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PROCESS OF ORE CONCENTRATION

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The present invention relates to an improved process of ore concentration of the type in which selected minerals of the ore are caused to be attached to bubbles of air or other gas with the view to bringing about their separation from the others.

The ores capable of treatment by the process of the present invention may contain minerals included in all three of the following classes:

A. This first class consists of metalliferous minerals having metallic, resinous, or adamantine luster. Among the many minerals of this type may be mentioned the sulfides of such common metals as lead, zinc, iron, copper, nickel, etc.; the native metals such as gold, silver, copper, etc.; and the precious metal compounds such as the gold tellurides, silver sulfides, silver selenides, etc.

B. This second class consists of non-silicon-bearing minerals characterized by what is known as vitreous or earthy luster. These minerals all contain metal atoms of such character and in such state of combination as to enable them to form insoluble soap in the presence of soluble soap. Well-known examples of minerals of this type are calcite, dolomite, rhodochrosite, magnesite, witherite, smithsonite, strontianite, siderite, anglesite, barite, celestite, gypsum, scheelite, fluorite, etc.

C. This third class consists of silicon-bearing minerals which also have vitreous or earthy luster, but which are in themselves incapable of reacting with soluble soap. These minerals either have no soap-producing metal atoms whatever or contain them in a form unavailable for soap production. Among the various minerals of this type are included quartz, micas, garnets, feldspars, and many other silicates.

In prior processes of concentration applicable to ores containing minerals of class A, it has always been the practice to effect the customary gas-bubble attachment on these minerals or at least to include them among the minerals selected for this attachment. In this respect the procedures of the present invention may be said to constitute an inverse of the usual procedures of concentration. Stated in other words, the process of the present invention is one which is carried out under conditions such as to cause a water wetting of the minerals of class A. In accordance with this process, it is the minerals of class B which are always included among the minerals selected for the customary air-bubble attachment. The process of the present invention is therefore one which invariably separates the minerals of class B from the minerals of class A by gas-bubble attachment to the minerals of class B. As to the minerals of class C, they may either be separated by gas-bubble attachment with the minerals of class B or be water wetted

with the minerals of class A, depending on the particular procedures employed.

In accordance with the invention, ores containing mixed minerals of classes A and B are treated with water-soluble soap in conjunction with one or more inorganic alkaline substances which are deliberately chosen with the view to depressing the class A minerals. By reaction with the metal atoms contained in the class B minerals, the water-soluble soap functions to selectively produce insoluble soap coatings on these minerals, which results in their selective attachment to gas bubbles. However, this gas-bubble attachment is actually made selective by the inorganic alkaline substance or substances employed along with the water-soluble soap. This is based on my discovery that inorganic alkaline substances yield ions in solution of more or less effective depressing action on class A minerals. As I have found, aside from the varying effectiveness of these depressing ions, there is considerable variation in the susceptibility of class A minerals to depression in this manner. Consequently, there must be proper choice of the inorganic alkaline substance or substances employed to depress the class A minerals in my process. The water-soluble soap is then effective as a selective gas-bubble attaching agent for the class B minerals, which in their state of gas-bubble attachment may be separated from the class A minerals.

The inorganic alkaline substances useful as the depressing agent of the invention include all alkalis and salts of alkaline reaction that may properly be referred to as inorganic. While these substances all have in common the property of yielding hydroxylion or promoting its appearance in aqueous solution, this should not be regarded in every case as the sole determining factor of their usefulness in my process. As the negatively charged portions of their molecules, they yield by simple dissociation a class of ions which are all capable in varying degree of depressing class A minerals. Only in the case of simple bases is hydroxylion produced in this manner. In the case of salts, it is produced merely by hydrolysis, but produced with the anion of the salts themselves as another depressing ion. Consequently, I may use substances like hydrosulfide of slight alkaline reaction and rely principally on their own negatively charged ions for depression. The depressing ions which inorganic alkalis and inorganic salts of alkaline reaction produce in aqueous solution rather than any property peculiar to the alkaline character of these various substances should be regarded as the criterion of their usefulness as the depressing agent of the invention.

While proper choice must be made of the inorganic alkaline substances in my process, there

is nevertheless real usefulness of these substances as a class. Of the common substances of the class I have found the effectiveness of depression decreasing approximately in the following order: 5 normal sulfide, hydrosulfide, polysulfide, cyanide, hydroxide, silicate, phosphate, and carbonate. While I have succeeded in keeping some minerals 10 of class A from sticking to gas in the presence of water-soluble soap by the use of alkali carbonate, it did not seem possible to achieve this result with other minerals of the same class when using any quantity of this alkaline substance. But in all cases I found it possible in the presence of water-soluble soap to effect a thorough 15 wetting of class A minerals by the use of alkali sulfide. Generally stated, substances yielding normal sulfide, hydrosulfide, or polysulfide ions may always be used in my process. These as the most effective may actually be required in some 20 cases, yet equally satisfactory results may be obtained in other cases with cyanide, in still other cases with hydroxide, and so on down the line to and including carbonate as the least effective. It is clear that any inorganic alkaline substance may be used in my process which is so 25 chosen from the point of view of its effectiveness as to bring about the desired depression of the particular class A minerals involved.

In addition to the alkaline substances which 30 have been specifically mentioned, trithiocarbonate devoid of alkyl groups has been found to have a certain degree of effectiveness.

The use of more than one inorganic alkaline substance in my process may frequently be found 35 to be of advantage. A combination which has proved particularly advantageous is normal sulfide and hydroxide; another is the same as the first with the addition of cyanide; and another still is cyanide with hydrosulfide.

It is understood that the various inorganic 40 alkaline substances capable of use in my process may contain any of the alkali metals or their equivalent ammonium. Such substances may also contain alkaline-earth metals, although this is 45 not preferred.

By the term "soap" as used herein is meant not only fatty acid soap, but also substances characterized by soap-like properties. The so-called resin acid soaps and sulfonic acid soaps 50 have thus the same useful function in the process of the present invention as fatty acid soap. Whichever substance is used as soap, it is also understood that it need not be added as such to the ore, but that it can be produced in situ by 55 reaction of soap-forming acid with alkali. For this purpose, of course, the alkali should be such as to result in the production of water-soluble soap.

When the substance used as soap is one depending on an aliphatic hydrocarbon chain for its effectiveness, as in the case of fatty acid and sulphonic acid soaps, this chain should be long enough to enable the production of insoluble 65 coatings on the minerals of class B. Generally stated, it is desirable that such chains should have not less than eleven carbon atoms. In this respect I have found oleic acid soap to be ideal, but the process of the present invention can also 70 be carried out with soaps containing such radicals as those derived from undecylenic, lauric, myristic, and palmitic acids. I have also successfully used stearic and linoleic acid soaps.

It is not required that the substances used as 75 soap be chemically pure. For example, the reac-

tion products of alkali with fish oil, corn oil, and many other oils are satisfactory.

In general, the process of the present invention may be more effectively carried out by the additional use of a hydrocarbon oil, which by itself 5 is worthless. Preferably, this oil should be one which is not appreciably volatile at ordinary temperatures and also one which is not too viscous nor yet too fluid. Suitable oils for this purpose are lubricating oil, kerosene, heavy petroleum distillate, etc. Gasoline can be used, but it is preferred to use a "heavier" oil. Although 10 fuel oil can be used, it is preferred to avoid it because of its frequent contamination with such organically combined sulfur compounds as mercaptans and other sulfides, which are more or less good gas-bubble attaching agents for minerals of class A. In view of the low market price of fuel oil, however, it may in certain cases be economically desirable to employ it in preference 20 to other oils. Whichever oil is used, of course, it may be initially treated to remove organic sulfur.

If the ore contains minerals of class C in addition to minerals of classes A and B, its treatment 25 by the agents of the invention (with or without hydrocarbon oil) ordinarily results in a separation of the class B minerals from both the class A minerals and the class C minerals. However, by the addition of suitable activators for the 30 minerals of class C, these can be made adherent to gas bubbles and therefore be separated with the minerals of class B. For this separation such activators should contain the necessary metal atoms for insoluble soap formation. Good and 35 convenient activators for this purpose are lime, lime salts, baryta, and barium salts.

It is understood that where the water used in carrying out the process of the present invention already contains salts of an activating nature 40 with reference to the minerals of class C, the aforementioned separation of these minerals with the minerals of class B can in certain cases be carried out without adding further quantities of such salts. 45

On the other hand, if the minerals of class C are to be water wetted with the minerals of class A, the presence in the water of salts of an activating nature with reference to the class C minerals is more or less objectionable. It may thus 50 be found desirable in some cases to soften the water, as by the use of zeolite.

It is of course understood that the use of soft water is in all cases recommended for a more effective wetting of the class C minerals. Clean 55 water is also preferred. It may even be found advisable in some instances to cleanse the surfaces of the class C minerals. This can be done by preliminary treatment of the ore with a dilute solution of an alkali cyanide, carbonate, 60 citrate, or fluorite; or with a dilute solution of a combination of these substances. Dilute solutions of this type may have a total salinity of the order of magnitude of 0.1 to 0.2%, although smaller quantities are often sufficient. 65

If desired, the wetting of class C minerals may be promoted by the use of depressors for such minerals, such as sodium silicate. In most cases, however, this practice will be found unnecessary, because of unresponsiveness of class C minerals 70 to gas-bubble attachment in the absence of activators.

In the usual manner the process of the present invention includes the preliminary step of conditioning the ore with the various agents em- 75

ployed. For this purpose any suitable device may be used in which the ore in aqueous suspension is thoroughly agitated with the agents under such conditions that air or other gas may enter the ore suspension. Such devices include barrel-type mixers, grinding mills, paddle-type agitators, and even conveying launders. For this conditioning operation the thickest kind of pulp is desirable, since this reduces the agent quantities required.

The subsequent step of separating the mineral particles adhering to gas from those adhering to water can be carried out on gravity concentrating devices of any type, such as shaking tables, vanners, etc., or in flotation machines of any type, such as mechanically agitated machines, pneumatic machines, etc. In tabling some of the mineral particles adhering to gas are lifted by the riffles or otherwise to the upper free surface of the water to form a skin float, while the others form aggregates in suspension below the free water surface and above the water-wetted mineral particles, both skin float and aggregates being ejected at the side of the table. In flotation sufficient gas is additionally introduced to float the mineral particles adhering to gas in the form of a mineral-bearing froth, which overflows the lip of the machine.

The process of the present invention is applicable to particle sizes of the following general classes: (1) coarsely granular particles ranging from approximately one-eighth of an inch to approximately one three-hundredth of an inch; and (2) finely granular particles smaller than approximately one one-hundredth of an inch, with or without a lower size limit. In dealing with particles of class (1) separation is effected by gravity concentrating apparatus, while in dealing with particles of class (2) separation is effected by flotation apparatus, it being understood that the limits mentioned in connection with the two size classes in no way constitute rigorous limits.

The particle size at which it is suitable to carry out the process is determined by the degree of locking in the ore. For some ores such grinding may be required as to adapt them entirely for flotation separation. On the other hand, other ores may require grinding merely to a size suitable for tabling operation. In still other cases the grinding may be such as to adapt the ores in part for flotation separation and in part for tabling separation. In any case the very finest particles of the ore may be passed to waste, to concentrates, or to further processing, as desired.

For the guidance of the operator, there will now be discussed the agent quantities to be used in the carrying out of my process. It is understood, of course, that the agent quantities required in each case depend on various conditions inclusive of the particle size of the affectable minerals, the purity of the water employed, the particular ore and separation contemplated, the consistency of the ore suspension, etc. For this reason, my invention should not be construed as being in any way limited to the particular agent quantities which will be indicated.

With coarsely granular material I prefer to use per ton of ore from 0.2 to 2.0 lbs. of water-soluble soap (fatty acid soap or its equivalent, added as such or produced in situ). On the other hand, the quantity of such soap should be larger for finely granular material because of the much greater mineral surface to cover. Convenient quantities in these instances are from 0.3 to 3.0 lbs. per ton of ore, although the amount may even be reduced below 0.3 lb. under favorable condi-

tions. In any case the amount of water-soluble soap required is largely determined by the quantity of salts contained in the water used during the conditioning operation, hard waters requiring a greater amount than soft waters. By the use of distilled water I found that as little as 0.2 lb. of water-soluble soap per ton of ore was required in the presence of sodium sulfide and hydrocarbon oil to make calcite wholly gas-adherent from delimed coarsely ground ore containing it in admixture with galena, pyrite, and sphalerite. On the other hand, when I used the water supplied to the city of Butte, Montana, which contains soluble salts to the extent of about 100 parts per million, I found it necessary to increase the quantity of the soap to 0.7 to 1.0 lb. per ton of ore to obtain similar results under conditions otherwise the same as before. In practice, therefore, a preliminary softening of the water may in certain cases represent a considerable economy in water-soluble soap, which more than pays for the cost of water softening, especially if the circuit water is reused.

The preferred quantities of hydrocarbon oil for coarsely granular material are from 1.0 to 3.0 lbs. per ton of ore, but these amounts are not strictly defined. In fact, the hydrocarbon oil may be left out altogether, although from an economical standpoint this is not recommended. If the hydrocarbon oil is omitted, there is a tendency of the coarsest grains of class B minerals to fail to adhere to gas, with the result that larger quantities of water-soluble soap are required. One of the useful features of hydrocarbon oil is that it makes relatively immaterial what kind of wash water is used on a shaking table after completion of the conditioning. The quantities of hydrocarbon oil for finely granular material should be larger not only from the point of view of increased mineral surface, but also from the point of view of excessive frothing of the ore pulp in flotation, a condition which is corrected by the use of hydrocarbon oil. Frequently good results are obtained with 2.0 to 10.0 lbs. per ton of ore.

With reference to the sodium sulfide depressing agent of the invention, its amount reckoned in proportion to the water used during conditioning should generally be about the same for both coarsely and finely granular material. I have found that the required amount of this agent is principally related to the particular class A minerals involved. Of the more common minerals of this class, namely, the sulfides of lead, copper, zinc, and iron, the lead sulfide appears to be the most difficult to prevent from adhering to gas. For practical purposes galena is best inhibited by conditioning in an alkaline sulfide, hydro-sulfide, or polysulfide solution of a concentration of the order of 0.1 to 0.5%, although a solution of this type may in certain cases be effective in depressing coarsely granular galena at a much lower concentration. Copper and iron sulfides are inhibited at a lower concentration than galena, while virgin sphalerite is inhibited at a mere fraction of the concentration required for lead sulfide. Activated sphalerite can also be inhibited, but a greater quantity of inorganic alkaline substance or substances is required. If several sulfides occur together, the quantity of depressing agent should be larger than in dealing with the more readily inhibited minerals, while perhaps not as large as in dealing with the more difficultly inhibited minerals.

If the ore pulp during conditioning contains one-half solids, the depressing agent requirement

is approximately 2.0 to 10.0 lbs. per ton of ore in the case of a galena ore, but less for ores containing other sulphides. On the other hand, if an ore pulp containing two-thirds solids is used, the depressing agent requirement can be reduced practically in half. This is one reason why it is preferred to carry out the conditioning operation in as thick a pulp as possible. In this connection it should be noted that in dealing with finely granular material the use of pulps as thick as those readily obtainable with coarsely granular material is very difficult to realize in practice, for which reason the consumption of depressing agent per ton of ore is likely to be higher for finely granular material than for coarsely granular material.

It is understood that the aforementioned quantities of depressing agent are merely approximate because of possible occurrence of other variables. Especially favorable conditions may thus prevail, such as a particularly clean surface on the class A minerals of the ore treated, with the result that a smaller quantity of depressing agent is sufficient to inhibit such minerals. Also, there may be present in the ore some substance like lead carbonate or copper carbonate, which is capable of consuming the depressing agent. In these instances, of course, a greater quantity of depressing agent has to be used, which is particularly true in connection with finely granular material, for the depressing agent consumer is in a finer state of subdivision and in this state does its damage faster. I have witnessed cases where the depressing agent requirement was as low as 0.1 lb. per ton, and others where it was as high as 20.0 lbs. per ton.

Also subject to wide variations are the required quantities of the substances used as activators in connection with class C minerals. Such substances can thus be added in amount ranging from 0.2 lb. to 3.0 lbs. per ton of ore, depending on such conditions as the alkalinity of the pulp, the hardness of the water, the extent of mineral surface to be activated, etc.

As to the aforementioned possible use of sodium silicate as a depressor for the minerals of class C, its quantity may range up to 2.0 lbs. per ton of ore and even more, a convenient quantity to start with being 0.05 lb. per ton.

When tabling is employed, the conditioning solution may be kept separate from the tabling water by settling, draining, or filtering the ore suspension from the conditioning solution, which results in an appreciable economy of the agents, particularly of the water-soluble soap and of other water-soluble substances.

In the carrying out of my process, it is desirable that the ore suspension be admixed with the various agents employed at a sufficiently high degree of alkalinity to promote the desired attachment of gas to the class B minerals. However, if class C minerals are present and are to be water wetted with the class A minerals, the alkalinity of the suspension should not be allowed to become excessively large to secure a thorough wetting of the class C minerals, for it is much easier to prevent gas-bubble attachment to these minerals at moderate degrees of alkalinity than at high degrees of alkalinity. The best range of alkalinity within which to operate in each case is obviously a question of simple preliminary experimentation. For the guidance of the operator, however, certain ranges will now be given which have been

found generally satisfactory in the practice of my process.

By experience I have found that the alkalinity of the conditioning solution should in all cases be preferably such as to exceed the pH value 9.0. If class C minerals are to be water wetted, it is desirable to maintain the alkalinity within the pH range 9.0 to 11.5. If on the contrary such minerals are to be made gas adherent, it is desirable to carry the alkalinity to a higher level, perhaps within the pH range 12.0 to 13.0. These ranges in pH values are not at all rigorous, since fair results have been obtained outside their limits. Generally stated, however, I have found the best results to agree with the ranges given.

Examples will now be given describing certain tests which have been made in carrying the invention into effect.

Example 1

A -20 to +100-mesh table middling consisting of chalcocite (copper sulfide) and calcite with minor occurrences of malachite, azurite, covellite, and pyrite, from Kennecott, Alaska, was mixed with 1.0 lb. of sodium oleate, 1.6 lbs. of light lubricating oil, and 1.5 lbs. of sodium sulfide (of 60% commercial grade), all per ton of ore. The resulting mixture was treated on a shaking table. The product which adhered to air was almost wholly calcite, while the product which adhered to water was almost wholly chalcocite. The copper carbonates were divided, the azurite going with the calcite and the malachite with the chalcocite. Most of the carbonate in the water-wetted product was introduced as malachite and azurite locked with the sulfide particles. The metallurgical results were as follows:

Product	Percent weight	Percent grade		Percent recovery	
		S	CO ₂	S	CO ₂
Feed.....		11.6	17.5		
Table side.....	39.0	0.2	42.9	0.7	92.5
Table end.....	61.0	19.6	2.2	99.3	7.5

Comparative test

The same feed as in Example 1 was processed in exactly the same manner except for the omission of sodium sulfide. No appreciable separation of calcite from copper was obtained, both being ejected as an air-attached product at the side of the table.

Example 2

A rhodochrosite ore from the Emma mine, Butte, Montana, crushed to 10-mesh and freed by classification of particles finer than 65-mesh, was taken for the purpose of this example. Besides rhodochrosite (manganese carbonate), this ore contains sulfides (pyrite, sphalerite, and galena), as well as quartz and such silicates as are currently contained in granitic rocks and veins. First the ore was mixed in thick pulp with 1.2 lbs. of sodium oleate, 1.5 lbs. of fuel oil, and 5.0 lbs. of sodium hydroxide, all per ton of ore, which mixing lasted about one minute and was performed by manual agitation in a large flask, the pH of the pulp during conditioning being 12.6. Thereafter, the pulp was passed over an ordinary Wilfley table, the sulfides and silica-bearing minerals going to the end of the table and the

rhodochrosite to the side. The metallurgical results were as follows:

Product	Percent weight	Percent grade			Percent recovery		
		Mn	S	Ins.	Mn	S	Ins.
Table side.....	69.6	39.6	0.37	4.1	92.0	17.2	12.5
Table end.....	30.4	7.9	4.12	68.7	8.0	82.8	87.5

Example 3

Another sample of the same batch of ore as used in Example 2 was mixed with 1.5 lbs. of common soap, 1.5 lbs. of light lubricating oil, and 0.1 lb. of sodium hydroxide, all per ton of ore. The pH during mixing dropped to 10.2, but the results were almost as good as those of Example 2.

Example 4

In this instance a sample of rhodochrosite ore very high in sphalerite (zinc sulfide), but practically free of lead or other sulfides, was employed. Although not representative of the Butte ore as a whole, this sample showed that a good separation of rhodochrosite from sphalerite is possible by attaching the manganese mineral to air while keeping the zinc mineral wet. The sample, approximately 10 to 100-mesh in particle size, was mixed with 1.0 lb. of sodium oleate, 1.8 lbs. of heavy kerosene distillate, and 3.0 lbs. of sodium hydroxide, all per ton of ore. After mixing it was passed on a Wilfley table, a heavy band of thoroughly wetted sulfides being observed on the table discharging at the end, with the rhodochrosite coming off as a skin float and aerated aggregates at the side. The metallurgical results were as follows:

Product	Percent weight	Percent grade		Percent recovery	
		Mn	Zn	Mn	Zn
Table side.....	42.6	38.0	0.9	84.7	1.5
Table end.....	57.4	5.1	43.9	15.3	98.5

Example 5

A sample of rhodochrosite ore very high in both lead and zinc sulfides, approximately 20 to 100-mesh in particle size, was treated in accordance with the same agents and procedures as in Example 4. There was a separation of rhodochrosite from the sulfides, but it was not as good as either of those obtained in Examples 4 and 6, either with reference to the lead or with reference to the zinc.

Example 6

Another sample of the same batch of ore as used in Example 5 was mixed with 1.0 lb. of sodium oleate, 1.8 lbs. of heavy kerosene distillate, and 3.0 lbs. of sodium sulfide, all per ton of ore, after which mixing it was treated on a Wilfley table. The metallurgical results were good as can be seen in the following tabulation:

Product	Percent weight	Percent grade			Percent recovery		
		Mn	Zn	Pb	Mn	Zn	Pb
Table side.....	47.2	38.5	0.5	0.7	91.5	1.8	3.4
Table end.....	52.8	3.2	25.5	17.8	8.5	98.2	96.6

Example 7

A sample of rhodochrosite ore from Butte, picked to contain much lead and zinc, was ground in a pebble mill for 15 minutes with half its weight of water. The pulp was then transferred to a flotation cell, some dilution being necessary for this transfer. The pulp in the flotation cell was conditioned at about 30% solids with 10.0 lbs. of sodium sulfide, 1.2 lbs. of sodium oleate, and 5 lbs. of light lubricating oil, all per ton of ore. A good rhodochrosite float was obtained practically free of sulfides, while the tailing was high in sulfides. The metallurgical results were as follows:

Product	Percent weight	Percent grade			Percent recovery		
		Mn	Zn	Pb	Mn	Zn	Pb
Floated.....	67.0	34.6	3.0	2.9	93.2	19.5	19.0
Non-floated.....	33.0	5.1	25.2	25.0	6.8	80.5	81.0

Example 8

A sample of the same table middling as in Example 1 was ground in a pebble mill for 15 minutes with half its weight of water. The pulp was then transferred to a flotation cell with some dilution. The pulp in the cell was conditioned with 10.0 lbs. of sodium sulfide, 6.0 lbs. of lubricating oil, and 2.0 lbs. of sodium oleate, all per ton of ore. The floated product was high in calcite, while the non-floated product was high in sulfides. The metallurgical results were as follows:

Product	Percent weight	Percent grade		Percent recovery	
		S	CO ₂	S	CO ₂
Floated.....	39.4	1.4	38.9	4.6	86.6
Non-floated.....	60.6	18.8	3.9	95.4	13.4

Example 9

In this instance a lead ore was taken containing galena and other sulfides in admixture with calcite, silica, and silicates. This ore, received in a coarse state of aggregation, was crushed to 20-mesh. The 20 to 100-mesh fraction was conditioned with 3.0 lbs of sodium sulfide, 3.0 lbs. of sodium hydroxide, 1.0 lb. of lime, and 1.0 lb. of common soap, all per ton of ore, after which it was passed on a shaking table. The metallurgical results were as follows:

Product	Percent weight	Percent grade			Percent recovery		
		Pb	CO ₂	Ins.	Pb	CO ₂	Ins.
Table side.....	72.4	0.6	12.5	65.3	6.0	96.5	86.3
Table end.....	27.6	24.6	1.2	27.2	94.0	3.5	13.7

Example 10

A sample of rhodochrosite ore from Butte containing galena, sphalerite, pyrite, quartz, and silicates was crushed to 65-mesh and mixed at a 40% pulp density with 2.0 lbs. of kerosene, 7.0 lbs. of sodium sulfide, and 2.0 lbs. of common soap, all per ton of ore, the pulp having a pH of 12.1 during this mixing. Thereafter, the pulp was

subjected to flotation with the following results:

Product	Percent weight	Percent grade			
		Pb	Zn	Mn	Ins.
Floated.....	65.5	0.08	0.32	38.8	11.4
Non-floated.....	34.5	2.6	6.2	11.0	54.5

Example 11

A duplicate sample of the same ore as in Example 10 was processed in identical manner except that the sodium sulfide was replaced by sodium hydrosulfide, which was used in the same amount of 7.0 lbs. per ton, the pulp in this instance having a pH of 9.6 during mixing. The results are shown in the following tabulation, it being noted that the rejection of insolubles in the floated product was clearly better than in Example 10:

Product	Percent weight	Percent grade			
		Pb	Zn	Mn	Ins.
Floated.....	61.3	0.10	0.28	42.4	6.9
Non-floated.....	38.7	2.4	5.6	7.6	62.2

It is understood that either of the two products separated by the agents of the invention can thereafter be treated in accordance with known methods for further separation of minerals from one another. These subsequent separations can thus be carried out as between galena, sphalerite, pyrite, and silicon-bearing minerals; also as between copper minerals, pyrite, and silicon-bearing minerals; etc. If the initial separation by the agents of the invention is performed on coarsely granular material, a thorough washing by water with a view to removing the inorganic alkaline substance is all that is required to render either of the table side or table end products ready for further processing. On the other hand, such washing alone is in general insufficient to remove the inorganic alkaline substances when the initial separation by the agents of the invention is performed on finely granular material. One way of obliterating the inorganic alkaline substances in these instances is by oxidation, for which purpose air can be passed through the floated or non-floated product, as the case may be. Another way is to separate solution from solids by classification, thickening, and filtration. Counter-current separation of solids from solution is possible and, in fact, desirable for the purpose of reducing agent consumption.

In carrying out the process of the present invention, the ore can first be sized so as to separate it into a coarsely granular fraction and a finely granular fraction, which in many cases enables improved metallurgical results to be obtained by effecting different separations on the two fractions by the agents of the invention.

The process of the present invention may obviously be carried out so as to repeat some of its steps. For example, a finished concentrate of gas-adhering minerals may first be obtained, after which the water-adhering product may be reground and retreated or merely retreated without regrinding. Again, a finished concentrate of water-adhering minerals may first be obtained, after which the gas-adhering product may be reground and retreated or merely retreated without regrinding. Such retreatment practices are familiar to those skilled in the art.

If desired, the ore may be deslimed prior to its treatment by flotation. By making the particle size fine enough at which this desliming is carried out, e. g., one one-thousandth of an inch or still finer, the loss in the slime may often be reduced to a level actually permitting economies in operation.

In the claims, the term "soap" should be regarded as including fatty acid soap and all of its equivalents (e. g., resin acid soap and sulfonic acid soap); the term "inorganic alkaline substance" as including all inorganic substances of alkaline reaction in aqueous solution; and the term "alkaline-reacting sulfide" as including normal sulfide, hydrosulfide, and polysulfide.

What is claimed is:

1. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing a recoverable portion of at least one metalliferous mineral of a metallic, resinous or adamantine luster, hereinafter referred to as class A mineral, and at least one non-silicon-bearing mineral of a vitreous or earthy luster, hereinafter referred to as class B mineral, in the presence of normal amounts of a collector consisting of a water-soluble soap and a depressing agent for class A mineral consisting of at least one inorganic alkaline substance, and subsequently separating a class B mineral enriched material adhering to gas from a class A mineral enriched material adhering to water.

2. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing a recoverable portion of at least one metalliferous mineral of a metallic, resinous or adamantine luster, hereinafter referred to as class A mineral, and at least one non-silicon-bearing mineral of a vitreous or earthy luster, hereinafter referred to as class B mineral, in the presence of normal amounts of a collector consisting of a water-soluble soap, a hydrocarbon oil, and a depressing agent for class A mineral consisting of at least one inorganic alkaline substance, and subsequently separating a class B mineral enriched material adhering to gas from a class A mineral enriched material adhering to water.

3. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing a recoverable portion of at least one metalliferous mineral of a metallic, resinous or adamantine luster, hereinafter referred to as class A mineral, at least one non-silicon-bearing mineral of a vitreous or earthy luster, hereinafter referred to as class B mineral, and at least one silicon-bearing mineral of a vitreous or earthy luster, hereinafter referred to as class C mineral, in the presence of normal amounts of a collector consisting of a water-soluble soap and a depressing agent for class A mineral consisting of at least one inorganic alkaline substance, and subsequently separating a class B mineral enriched material adhering to gas from a class A mineral enriched material adhering to water.

4. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing a recoverable portion of at least one metalliferous mineral of a metallic, resinous or adamantine luster, hereinafter referred to as class A mineral, at least one non-

silicon-bearing mineral of a vitreous or earthy luster, hereinafter referred to as class B mineral, and at least one silicon-bearing mineral of a vitreous or earthy luster, hereinafter referred to as class C mineral, in the presence of normal amounts of a collector consisting of a water-soluble soap, a depressing agent for class A mineral consisting of a least one inorganic alkaline substance, and an activating agent for class C mineral consisting of an inorganic substance containing an alkaline earth metal for insoluble soap formation, and subsequently separating a class B mineral enriched material adhering to gas from a class A mineral enriched material adhering to water.

5. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing a recoverable portion of at least one metalliferous mineral of a metallic, resinous or adamantine luster, hereinafter referred to as class A mineral, and at least one non-silicon-bearing mineral of a vitreous or earthy luster, hereinafter referred to as class B mineral, in the presence of normal amounts of a collector consisting of a water-soluble soap and a depressing agent for class A mineral consisting of an inorganic alkaline-reacting sulfide, and subsequently separating a class B mineral enriched material adhering to gas from a class A mineral enriched material adhering to water.

6. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing a recoverable portion of at least one metalliferous mineral of a metallic, resinous or adamantine luster, hereinafter referred to as class A mineral, and at least one non-silicon-bearing mineral of a vitreous or earthy luster, hereinafter referred to as class B mineral, in the presence of normal amounts of a collector consisting of a water-soluble soap and a depressing agent for class A mineral consisting of an inorganic alkaline-reacting sulfide in combination with at least one other inorganic alkaline substance, and subsequently separating a class B mineral enriched material adhering to gas from

a class A mineral enriched material adhering to water.

7. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing rhodochrosite admixed with a recoverable portion of at least one metalliferous sulfide mineral in the presence of normal amounts of a collector consisting of a water-soluble soap and a depressing agent for metalliferous sulfide mineral consisting of at least one inorganic alkaline substance, and subsequently separating the rhodochrosite particles adhering to gas from the metalliferous sulfide mineral particles adhering to water.

8. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing rhodochrosite admixed with a recoverable portion of at least one metalliferous sulfide mineral and at least one silicon-bearing gangue mineral in the presence of normal amounts of a collector consisting of a water-soluble soap and a depressing agent for metalliferous sulfide mineral consisting of at least one inorganic alkaline substance, and subsequently separating the rhodochrosite particles adhering to gas from the particles of metalliferous sulfide mineral and silicon-bearing gangue mineral adhering to water.

9. A process of concentration which comprises agitating under gas-introducing conditions an aqueous suspension of suitably divided particles of an ore containing rhodochrosite admixed with a recoverable portion of at least one metalliferous sulfide mineral and at least one silicon-bearing gangue mineral in the presence of normal amounts of a collector consisting of a water-soluble soap, a hydrocarbon oil, and a depressing agent for metalliferous sulfide mineral consisting of at least one inorganic alkaline substance, and subsequently separating the rhodochrosite particles adhering to gas from the particles of metalliferous sulfide mineral and silicon-bearing gangue mineral adhering to water.

ANTOINE M. GAUDIN.

CERTIFICATE OF CORRECTION.

Patent No. 2,231,265.

February 11, 1941.

ANTOINE M. GAUDIN.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, first column, line 53, for "air-bubble" read --gas-bubble--; page 2, second column, line 61, for "fluorite" read --fluoride--; page 3, second column, line 45, strike out the words "sodium sulfide"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of March, A. D. 1941.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)