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FLOTATION PROCESS

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This invention relates to a froth flotation process and more particularly refers to a process wherein minerals are floated by means of sulfonated hydrocarbons either alone or in admixture with other flotation agents.

It is an object of this invention to float minerals by a process which is more efficient than those heretofore employed. A further object is to obtain a high quantity and quality concentrate by a process which utilizes agents heretofore unknown to have flotation properties. A still further object is to utilize said agents under such conditions that they will be of maximum value. A still further object is to improve upon prior art flotation processes by the addition thereto of certain compounds never before used for such purposes. Additional objects will become apparent from a consideration of the following specification and claims.

These objects are attained according to the herein described invention which broadly comprises the use in flotation processes of a sulfonated hydrocarbon while maintaining the hydrogen ion concentration of the circuit within the range of about 5.0 to about 9.0. In a more limited sense the invention pertains to a flotation agent comprising sulfonated alcohols preferably containing at least eight carbon atoms in the molecule. The preferred embodiment of this invention comprises flotation agents which are salts of sulfate esters of normal primary alcohols having from twelve to eighteen carbon atoms in the molecule, and in particular organic salts of said sulfate esters.

The invention may be more readily understood by a consideration of the following illustrative examples:

Example 1

1054 grams of a Travancore, India, beach sand middlings obtained from magnetic separators were suspended in water. This middlings product assayed sillimanite 57%, zircon 4%, cyanite 5%, rutile 14.5%, quartz and miscellaneous 19.5%. To the suspension was added 0.3 gram of the lead sulfate salt of lauryl alcohol, small portions of the lead sulfate salts of myristyl, cetyl and stearyl alcohols also being present. The aforementioned flotation agent was water-insoluble so prior to its addition to the flotation cell it was dissolved in 25 cc. ethyl alcohol. The aforesaid suspension was agitated and air passed therethrough, the pH of the circuit being maintained at 5.4 during the run.

An (A) concentrate was obtained weighing 425 grams and containing 99.5% sillimanite.

A (B) concentrate was obtained weighing 104 grams and containing 75% sillimanite.

Tailings weighed 525 grams and contained about 15% sillimanite.

Example 2

1000 grams of the same ore used in Example 1 was suspended in water. To this suspension was added 0.2 gram of the sodium sulfate salt of lauryl alcohol and 0.2 gram of the sodium sulfate salt of stearyl alcohol, small amounts of the sodium sulfate salts of myristyl and cetyl alcohols also being present.

pH was maintained at 5.4 during the run.

527 grams of a high quality concentrate were obtained.

The tailings weighed 473 grams and contained about 12% sillimanite.

Example 3

Example 2 was repeated substituting for the flotation agents used therein 0.6 gram of calcium amyl sulfate. Practically no froth was obtained upon agitation. Only one gram of concentrate was produced, and the quality of this concentrate was practically the same as that of the original ore.

This example was repeated increasing the pH value of the circuit up to 8.4. However, no improvement in the frothing or concentrate of the ore was noted.

Example 4

1000 grams of a lead-zinc sulfide ore from Field, British Columbia, containing 13.84% lead and 12.39% zinc was suspended in water. To this suspension was added the following reagents:

1.5 grams sodium carbonate,

0.05 gram of the sodium sulfate salts of cetyl, oleyl and stearyl alcohols,

0.20 gram of sodium cyanide,

4 drops of oleyl alcohol and 3 drops of a mixture of primary and secondary alcohols and some ketones, the average number of carbon atoms in this mixture being about 7.

The resulting suspension was agitated and 300 grams of a concentrate obtained which assayed 44.1% lead and 21.3% zinc.

To the flotation cell was then added the following reagents: 0.5 gram copper sulfate, 4 drops oleyl alcohol, 4 drops of a mixture of primary and secondary alcohols and ketones averaging about seven carbon atoms to the molecule and 0.05 gram of the sodium sulfate salts of

cetyl, stearyl and oleyl alcohols. This suspension was agitated. The concentrate weighed 241 grams assaying 2.18% lead and 22.4% zinc.

The tailings weighed 459 grams and assayed 1.5% lead and 1.30% zinc.

Example 5

A copper sulfide ore from the Chino Copper Co., Chino, New Mexico, containing 2.98% copper was used in this experiment. 1000 grams of said ore were suspended in water, and to this suspension was added 1.5 grams of sodium carbonate and 0.05 gram of the sodium sulfate salt of lauryl alcohol, small quantities of the sodium sulfate salts of myristyl, cetyl and stearyl alcohols also being present.

The pH was maintained at 7.0 during the run.

The concentrate weighed 242 grams and assayed 9.91% copper.

Example 6

A pulp was made with 1000 grams of copper sulfide ores of the Ray Consolidated Mine, Ray, Arizona, containing 2.92% copper. To this pulp was added 1.5 grams of sodium carbonate and 0.08 gram of pine oil.

The pH was maintained at 7.0 during the run. 35 grams of concentrate were obtained assaying 14.60% copper.

Example 7

The preceding example was repeated substituting 0.05 gram of calcium amyl sulfate for the pine oil referred to therein, all other conditions being maintained exactly the same.

20 grams of concentrate were obtained assaying 13.88% copper.

Example 8

The preceding example was repeated substituting 0.05 gram of the sodium sulfate salt of lauryl alcohol for the calcium amyl sulfate referred to therein.

The concentrate weighed 56 grams and assayed 22.4% copper.

Example 9

1000 grams of bituminous coal containing 8.81% ash were suspended in water. To this suspension was added 0.18 gram of the sodium sulfate salt of lauryl alcohol.

The pH during the run was maintained at about 7.0.

The following concentrates were obtained:

Cleaner concentrate (A) 503 grams, containing 4.11% ash. Cleaner concentrate (B) 287 grams, containing 7.21% ash. Cleaner tails (A) 137 grams, containing 13.46% ash. Cleaner tails (B) 9 grams, containing 56.51% ash. Rougher tails 53 grams, containing 43.73% ash.

Example 10

1000 grams of Alabama barytes containing about 62.5% barium sulfate were suspended in water. To this suspension was added 0.05 gram of the true sodium sulfonate salt of lauryl alcohol.

The pH during the run was maintained at 7.4.

603 grams of concentrate were obtained containing about 98% barium sulfate.

Example 11

The previous example was repeated substituting 0.05 gram of the mono-methyl-cyclohexylamine sulfate salt of lauryl alcohol for the sodium sulfonate salt of the same alcohol used therein.

The concentrate weighed 624 grams and contained about 98% barium sulfate.

The tails were practically stripped of barytes.

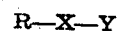
It is to be understood that the aforementioned experiments are illustrative merely of the present invention. Numerous other flotation agents or mixtures thereof as well as innumerable ores may be substituted in these examples without departing from the scope of the present invention. For instance, in place of the sulfate salts of the alcohols referred to sulfate salts of other alcohols may be used. Among these alcohols mention may be made of cetyl, stearyl, octyl, decyl, oleyl, ricinoleyl and linoleyl alcohols. In addition thereto alcohols containing more than one hydroxy group and/or branched-chains may be used as sources of these sulfonated compounds. Mention might here be made of the fact that where reference is made herein to sulfonated hydrocarbons this is meant to include both true sulfonates and sulfate esters of said hydrocarbons.

While the aforementioned sulfonated alcohols are preferred it is to be understood that the sulfonated compounds utilized herein may be derived from other sources, for example olefines, di-olefines and hydrocarbons having one or more commonly occurring groups substituted thereon such as the amino, halogen and nitro groups. Furthermore, fatty acids corresponding to said alcohols and/or to the substituted derivatives thereof may be used in place thereof or in addition thereto.

After sulfonation of the aforementioned hydrocarbons it is advisable to neutralize the sulfonated products with salt-forming constituents. These constituents may be of inorganic or organic origin. Among the salts of inorganic origin mention may be made of the lead, copper, iron, manganese, magnesium, sodium, potassium, calcium, ammonium, lithium, barium, nickel, tin, etc. These salts may be either water-soluble or water-insoluble. Where they are water-insoluble it is in general advisable to dissolve or suspend them in an organic liquid, preferably alcohols containing less than eight carbon atoms, although analogous ketones, ethers, esters and aldehydes may also be used in place thereof or in admixture therewith.

Salt-forming constituents of organic origin have been found to be particularly suitable for the flotation of ores. These salt-forming constituents are preferably amines of either aliphatic or cyclic character. Compounds representing this class of constituents are, for example, pyridine, piperidine, triethanolamine, methylamine, dimethylamine, trimethylamine, cyclohexylamine, mono-methyl-cyclohexylamine, etc.

The aforementioned particularly satisfactory flotation agents may be represented by the following general formula:



wherein R represents a radical containing a hydrocarbon group of at least 8 carbon atoms, X represents a sulfuric acid or sulfonic acid group, and Y represents the residue of an organic salt forming compound. In the preferred embodiment thereof R represents the residue of a normal primary alcohol containing from 12 to 18 carbon atoms, X represents a sulfuric acid group, and Y represents the residue of an organic amine.

In the flotation of ores according to the present invention it is desirable that the hydrogen ion concentration of the circuit be maintained with-

in the range of about 5.0 to about 9.0. If the pH value of the circuit is reduced it has been observed that the froth becomes stronger. Consequently, in order to float a difficulty floatable ore it is ordinarily advisable to utilize a low pH, in some cases a pH sufficiently low to be within the acid range. On the other hand, where the ore is easily floatable it may readily be separated from other ores by utilizing a high pH value.

10 The present invention is applicable to numerous minerals, contained in both sulfide and non-sulfide ores. For example, it may be applied to the following representative ores:

15 Barytes, fluorspar, sillimanite, and other non-sulfide ores.

Coal, both bituminous and anthracite.

Sulfide ores of copper, zinc, lead, iron, nickel, cobalt, molybdenum and other sulfide ores.

20 Arsenides, antimonides, tellurides, and sulfo salts of the metals.

Carbonates, sulfates, tungstates, molybdates, chromates, phosphates, oxides anhydrous and hydrous of the metals and semi-metals.

25 Gold, graphite, sulfur and other native elements.

It is contemplated herein to utilize the sulfonated hydrocarbons referred to in place of prior art sulfide and non-sulfide flotation agents. However, it is also to be understood that the aforesaid sulfonated hydrocarbons may be used in admixture with said prior art flotation agents. This is particularly true in the case of the sulfide agents. Such sulfide agents, as is well known, are ordinarily mercaptans, xanthates, carbamates, etc. In using such customary sulfide flotation agents it has been found that their efficiency is surprisingly increased by the addition thereto of a small amount of the sulfonated hydrocarbons referred to herein, in particular salts of sulfate esters of normal primary alcohols containing from twelve to eighteen carbon atoms.

30 The amount of sulfonated hydrocarbon utilized according to the present invention will, of course, depend to a great extent upon the particular ore to be treated and the other reagents which are to be used. In general, it may be stated that the amount will vary from about 0.001% to about 0.2%, based upon the weight of ore to be floated. For optimum results under a wide variety of conditions an amount of sulfonated hydrocarbon approximately midway between these limits will ordinarily be more satisfactory than either extreme.

35 The present invention permits the flotation of both sulfide and non-sulfide ores in a much more efficient manner than was heretofore possible. It permits prior art flotation agents to be improved or to be entirely replaced by compounds which were previously unknown for this purpose. Likewise, it permits flotation processes which were defective for various reasons to be revived and operated at a minimum of expense and with the production of a high quality concentrate. In accordance with this invention minerals which formerly were difficult or almost impossible to separate may be readily and economically obtained in a concentrated form.

40 As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.

We claim:

75 1. A process for the froth flotation of ores

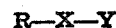
which comprises frothing a suspension of ore in the presence of a flotation agent having the following general formula:



5 wherein R represents a radical containing a hydrocarbon group of at least 8 carbon atoms, X represents a sulfonic acid or sulfuric acid group, and Y represents the residue of an organic amine.

2. The process of claim 1 wherein the pH of the circuit is maintained within the range of about 5.0 to about 9.0.

3. A process for the froth flotation of ores which comprises frothing an aqueous suspension of ore in the presence of a flotation agent having 15 the following general formula:



20 wherein R represents the residue of a normal primary alcohol containing at least 8 carbon atoms, X represents a sulfonic acid or sulfuric acid group, and Y represents the residue of an organic amine.

4. A process for the froth flotation of ores which comprises frothing an aqueous suspension 25 of ore in the presence of a flotation agent having the following general formula:



30 wherein R represents the residue of a normal primary alcohol containing from 8 to 18 carbon atoms, X represents a sulfonic acid or sulfuric acid group, and Y represents the residue of an organic amine, the pH of the circuit being maintained within the range of about 5.0 to about 9.0 35 during said operation.

5. A process for the froth flotation of minerals which comprises agitating and aerating an aqueous suspension of minerals in the presence of a flotation agent having the following general 40 formula:



45 wherein R represents the residue of a normal primary alcohol containing from 8 to 18 carbon atoms, and Y represents the residue of an organic amine, the pH of the circuit being maintained within the range of about 5.0 to about 9.0 during said operation.

6. In a froth flotation process wherein an aqueous suspension of minerals is agitated and aerated in the presence of flotation agents the step which comprises conducting said operation in the presence of an agent having the following general formula:



55 wherein R represents the residue of a normal primary alcohol containing from 8 to 18 carbon atoms, and Y represents the residue of an organic amine.

7. A process for the froth flotation of minerals which comprises agitating and aerating an aqueous suspension of minerals in the presence of a water-soluble flotation agent having the following general formula:



60 wherein R represents the residue of a normal primary alcohol containing from 12 to 18 carbon atoms, and Y represents the residue of an organic amine, the pH of the circuit being maintained within the range of about 5.0 to about 9.0 during said operation.

8. A process for the froth flotation of minerals which comprises agitating and aerating an aqueous 75

ous suspension of minerals in the presence of a water-soluble flotation agent having the following general formula:



- 8 wherein R represents the residue of a normal primary alcohol containing from 12 to 18 carbon atoms, and Y represents the residue of a cyclohexylamine, the pH of the circuit being maintained within the range of about 5.0 to about 9.0 during said operation.
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9. A process for the froth flotation of minerals which comprises agitating and aerating an aqueous suspension of minerals in the presence of the mono-methyl-cyclohexylamine sulfate salt of lauryl alcohol, the pH of the circuit being maintained within the range of about 5.0 to about 9.0 during said operation.

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