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CONCENTRATION OF MINERALS

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This invention relates to the separation of minerals and the concentration of ores by flotation processes, and is particularly directed to such separation and concentration carried out with the utilization of certain organic sulfur compounds.

According to the present invention, improved results can be obtained in the separation of minerals and the concentration of ores by carrying out the flotation operation with the addition to the mineral pulp or ore of a sulfide belonging to or related to the aliphatic series.

The sulfides employed as flotation agents or adjuvants in the process of the present invention are those represented by the formula $R—S_x—R'$ wherein R and R′ stand for the same or different alkyl or aralkyl hydrocarbon radicals or groups such as CH_3, C_2H_5, C_3H_7, C_4H_9, C_5H_{11}, $C_6H_5.CH_2$, etc., and x signifies the number 1 or a number greater than 1. In these sulfides, the group $—S_x—$ is attached or bound on each side to a saturated aliphatic carbon atom. The disulfides as represented by the formula $R—S—S—R'$ where R and R′ stand for the same or similar alkyl or aralkyl groups are particularly important, and especially those which contain no nitrogen in their composition.

In general, the sulfides employed in the present invention can be prepared in any suitable or well-known manner such as, for example, by the action of a halogen derivative of a hydrocarbon, in which the halogen is bound to a saturated aliphatic carbon, on a metal sulfide or polysulfide; by the oxidation of mercaptans wherein the mercapto group, —SH, is bound to an aliphatic carbon atom; by the decomposition by chemical or electrolytic means of the salts of an alkyl—or an aralkyl-thiosulfuric acid; and by dissolving sulfur in the lower sulfides to form the higher or polysulfides. They may be used as flotation agents in the pure or purified state; and, in general, they may be also employed in the crude or impure state.

In carrying out the flotation process of the present invention, the flotation agent comprising the sulfide belonging to or related to the aliphatic series may be incorporated with the ore or the mineral pulp in any suitable manner and at any suitable time which will insure a satisfactory flotation operation. For example, it may be introduced in the free state or it may be dissolved, suspended or dispersed in any suitable solvent or dispersing agent such as, for example, water, or one or more of the usual flotation oils or oil mixtures, or in a suitable organic solvent or medium, and incorporating the resulting solution, suspension or dispersion with the ore or ore pulp. While the agents of the present invention show marked action as flotation agents in ore concentration, some of them also exhibit considerable frothing properties and others not. Ordinarily, they are used to advantage in conjunction with a suitable frothing agent, e. g., pine oil, crude turpentine, terpineol, tar acids, etc. They are sometimes used also to advantage in admixture with each other or in conjunction with other flotation agents, and are particularly valuable when used in conjunction or in admixture with a mercaptan, such as a thioalcohol or a thiophenol, in which they dissolve to form a liquid.

The process of the present invention may be carried out in any suitable apparatus, for example, those of the pneumatic type such as the Callow cell, or those where the air is incorporated with the mixture by mechanical agitation such as the Janney apparatus, or the like.

It is of advantage in many cases, as with certain copper ores, to subject the ore pulp to the action of an amount of alkali sufficient to give it a neutral or an alkaline reaction before subjecting it to flotation with

the aid of the flotation agents of the present invention. The alkali may be caustic alkali such as caustic soda or an alkaline salt such as soda ash, or it may be calcium oxide or hydrate, etc.

In the differential separation of various minerals, such as zinc blende from associated minerals, the presence of an alkali cyanide, or of copper sulfate or other salts, is sometimes advantageous.

The amount of flotation agent required to be used in the flotation process will vary, it depending partly on the character and composition of the ore, partly on the particular sulfide employed, and partly on other factors.

Ordinarily, one-fifth to one-half pound of the flotation agent per ton of ore will be sufficient, but larger or smaller amounts than this may be required.

The invention will be further illustrated by the following specific example. The parts are by weight.

Example: 500 parts of a copper sulfide ore (of Miami Copper Company) assaying 1.22 percent copper was ground in a ball mill with 220 parts water, 0.0625 parts of dibenzyl disulfide,

$$C_6H_5.CH_2—S—S—CH_2.C_6H_5,$$

(equivalent to one-fourth pound per ton of ore), and 0.75 parts hydrated lime (equivalent to 3 pounds per ton of ore) until practically all of the mixture was sufficiently fine to pass a 40 mesh screen. The ground pulp was diluted with water to give a mixture containing about 16 percent solids and subjected to flotation in a Janney flotation apparatus. After agitating for two or three minutes, a small amount of pine oil, e. g., about 0.02 to 0.03 parts, was added. A satisfactory mineral froth was produced. During the next 20 minutes of agitation, a further amount of pine oil was added, sufficient to make a total of about 0.06 to 0.08 parts. Mechanical agitation of the pulp was continued for about 5 minutes after all the pine oil was added. 24.9 parts of concentrate assaying 17.2 per cent copper was obtained which is a recovery of 69. 75 percent of copper. The tailings assayed 0.38 percent copper. It will be noted that the equivalent of about 20.3 tons of ore was required to give 1 ton of concentrate.

In a similar test using 500 parts of an Anaconda copper ore analyzing 152 percent copper, and employing 0.0625 parts of isoamyl disulfide in place of dibenzyl disulfide, there was obtained 46.4 parts concentrate assaying 15.3 percent copper which is a recovery of 93.5 percent copper.

Example 2: 500 parts of a copper ore (of the Anaconda Copper Company) assaying 1.52 percent copper was treated as in Example 1 except 0.0625 parts of n-butyl monosulfide was used in place of dibenzyl disulfide. 68.1 parts of concentrate assaying 10.05 percent copper was obtained which is a recovery of 90.6 percent. The tailings assayed 0.16 percent copper. It may be mentioned that n-butyl monosulfide possesses considerable frothing qualities and may be employed without the use of an additional frothing agent.

In a similar test on the same ore except that 0.0625 parts of allyl monosulfide was used in place of isoamyl disulfide there was obtained 49.2 parts concentrate assaying 13.7 percent copper which is a recovery of 89.5 percent.

Other flotation agents, such as ethyl monosulfide, n-propyl monosulfide, isopropyl monosulfide, isoamyl monosulfide, benzyl monosulfide, ethyl disulfide, n-propyl disulfide, isopropyl disulfide, and n-butyl disulfide, have been found to give analogous results. In general, the disulfides effect a better separation than the monosulfides.

It will thus be noted that the present invention contemplates the utilization as flotation agents in the separation of minerals and the concentration of ores of those sulfides and polysulfides wherein sulfur is attached to a saturated aliphatic carbon atom; that said flotation agents may be incorporated in or with the ore or mineral pulp at any suitable time and in any suitable manner; that they may be used in the free state or in admixture with one another or in solution, suspension or dispersion in any suitable solvent or medium; and that they may be used in conjunction with other flotation agents or with frothing agents, or with both.

It will be understood that the present invention is applicable to the treatment of various kinds of mineral mixtures, both natural and artificial, which are amenable to concentration by flotation processes.

It will be further understood that the invention is not limited in this specification to the use of the particular agents or other ingredients mentioned in the example, and that other agents, particularly other flotation agents of the class mentioned, can be used.

In the specification and claims, the terms "alkyl" and "aralkyl" denote hydrocarbon radicals, that is, radicals composed only of carbon and hydrogen in their composition.

We claim:

1. In effecting the concentration of minerals by flotation, the process which comprises mixing with the mineral pulp a sulfide of the probable formula $R—S_x—R'$ wherein R and R′ stand for the same or different alkyl or aralkyl hydrocarbon radicals and x has a value of 1 or more, and subjecting the resulting mixture to a froth flotation operation.

2. In effecting the concentration of minerals by flotation, the process which comprises

mixing with the mineral pulp a sulfide of the probable formula $R—S_x—R'$ where R and R′ stand for an alkyl hydrocarbon or aralkyl group and x has a value of 2 or more, and subjecting the resulting mixture to a froth flotation operation.

3. In effecting the concentration of minerals by flotation, the process which comprises subjecting a mineral pulp to a froth flotation operation in the presence of a sulfide of the probable formula R—S—S—R′ wherein R and R′ stand for the same or different alkyl or aralkyl hydrocarbon radicals.

4. In effecting the concentration of minerals by flotation, the process which comprises subjecting a mineral pulp to a froth flotation operation in the presence of dibenzyl disulfide.

5. In effecting the concentration of minerals by flotation, the process which comprises subjecting the mineral in the form of an alkaline pulp to a froth flotation operation in the presence of an organic sulfide having the following probable formula: $R—S_x—R'$ where R and R′ stand for the same or different alkyl or aralkyl hydrocarbon radicals and x has a value of 1 or more.

6. In effecting the concentration of ores by flotation, the process which comprises subjecting the ore in the form of a suitable pulp to a froth flotation operation in the presence of a diaralkyl polysulfide, the diaralkyl radical containing only carbon and hydrogen in its composition.

7. In effecting the concentration of minerals by flotation, the process which comprises subjecting a mineral pulp to a froth flotation operation in the presence of a sulfide having the following probable formula: $R—S_x—R'$ where x has a value of 1 or more, and R and R′ stand for the same or different aralkyl hydrocarbon radicals.

8. In effecting the concentration of ores by flotation, the process which comprises subjecting an ore pulp to a froth flotation operation in the presence of a sulfide embodying within its composition the probable grouping $—S_x—$ where x has a value of 1 or more, and said grouping being attached on each side to a saturated aliphatic carbon atom of a hydrocarbon radical.

9. In effecting the concentration of copper sulfide ores by flotation, the process which comprises mixing with a copper sulfide ore pulp a sulfide of the probable formula, $R—S_x—R'$ wherein R and R′ stand for the same or different alkyl or aralkyl hydrocarbon radicals and x has a value of one or more, and subjecting the resulting mixture to a froth flotation operation.

10. In effecting the concentration of copper sulfide ores by flotation, the process which comprises subjecting a copper sulfide ore pulp to a froth flotation operation in the presence of a sulfide of the probable formula, R—S—S—R′ wherein R and R′ stand for the same or different alkyl or aralkyl hydrocarbon radicals.

11. In effecting the concentration of copper sulfide ores by flotation, the process which comprises subjecting a copper sulfide ore pulp to a froth flotation operation in the presence of dibenzyl disulfide.

In testimony whereof we affix our signatures.

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