and thus cause appreciable decrease in recovery of the valuable material. The presence of slimes in the pulp often renders it impractical to use such materials as oleic acid, for the reason that the oleic acid is a strong frothing agent and a collector for nearly all slimed minerals, so that a dirty, tough and tenacious froth is formed which cannot be readily broken, thus rendering the use of oleic acid impractical for commercial operations on ores having appreciable quantities of slime. Slimes are present in substantially all ore pulps and the amount of slimes is materially increased by the conventional methods of preparing ore for flotation.

When valuable metallic minerals are associated with nonmetallic materials, it has been customary to grind all of the material to a very fine degree of subdivision in order to liberate the valuable material from the gangue. Grinding the ore to this extent unavoidably increases the amount of slimes, and this very finely divided material reacts undesirably in flotation, as pointed out above. Additionally, the cost of recovery of the valuable materials is greatly increased by the grinding operations, inasmuch as much power is required to reduce the ores to the fineness required in ordinary flotation operations. Also these finely ground ores require more reagents for satisfactory flotation than coarsely ground ores.

An object of the present invention is to overcome the disadvantages of the prior practice in the treatment of stained or oxidized ores and thereby effect economical recovery of the valuable minerals occurring in such ores.

Another object of the invention is to provide novel flotation agents which function effectively in the presence of slimes.

An additional object of the invention is to provide flotation agents which are selective in separating metallic and valuable nonmetallic components of an ore from valueless nonmetallic components.

Another object of the invention is to provide processes utilizing novel collectors, whereby high grades of the concentrates may be obtained from ores without the necessity of finely comminuting all of the ore.

Another object of the invention is to provide flotation processes whereby high recoveries of valuable material from ores may be obtained with a minimum amount of grinding.

Other objects of the invention will become apparent from a disclosure of typical flotation agents and processes embodying the present invention.

In its most general aspects, the invention involves the flotation of ores with mahogany sulphonates and oil soluble sulfonic acids derived from petroleum, either alone or in conjunction with other known types of flotation agents.

The term "mahogany sulphonates," as used herein, refers to those crude, partially refined or completely refined sulphonates derived from petroleum stock which are oil soluble, substantially insoluble in water, but dispersible in water. The refined mahogany sulphonates which are preferably used in flotation operations are characterized by a wine color. These mahogany sulphonates form dispersions similar to colloidal gels when used with water in a concentration of about 12%, and readily disperse upon agitation in hot water. Upon dilution of the dispersion, the viscosity decreases until the dispersion becomes very fluid. The mahogany sulfonates preferably are dispersed in hot water and then boiled for about 10 minutes. The dispersion, at any desired temperature, is added to the flotation system. The active principals of the mahogany sulphonates appear to be the sodium sulphonates or sulphonic acid groups.

The mahogany sulphonates exert a strong collecting action not only on metallic minerals but also on non-metallic materials, such as readily flotable lime and iron-bearing gangues which are present in many types of ore and which in many instances have been instrumental in the deposition of the valuable metallic minerals so that they are segregated in and intimately associated with the lime and iron-bearing gangue minerals. Microscopic examination shows that mahogany sulphonates are capable of collecting these gangues which have metallic minerals either entirely occluded or showing on their surfaces, even when rather coarsely ground. This ability of the mahogany sulphonates to collect non-metallic gangues which are intimately associated with more valuable minerals affords a simple and effective way of effecting a high recovery of value-bearing materials. When mahogany sulphonates are used, for example, with such metallic mineral collectors as the xanthates or the dithiophosphates, middling composed of readily flotable non-metallic gangue and occluded metallic minerals are selectively floated from other gangue with the mahogany sulphonate or sulphonic acids and the occluded metallic minerals have no part in this selective flotation. With the same combination of reagents, middling, composed of readily flotable non-metallic gangue and exposed metallic minerals, are floated by covering the metallic mineral part with the metallic mineral collector or reaction products thereof and the non-metallic mineral part with the non-metallic mineral collector or reaction products thereof. Middling composed of relatively unfloatable non-metallic gangue and exposed metallic minerals is floated by coating the exposed metallic mineral part with a metallic mineral collector or products thereof; thereafter the coated metallic mineral portion serves as a nucleus from which filming of the relatively unfloatable non-metallic portion proceeds with the reaction product of a non-metallic mineral collector, such as, mahogany sulphonate, and an activator. In this way, middling, unrecoverable by usual flotation because of being relatively coarse or containing a relatively small metallic mineral portion, are readily floated by the present process because both the metallic and non-metallic mineral portions have been rendered floatable whereas with usual metallic mineral flotation only the metallic mineral part has been made floatable. When oxidized metallic ores are floated with a metallic mineral collector, such as a xanthate or dithiophosphate and a non-metallic mineral collector, such as mahogany sulphonate, the oxidized metallic minerals are first coated with the metallic mineral collector or products thereof and thereafter with the non-metallic mineral collector or products thereof. In this way the selectivity of the first and the flotative power of the second class of collectors are obtained so that good grades of concentrates and recoveries can be made from oxidized ores that are refractory to usual flotation. It has been found that the collecting action of the mahogany sulphonates or petroleum sulphonic acids as collectors is materially enhanced by the presence of hydrocarbons, such as, for example, fuel oil, which apparently forms an additional coating on the surface of the already coated particle, and thus renders it more readily flotable. Fuel oil controls the quality of froth and prevents the inclusion of unwanted minerals in the froth inasmuch as fuel oil is, in itself, an excellent collector. Many of the advantages of the mahogany sulphonates and oil-soluble petroleum sulphonic acids arise from the fact that they are excellent emulsifiers for fuel oil which is one of the most powerful and cheapest collectors known, but heretofore little used because of lack of a satisfactory emulsifier.

It has been found that mahogany sulphonates, alone or in combination with other collecting agents, may be used to efficiently recover valuable minerals from widely different ores such as siliceou pyritical and arsenopyritical gold; barite, galena, anglecite, complex lead oxides, sulphides and sulphates of silver, weathered amygdaloidal native copper tailings, hematite, calcite and epidote.

Activators such as, for example, lime, improve the collecting characteristics of mahogany sulphonates, particularly when used in the flotation of copper ores. In the presence of such other activators as lead acetate, mahogany sulphonates and fuel oil have produced satisfactory recoveries of zinc from zinc sulphide ores. Other classes of reagents such as frothers, for example, pine oil, cresylic acid, conditioners, such as lime and soda ash, and depressors, such as sodium silicate, under proper conditions, improve flotation with the mahogany sulphonates.

In addition to the characteristics noted above, mahogany sulphonates are devoid of the strong frothing properties, and may be used in flotation operations without being adversely affected by the presence of slimes. Mahogany sulphonates also often are froth conditioners as they have a beneficial effect on the froth produced by other reagents.

This ability of the mahogany sulphonates and oil-soluble petroleum sulphonic acids to selectively collect, at relatively coarse size, the non-metallic gangue materials containing valuable minerals permits the amount of grinding to be reduced without adversely affecting separation of valueless from valuable material by flotation operations. For example, grinding of a native copper ore so that 38% of it was of —200-mesh size produced metallurgical results which were as satisfactory as those with usual flotation when 70% of the ore was ground to —200-mesh size. Experiments proved that grinding 38% of the ore to —200-mesh size cost only about one-half as much as grinding 70% of it to the same size.

Thus, in accordance with the present process, the ore may be only coarsely ground as compared with prior operations and subjected to a flotation operation in the presence of a metallic mineral collector and with or without mahogany sulphonates or oil-soluble petroleum sulphonic acids in order to separate from the ore a high grade concentrate containing substantially all of the free metallic mineral content of the ore. The tailing from this first flotation operation is subjected to a second flotation operation in the presence of a metallic mineral collector and a metallic and/or non-metallic mineral collector, such as, mahogony sulphonate, or the oil-soluble sulphonic acids, to float relatively coarse metallic mineral particles, middling, oxidized metallic mineral particles and other material which is refractory to usual flotation. The concentrate from this second flotation may then be reduced to a more finely divided form and again subjected to a flotation operation in order to produce a high grade of metallic mineral concentrate. Thus, in accordance with the present invention, only a very small proportion of the ore is ground to a finely divided state in order to recover the valu-

able material. The reduction in amount of grinding materially reduces the cost of recovering the valuable material and renders practical the treatment of ores which previously did not economically justify treatment.

In addition to the ability of the mahogany sulphonates and oil-soluble petroleum, sulphonic acids to act as non-metallic collectors, these materials are relatively inexpensive and can replace or be substituted in part for more expensive metallic collectors, such as the xanthates, thus resulting in decided economy in the flotation operation.

For a better understanding of the invention reference may be had to the accompanying drawing in which the single figure discloses diagrammatically a typical process embodying the present invention.

As illustrated in the drawing, the ore which has been subjected to a crushing operation in order to reduce it to 0.25-inch size is further ground in a ball mill 10 to produce a pulp containing about 50 to 60% solids, of which only a minor proportion is of 200 mesh or smaller size. This pulp, after classification in the classifier 11, is then passed through the first flotation cells 12 where a relatively high grade concentrate may be produced by floating in the presence of a metallic mineral collector and/or mahogany sulphonates and other agents, such as pine oil, fuel oil, lime and the like. The tailings from the flotation cells, 12, are subjected to a further flotation in the cells 13, in the presence of a metallic mineral collector and a metallic and/or non-metallic mineral collector. The metallic collector may be a xanthate or dithiophosphate and the metallic and/or non-metallic mineral collector a mahogany sulphonate or an oil-soluble sulphonic acid of the type described above. The metallic and non-metallic collectors form an insoluble film on the middling material, on relatively coarse unoxidized, and on stained and oxidized metallic minerals, and thus this material is concentrated in the froth and separated as concentrate. The tailings from this operation are waste, inasmuch as substantially all of the valuable material has been segregated in the concentrates by the successive flotation operations. The concentrate may then be ground to fine particle size, for example 200 mesh or smaller in a ball mill 10 or another ball mill not shown in this figure, and subjected to a third flotation operation in the flotation cells 12 or other cells not shown in this figure, thus separating the valuable materials which have been freed from the non-valuable or gangue material.

The use of mahogany sulphonates or oil-soluble sulphonic acids renders unnecessary the removal of the slimes from the ores, inasmuch as the froth formed during flotation will break quite readily to allow separation of the concentrate from the froth. In this connection, it has been found that only a small percentage of the slimes are floated in the presence of mahogany sulphonates, or oil-soluble sulphonic acids, and these are the slimes that contain valuable material, thus showing that these collectors are highly selective regardless of the particle size within wide limits. Thus the use of mahogany sulphonates or oil-soluble sulphonic acids overcomes the necessity of utilizing an additional separating step to eliminate the slimes and provides more effective recovery of the valuable materials.

Mahogany sulphonates and oil-soluble sulphonic acids have a wide field of use for the flotation of the various types of ores, of which the following typical examples are given.

EXAMPLE I

A weathered amygdaloidal native copper tailing from the copper country of Michigan was used in the flotation operation. This tailing was so badly oxidized that the copper in the tailing was, in part, converted into cuprite, azurite and malachite. This ore was crushed to pass a 10 mesh sieve and then 1500 grams of it were wet-ground in a ball mill at a concentration of 50% solids.

The ground ore was subjected to flotation in a 1000 gram mechanical flotation machine in the presence of .25 lb. of ethyl xanthate, .01 lb. mahogany sulphonate, .01 lb. fuel oil, and .10 lb. pine oil to produce a xanthate concentrate and tailing. The xanthate tailing was subjected to flotation with .04 lb. mahogany sulphonate, and .12 lb. of fuel oil to produce a mahogany sulphonate concentrate and tailing. The results of these tests are as follows:

Grinding percent −200	Product	Weight distrib.	Per cent copper	Copper distrib.	Copper recov.
37.7	Xanth. conc.	0.5	29.20	51.5	
	Mah. S. conc.	0.9	6.68	19.1	
	Final tail	98.6	0.114	29.4	
		100.0		100.0	70.6

It is shown that the recovery of copper from the tailings is excellent for this type of material and that mahogany sulphonate flotation recovered 19% more copper after flotation with xanthate in the usual way.

EXAMPLE II

An unoxidized porphyry copper-iron sulphide ore (chalcocite and pyrite) was floated with a combination of ethyl xanthate, mahogany sulphonate and fuel oil. In this example, the ore was reduced, as described in Example I, except that 2.5 lbs. of lime were added to the ball mill, and the pulp was subjected to flotation with .10 of a lb. ethyl xanthate, .01 lb. mahogany sulphonate, .01 lb. fuel oil and .10 lb. pine oil to produce a concentrate and tailing. The xanthate tailing was subjected to a scavenger flotation with .10 lb. mahogany sulphonate, .30 lb. fuel oil to produce a mahogany sulphonate concentrate and a tailing. The results of this procedure were as follows:

Grinding percent −200	Product	Weight distrib.	Per cent copper	Copper distrib.	Copper recov.
29.3	Xanth. conc.	3.1	15.85	76.0	
	Mah. S. conc.	3.2	2.44	11.9	
	Final tail	93.7	0.083	12.1	
		100.0		100.0	87.9

An easily controlled and brittle froth was obtained with the mahogany sulphonate which was readily broken and contained only about 30% of −200 mesh material.

EXAMPLE III

A mixed sulphide oxide lead ore from the Tintic District of Utah was floated with mahogany sulphonate and with a combination of ethyl xanthate and mahogany sulphonate together with other agents, in order to determine whether the mahogany sulphonates could be substituted

in part for ethyl xanthate. In each instance, the ore was crushed to pass a 10 mesh screen and wet-ground to produce a pulp containing 50% solids. One sample of the material was floated with

(1) 3 lbs. sodium silicate
2 lbs. ethyl xanthate
1.2 lbs. mahogany sulphonate
.3 lb. fuel oil
.1 lb. pine oil

In this operation, the first flotation step was performed before any mahogany sulphonate was added. The mahogany sulphonate was added prior to the second flotation step. In the two flotation steps a xanthate concentrate, a xanthate-mahogany sulphonate scavenger concentrate and tailings were produced. The other sample of ground pulp was floated with

(2) 1 lb. sodium silicate
5 lbs. mahogany sulphonate
2.5 lbs. fuel oil
.15 lb. of pine oil

to obtain a mahogany sulphonate concentrate, after which .5 lb. of ethyl xanthate was added and the second flotation operation used to obtain a xanthate-mahogany sulphonate concentrate and a tailing.

The results of these comparative tests are as follows:

Test No.	Product	Wt. distrib.	Per cent Pb	Pb distrib.	Pb recov.
1	Xanthate conc.	6.3	28.12	11.3	
	Xanth-M. S. conc	28.1	27.58	49.7	
	Tailing	65.6	9.28	39.0	
		100.0		100.0	61.0
2	M. S. conc.	38.0	29.58	76.7	
	Xanth-M. S. conc	5.4	29.24	10.7	
	Tailing	56.6	3.27	12.6	
		100.0		100.0	87.4

These tests show that the mahogany sulphonate is an excellent collector of lead, and that mahogany sulphonates may be readily substituted, at least in part, for the more costly xanthates.

Example IV

Test No. 1

Unoxidized zinc sulfide ore was ground, as set forth in Example I, and the ground pulp floated with .10 lb. of mahogany sulphonate, .10 lb. fuel oil, .10 lb. pine oil, to form a mahogany sulphonate concentrate and tailing. The mahogany sulphonate tailing was subjected to flotation with the addition of .20 lb. more of fuel oil to obtain an additional mahogany sulphonate concentrate.

Test No. 2

A similar test was made using .10 lb. of mahogany sulphonate, .10 lb. of pine oil, .30 lb. of fuel oil and 0.30 lb. of lead acetate. The results of these tests are as follows:

Test No.	Product	Wt. distrib.	Percent Zu	Zu distrib.	Zu recov.
1	M. S. conc.	11.1	50.83	39.4	
	M. S. midd.	7.4	57.43	29.5	
	M. S. tail.	81.5	5.47	31.1	68.9
		100.0		100.0	
2	M. S. conc.	26.3	51.97	91.1	
	M. S. tail.	73.7	1.79	8.9	91.1
		100.0		100.0	

These tests show that mahogany sulphonates are excellent collectors of zinc and that lead acetate acts as an activator to increase the recovery of zinc.

Example No. V

A series of two tests was made to determine whether mahogany sulphonates could be substituted in part for xanthate in the flotation of porphyry copper-iron sulphide (chalcocite and pyrite) ore.

The ore was reduced as in the prior examples, 2.5 pounds of lime being added to the ball mill.

In Test No. 1 flotation was conducted with ethyl xanthate and pine oil to produce a concentrate and tailing.

In Test No. 2, the ore was floated with ethyl xanthate, mahogany sulphonate, fuel oil and pine oil.

The results of these tests are given in the following table:

Test No.	Lb. xanth.	Lb. fuel oil	Lb. mah. sulph.		Wt. dist.	Per cent Cu	Cu dist.	Cu recov.
1	0.10	.....	.....	Xanth. conc.	4.1	13.72	92.9	
				Xanth. tail.	95.9	0.044	7.1	92.9
					100.0		100.0	
2	0.05	0.10	0.05	Xanth. M. S. conc.	5.2	10.86	93.6	
				Xanth. M. S. tail.	94.8	0.040	6.4	93.6
					100.0		100.0	

Example VI

The flotation properties of unneutralized oil-soluble petroleum sulphonic acids were tested with an unoxidized amygdaloidal native copper ore.

The ore was reduced to pass 10 mesh and wet ground at 50 percent solids.

The ground ore was floated with 0.25 pound ethyl xanthate, 0.01 pound sulphonic acid, 0.02 pound fuel oil and 0.10 pound of pine oil to obtain a concentrate and tailing.

The tailing was floated with 0.10 sulphonic acid and 0.20 pound fuel oil to obtain a sulphonic acid concentrate and tailing.

The results of this test are given in the following table:

	Wt. dist.	Per cent Cu	Cu dist.	Cu recov.
Xanthate conc.	1.5	32.72	68.0	
S. acid conc.	5.4	3.50	25.7	
Final tailing	93.1	0.050	6.3	
	100.0		100.0	93.7

Example VII

To determine whether gold was flotable with mahogany soap, two representative gold ores were tested. In ore A the gold occurred free and also "followed" pyrite (unoxidized and partially oxidized) and oxides of iron and manganese. Besides the gold, ore A contained considerable native silver as relatively large-size grains. In ore B, there was no visible free gold and it apparently was all intimately intermingled with arsenopyrite.

The pertinent steps of the tests on ore A given in the order in which they were performed are as follows:

(a) Crushing of the ore to pass 10-mesh

(b) Wet grinding of the crushed ore at 50 percent solids

In Test 1 with 1.0 pound soda ash and 1.0 pound potassium amyl xanthate (KAX);

In test 2 with 1.0 pound soda ash, 0.10 pound mahogany sulphonate and 0.10 pound fuel oil;

In Test 3 with 1.0 pound soda ash, 0.50 pound potassium ethyl xanthate (KEX), 0.05 pound mahogany sulphonate and 0.05 pound fuel oil.

(c) Flotation of the ground pulp from (b) as follows:

In Test 1, addition of 0.10 pound pine oil and collection of a potassium amyl xanthate (KAX) concentrate followed by the addition of 0.20 pound mahogany sulphonate and 0.20 pound fuel oil and further flotation to obtain a mahogany sulphonate middling and a tailing.

In Test 2, addition of 0.10 pound pine oil, and flotation of a mahogany sulphonate concentrate followed by the addition of 0.20 pound mahogany sulphonate and 0.20 pound fuel oil and further flotation of a mahogany sulphonate middling product—the reject from this flotation being the tailing.

In Test 3, addition of 0.10 pound pine oil and flotation of a KEX-mahogany sulphonate concentrate followed by the addition of 0.10 pound mahogany sulphonate and 0.10 pound fuel oil and further flotation to obtain a mahogany sulphonate middling and a tailing.

The results of these tests are recorded in the following table and they show that mahogany sulphonate and fuel oil do not collect gold as well as when a sulfide collector, potassium amyl or ethyl xanthate, also is present. On the other hand mahogany sulphonate and fuel oil showed marked collective tendencies toward the silver in this ore which was present largely as native silver (many unusually coarse particles in concentrate).

Test No.	Product	Wt. distrib.	Oz Au	Au dist.	Au recov.	Oz Ag	Ag dist.	Ag recov.
1	KAX conc...	1.5	25.68	69.9		106.04	30.1	
	M. S. midd..	5.0	1.99	18.7		30.58	30.0	
	Tailing.....	93.5	.065	11.4		2.19	39.9	
		100.0		100.0	88.6		100.0	60.1
2	M. S. conc...	5.3	6.40	66.1		48.33	49.4	
	M. S. midd..	4.9	1.65	15.7		7.32	6.9	
	Tailing.....	89.8	.105	18.2		2.55	43.7	
		100.0		100.0	81.8		100.0	56.3
3	KEX M. S. conc.....	1.7	19.41	43.2		138.16	42.1	
	M. S. midd..	5.2	7.00	47.2		20.69	19.1	
	Tailing.....	93.1	.080	9.6		2.36	38.8	
		100.0		100.0	90.4		100.0	61.2

The pertinent steps of the tests on ore B given in the order in which they were performed are as follows:

(a) Crushing of the ore to pass 10-mesh

(b) Wet grinding of the crushed ore at 50 percent solids

In Test 1, with 0.20 pound mahogany sulphonate and 0.60 pound fuel oil.

In Test 2, with 0.40 pound potassium ethyl xanthate KEX

(c) Flotation of the ground pulp from (b) as follows:

In Test 1, addition of 0.10 pound pine oil, 0.40 pound mahogany sulphonate and 1.20 pounds fuel oil and the collection of a mahogany sulphonate concentrate—the reject from this treatment being the tailing.

In Test 2, addition of 0.10 pound pine oil and collection of KEX mahogany sulphonate concentrate followed by the addition of 0.30 pound mahogany sulphonate and 1.20 pound fuel oil and further flotation to obtain a mahogany sulphonate midd. and finally scavenger flotation was performed with 0.30 pound sodium silicate and 0.01 pound mahogany sulphonate—this last flotation producing a mahogany sulphonate scavenger concentrate and tailing.

The metallurgical results from the tests on ore B, in the following table, indicate that mahogany sulphonate and fuel oil are only mediocre collectors for gold (actually arsenopyrite) but when used in combination with xanthate, these same reagents floated more than one-half the recovered gold after the pulp had been floated with 0.40 pound of ethyl xanthate.

Test No.	Product	Wt. dist.	Oz Au	Au dist.	Au recov.
1	M. S. conc.....	15.0	0.75	45.2	
	Tail.....	85.0	0.16	54.8	
		100.0		100.0	45.2
2	KEX—M. S. conc	3.5	3.40	42.9	
	M. S. midd.....	5.9	1.25	26.4	
	Scav. conc.....	10.3	.55	20.5	
	Tailing.....	80.3	.035	10.2	
		100.0		100.0	89.8

The above examples show that mahogany sulphonates and sulfonic acids can be substituted for ethyl xanthate without decreasing the recovery of copper from a porphyry copper-iron sulphide and that good recoveries of lead and zinc from oxidized lead sulphide and unoxidized zinc sulphide ores, and gold both native and following other minerals, respectively, can be made using only mahogany sulphonates and fuel oil, or a combination of these reagents with the xanthates.

Similar tests have shown that mahogany sulphonates are strong collectors for native silver, silver in the sulphide form and that mahogany sulphonates and fuel oil are highly selective in separating silver bearing tetrahedrite from pyrites and are good collectors for minerals with metals whose sulphates are relatively insoluble. Thus, it will be seen that mahogany sulphonates and oil-soluble petroleum sulphonic acids exert strong collective powers for many different types of metallic as well as non-metallic minerals, and that they may be used together with known types of collecting agents or substituted in part therefor to obtain a highly efficient separation of the metallic elements from the non-metallic and valueless materials which accompany the valuable materials. Further, as the chemical and physical-chemical phenomena involved in flotation separation are the same regardless of whether the separated materials are of natural or artificial origin, the described reagents and processes are also applicable to the separation of artificial chemical compounds.

Accordingly, it should be understood that mahogany sulphonates and oil-soluble petroleum sulphonic acids may be used in conjunction with various types of collecting and other agents and that the proportions of mahogany sulphonates and sulphonic acids may be varied in concentration as the purpose demands and that separation may also be made by agglomeration tabling or like processes instead of by froth flotation. Therefore, the examples given above should be considered as illustrative, and not as limiting the scope of the following claims.

I claim:

1. A froth flotation process which comprises agitating an aqueous suspension of an oxidized metallic sulphide ore in the presence of a mahogany sulphonate to cause said mahogany sulphonate to collect the metal bearing ore at the surface of said suspension.

2. A froth flotation process which comprises agitating and aerating an oxidized metallic sulphide ore in the presence of mahogany sulphonates and fuel oil to cause said mahogany sulphonates and fuel oil to coat and float the metal bearing particles of said ore, and separating the floating ore to recover said metal bearing particles.

3. A method of concentrating a metallic sulphide ore which comprises agitating and aerating an aqueous suspension of such an ore in the presence of a xanthate and at least one collector of metallic minerals and non-metallic minerals containing occluded metallic minerals of the class consisting of oil-soluble, water-insoluble, but water dispersible mahogany sulphonates and petroleum sulphonic acids to collect the metallic-minerals bearing portion of said ore as a concentrate at the surface of said suspension, and segregating said concentrate.

4. A method of concentrating an ore of the class consisting of weathered, stained or oxidized metallic mineral ore which comprises agitating and aerating an aqueous suspension of such an ore in the presence of a xanthate and at least one collector of metallic minerals and non-metallic minerals containing occluded metallic minerals of the class consisting of oil-soluble, water-insoluble, but water dispersible mahogany sulphonates and petroleum sulphonic acids to collect the metallic-mineral bearing portion of said ore as a concentrate at the surface of said suspension, and segregating said concentrate.

5. A method of concentrating an ore of the class consisting of weathered, stained or oxidized metallic mineral ore which comprises agitating and aerating an aqueous suspension of such an ore in the presence of a dithiophosphate and at least one collector of metallic minerals and non-metallic minerals containing occluded metallic minerals of the class consisting of oil-soluble, water-insoluble, but water dispersible mahogany sulphonates and petroleum sulphonic acids to collect the metallic-mineral bearing portion of said ore as a concentrate at the surface of said suspension, and segregating said concentrate.

6. A froth flotation process which comprises agitating and aerating an aqueous suspension of particles of a metallic mineral ore, particles of non-metallic gangue and particles of gangue containing said metallic mineral in the presence of a collector of the group consisting of oil-soluble, water-dispersible, and substantially water-insoluble mahogany sulphonates and petroleum sulphonic acids to cause said collector to coat and float said particles of the metallic mineral and said particles of said non-metallic gangue containing metallic mineral.

7. A froth flotation process which comprises agitating and aerating an aqueous suspension of particles of a metallic mineral ore, particles of non-metallic gangue and particles of gangue containing said metallic mineral in the presence of oil-soluble, water-dispersible, and substantially water-insoluble mahogany sulphonates to cause said mahogany sulphonates to coat and float said particles of the metallic mineral and said particles of said non-metallic gangue containing metallic mineral.

8. A froth flotation process which comprises agitating an aqueous suspension of metallic oxide ore in the presence of an oil-soluble, water-dispersible, and substantially water-insoluble mahogany sulphonate to cause said mahogany sulphonate to collect the metallic oxide-bearing portion of the ore at the surface of said suspension.

9. A froth flotation process which comprises agitating an aqueous suspension of a metallic sulphide ore in the presence of an oil-soluble, water-dispersible and substantially water-insoluble mahogany sulphonate to cause said mahogany sulphonate to collect the metallic sulphide-bearing portion of the ore at the surface of said suspension.

10. A method of concentrating a metallic oxide ore which comprises agitating and aerating an aqueous suspension of such an ore in the presence of a xanthate and at least one collector of metallic minerals and non-metallic minerals containing occluded metallic minerals of the class consisting of oil-soluble, water-dispersible, and substantially water-insoluble mahogany sulphonate and petroleum sulphonic acids, to collect the metallic oxide bearing portion of said ore as a concentrate at the surface of said suspension, and aerating said concentrate period.

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