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RECOVERY OF MOLYBDENITE BY FLOTATION

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This invention relates to the separation of molybdenite by selective flotation from a complex ore containing molybdenite together with various other metallic sulfides. The invention provides an improved process which is particularly suited for recovering molybdenite in high concentration from a preliminary flotation concentrate containing large amounts of both copper sulfide and iron sulfide and only a very small amount of molybdenite.

Although molybdenite (molybdenum sulfide, MoS_2) is found in barely discernible quantities practically whereever igneous rocks are known, by far the largest molybdenite deposits found throughout the world are closely associated with those acidic plutonic rocks which frequently contain relatively large concentrations of other sulfides, notably copper sulfide and iron sulfide. Because molybdenite is but a minor constituent in these complex cupriferous ores, the bulk sulfide flotation concentrates isolated from the ore contain a very small proportion of molybdenite, usually less than 0.5 percent. In addition to the problem of extricating and concentrating this small amount of molybdenite from the concentrate, the recovery of molybdenite is usually further complicated by a residual coating of sulfhydric collector and frother which is carried over with the concentrate. Despite the ease with which molybdenite floats, before any molybdenite can be selectively floated from the concentrate the residual collector usually must be decomposed or a specific depressant employed to depress the flotation of the bulk mineral sulfides (i.e. copper and iron sulfides).

The residual sulfhydric collector coating which adheres to the bulk sulfide concentrate is generally either a thiophosphate or a xanthate, both of which may be chemically destroyed by one of two heretofore proposed methods. In the first, the concentrate is heated to a temperature of about 100° C. either by prolonged treatment of an aqueous pulp of the concentrate with live steam or by drying the bulk sulfide concentrate with hot flue gases. Heating of flotation concentrate destroys both types of sulfhydric collector coatings by decomposing the collector ion. In the second method of chemically decomposing the collector coating, the flotation concentrate is conditioned with an oxidizing agent in either an acidic or alkaline medium to oxidize the collector coating. With either method, however, undesirable results accrue, for the thermal destruction of the collector coating is exceptionally wasteful of heat, requiring the boiling or roasting of massive amounts of pulp to recover a very small quantity of molybdenite, while the oxidative conditioning of the bulk sulfide flotation concentrate with an oxidizing agent is ineffective unless the oxidation is substantially carried to completion.

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Another method of inhibiting the flotation of the bulk (copper and iron) mineral sulfides while selectively floating molybdenite is based upon the use of certain inorganic compounds which are capable of exerting a specific depressive effect on the flotation of copper sulfides. These inorganic compounds (described in the Nokes, Quigley and Pring United States Patent No. 2,492,936, granted December 27, 1949, and commonly known as "Nokes' reagents") contain phosphorus, arsenic, or antimony combined with bivalent sulfur and an inorganic cation. The effectiveness of these reagents as depressants of the bulk sulfides is more or less impaired, however, when the sulfide flotation concentrate is contaminated with residual flotation agents from the preliminary flotation operation by which it was formed (i.e. a residual collector, such as a xanthante or a thiophosphate, and a residual frother such as amyl alcohol or pine oil). To meet this problem it has been proposed to employ the "Nokes' reagent" depressant in conjunction with either activated carbon or charcoal, both of which enhance the effectiveness of the depressant in the presence of residual flotation reagents.

These carbonaceous materials, however, have a pronounced tendency to float along with molybdenite, and so seriously dilute the proportion of molybdenum sulfide in the concentrate; moreover, the carbon must be subsequently removed from the concentrate to produce a high grade and readily marketed molybdenum sulfide product.

I have found that a notable improvement in the recovery of molybdenite by flotation from a bulk sulfide flotation concentrate containing a relatively very large concentration of copper is achieved when the "Nokes' reagent" depressant is used in conjunction with a small concentration of a dimethylpolysiloxane. By subjecting an aqueous pulp of the bulk sulfide concentrate to froth flotation in the presence of the inorganic (Nokes' reagent) compound and a dimethylpolysiloxane, an exceptionally good grade of molybdenite concentrate is selectively floated, and a markedly improved recovery of molybdenite from a material containing it in only very low concentration, is attained. Moreover, these results are secured without the necessity of using any activated carbon or charcoal, or heating or oxidizing the bulk mineral sulfide concentrate to destroy residual flotation agents.

Based on these discoveries, the invention provides an improved process for recovering molybdenite from a flotation concentrate containing copper sulfide and molybdenite which comprises subjecting an aqueous pulp of the concentrate to froth flotation in the presence of a frothing agent, a dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and an inorganic compound of an element selected from the group consisting of phosphorus, arsenic, and antimony, said inorganic compound containing bivalent sulfur and an inorganic cation and being present in an amount sufficient to depress the bulk sulfide minerals without substantial depression of molybdenum sulfide.

An extremely large number of chemically individual bulk sulfide depressants are available for use to selectively depress the flotation of the bulk sulfides (i.e., copper sulfide and iron sulfide) without hindering the selective flotation of molybdenite. As indicated above, these depressants are the reagents described in the aforementioned Nokes, Quigley and Pring United States Patent No. 2,492,936, and are inorganic compounds which contain phosphorus, arsenic or antimony together with bivalent sulfur and an inorganic cation. Where the depressant is a phosphorus compound, it may be prepared by reacting thiophosphoryl chloride (in which sulfur is already present in the bivalent state) together with either sodium hydroxide, calcium hydroxide, sodium silicate, sodium carbonate, ammonium hydroxide, ammonium phosphate, sodium phosphate or sodium borate. Another method of preparing phosphorus-containing depressants is based on the use of phosphorus sulfides, notably phosphorus pentasulfide. In such cases, the phosphorus pentasulfide is reacted with either sodium hydroxide, calcium hydroxide, sodium silicate, sodium carbonate, ammonium hydroxide, ammonium carbonate, ammonium phosphate, sodium phosphate, sodium borate, calcium cyanide or sodium cyanide, all of which react with phosphorus pentasulfide to form bulk sulfide depressants.

Arsenic-containing compounds which depress the flotation of the bulk mineral sulfides but not molybdenite may be prepared by reacting arsenic sulfide with either sodium hydroxide, potassium hydroxide or calcium hydroxide, or alternatively, by reacting arsenic oxide together with sulfur and an alkali metal hydroxide. Antimony-containing depressants may be prepared in a similar manner, such as via the reaction of antimony oxide, sulfur and an alkali metal hydroxide.

The dimethylpolysiloxanes, or silicone oils as they are frequently called, which are used in the method of the invention, are usually represented by the formula

$$H_3C-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{Si}}}}-\left[O-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{Si}}}}\right]_n-O-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{Si}}}}-CH_3$$

in which n is an integer, the formula representing a trimethyl silyl end-blocked dimethylpolysiloxane. However, either or both the terminal and intermediary methyl groups may be replaced or substituted in whole or in part with other organic (i.e. ethyl and phenyl) or even inorganic radicals. Even when thus substituted, the polymers are generically known as polysiloxanes and are the full equivalent of the dimethylpolysiloxanes. These silicone oils are high molecular weight polymers whose viscosity varies directly with the molecular weight. For effective use in conjunction with the "Nokes' reagent" in carrying out the method of this invention, especially in treating concentrates containing residual flotation agents, the molecular weight of the dimethylpolysiloxane should be high enough to impart to it a viscosity of at least 200 centipoises at 25° C. Dimethylpolysiloxanes having such high viscosities are soluble in benzene but very sparingly soluble in water, and consequently these substances are generally added to the flotation pulp in the form of an aqueous emulsion. Various thickening agents, such as silica gel, may be incorporated in the emulsion to stabilize it.

The quantities of reagents used in the process are, of course, dependent upon many factors, including the relative concentrations of molybdenite and copper sulfide in the bulk mineral sulfide flotation concentrate and the amount and type or organic collector and frother present. In the rougher flotation of molybdenite, for example, the processing of a ton of concentrate generally requires from 2 to 5 pounds of the bulk sulfide depressant ("Nokes' reagent") and from 0.1 to 0.5 pound of an oil-in-water emulsion containing from about 5 to 30 percent of a dimethylpolysiloxane. Lesser amounts of the bulk sulfide depressant are required in subsequent cleaner flotations; generally a further addition of from 0.25 to 0.5 pound per ton of cleaner concentrate has been found satisfactory in the cleaner operations.

Although further additions of the dimethylpolysiloxane may also be made to the pulp in the subsequent cleaner flotation operations, once it has been used in the rougher flotation a sufficient quantity ordinarily is carried over into subsequent flotation operations so that no further additions are required.

The flotation reagents present in carrying out the method of the invention need be only those present as residuals from the production of the original bulk sulfide concentrate. Any sulfhydric collector for sulfide minerals, and any frothing agent, may be used. Indeed, the collector may be absent altogether, for molybdenite will float in the presence of a frother alone. The amount of frother, and collector if present, will normally be in the range from a mere trace amount to perhaps 3 pounds per ton of concentrate produced in the molybdenite rougher operations, and usually no further addition will be made in the subsequent cleaner operations.

Any standard flotation cell may be used in both the rougher and cleaner flotations of molybdenite in accordance with the invention, including the standard Fagergren and subaeration types of flotation cells. The equipment may be arranged in any convenient manner.

The applicability of using a "Nokes' reagent" bulk sulfide depressant in conjunction with a dimethylpolysiloxane to recover molybdenite in accordance with the process of the invention is illustrated by the following two series of flotation operations which were carried out on a bulk sulfide concentrate containing only about 0.04 percent molybdenite and 10 to 13 percent copper. Table I summarizes the results achieved in the first series of eight separate tests (designated as Tests 1 to 8), in which an aqueous pulp of the concentrate was initially heated with steam to a temperature of about 100° C. to deactive any residual collector and frother, and then subjected to a rougher flotation and five cleanings, the reagents being 2 pounds of a bulk sulfide depressant per ton of concentrate in the rougher flotation, and 0.25 pound per ton in each of the subsequent cleanings. In the second series of eight tests (designated as Tests 9 to 16), which are summarized in Table II, an aqueous pulp of the concentrate was subjected to a rougher flotation and seven cleanings, using 2 pounds of a bulk sulfide depressant and 0.25 pound of an aqueous (oil-in-water type) emulsion containing 30 percent by weight of a dimethylpolysiloxane (viscosity greater than 200 centipoises at 25° C.) per ton of concentrate in the rougher flotation, and further addition of only 0.25 pound per ton of the sulfide depressant in each of the subsequent seven cleanings. The "Nokes' reagent" bulk sulfide depressant used in all of the tests was prepared by reacting 10 parts by weight of phosphorus pentasulfide with 13 parts by weight of sodium hydroxide in aqueous solution. In the first series of tests (Table I) a matty, uncontrollable foam was formed during the flotation operation, but in the second series of tests (Table II) no such foam was formed. The test results demonstate that the depressant effect which is exerted by the "Nokes' reagent" on the flotation of the bulk mineral sulfides is enhanced by the concurrent use of the dimethylpolysiloxane, with the result that a high concentration of molybdenite and a notably low concentration of copper is recovered from a heads in which the molybdenite concentration is extremely low.

TABLE I

Metallurgical results

[Nokes' reagent and steam treatment]

Test No.	Heads, Percent Mo	Rougher Tails, Percent Mo	Concentrate			
			Percent Mo	Percent Ins.	Percent Fe	Percent Cu
1	.07	.03	54.91	2.52	.71	2.08
2	.07	.03	54.96	2.60	.62	1.64
3	.08	.03	37.77	3.46	3.16	16.90
4	.04	.01	41.30	2.32	2.80	12.00
5	.12	.02	55.97	2.72	0.83	1.73
6	.08	.01	46.46	2.00	1.66	11.30
7	.07	.02	48.07	1.52	1.24	8.21
8	.10	.03	55.00	4.24	0.52	0.31
Average	.08	.023	49.31	2.67	1.44	6.77

TABLE II

Metallurgical results

[Nokes' reagent and dimethylpolysiloxane]

Test No.	Heads, Percent Mo	Rougher Tails, Percent Mo	Concentrate			
			Percent Mo	Percent Ins.	Percent Fe	Percent Cu
9	.07	.03	55.03	2.56	.71	1.02
10	.08	.04	53.70	2.68	.62	.84
11	.07	.02	53.27	2.28	.71	1.93
12	.05	.02	44.97	2.90	1.86	8.20
13	.12	.02	52.26	3.42	0.93	4.19
14	.08	.01	52.15	3.34	1.13	1.66
15	.08	.02	52.96	2.30	1.24	2.57
16	.09	.02	56.03	2.98	0.93	0.33
Average	.08	.023	52.55	2.81	1.02	2.59

Two additional series of flotation operations covering fourteen separate tests were carried out on a bulk sulfide concentrate containing an average molybdenite content of only about 0.08 percent. Table III summarizes the results achieved in seven of these tests (designated as Tests 17 to 23), in which an aqueous pulp of the concentrate was subjected to a rougher flotation and five cleanings, using 2 pounds of the "Nokes' reagent" depressant and 2 pounds of activated carbon per ton of concentrate in the rougher flotation, and further additions of 0.25 pound of the sulfide depressant per ton of concentrate in each of the subsequent cleanings. In the next seven tests (designated as Tests 24 to 30), which are summarized in Table IV, an aqueous pulp of the bulk mineral concentrate was subjected to rougher flotation and five cleanings, the reagents being 2 pounds of "Nokes' reagent" and 0.5 pound of an oil-in-water type emulsion containing 30 percent by weight of a dimethylpolysiloxane (viscosity greater than 200 centipoises at 25° C.) per ton of concentrate in the rougher flotation with further additions of only 0.25 pound of the sulfide depressant per ton of concentrate in each subsequent cleaner flotation operation. As before, the "Nokes' reagent" bulk sulfide depressant used in all of the tests was prepared by reacting 10 parts by weight of phosphorus pentasulfide with 13 parts by weight of sodium hydroxide in aqueous solution. In the tests summarized in Table III a matty and voluminous foam, formed; whereas the tests summarized in Table IV were untroubled by such foaming. The average amounts of molybdenite recovered when the "Nokes' reagent" was used in conjunction with a dimethylpolysiloxane (Table IV) was five times greater than when the "Nokes' reagent" was employed with activated charcoal (Table III). In addition, the average grade of the molybdenite concentrate produced was greater, and its average copper contact was less, in each of Tests 24 to 30, which employed the process of the invention, than in Tests 17 to 23, in which activated charcoal was used.

TABLE III

Metallurgical results

[Nokes' reagent and activated carbon]

Test No.	Heads, Percent Mo	Rougher Tails, Percent Mo	Concentrate				Percent Recovery Mo
			Percent Mo	Percent Ins.	Per cent Fe	Per cent Cu	
17 [1]	.10	.04	50.66	6.40	.87	1.27	6.86
18 [2]	.07	.02	45.85	4.32	1.80	3.35	2.55
19	.12	.04	48.23	7.74	.71	2.19	4.14
20	.17	.03	54.08	2.96	.61	.63	3.14
21	.13	.04	49.43	3.58	.61	.61	4.93
22	.11	.04	55.30	2.00	.92	.46	3.39
23	.11	.06	54.26	4.26	.76	.47	8.59
Average [3]	.12	.034	50.58	4.12	.93	1.45	3.63

[1] Concentrate cleaned only four times.
[2] Concentrate cleaned only three times.
[3] Average does not include test 23, since spillage occurred because of excessive froth.

TABLE IV

Metallurgical results

[Nokes' reagent and dimethylpolysiloxane]

Test No.	Heads, Percent Mo	Rougher Tails, Percent Mo	Concentrate				Percent Recovery Mo
			Percent Mo	Percent Ins.	Per cent Fe	Per cent Cu	
24	.12	.04	47.40	13.80	1.07	1.49	26.44
25	.14	.04	49.97	8.90	.76	2.06	30.21
26	.08	.02	55.78	3.96	.51	.70	17.85
27	.13	.03	53.43	7.16	.66	.77	13.64
28	.18	.03	52.77	5.80	.71	2.03	13.48
29	.16	.03	54.39	4.20	.51	.99	22.56
30	.14	.02	55.31	4.26	.66	1.47	37.28
Average	.138	.026	54.34	5.10	.61	1.19	20.96

To further illustrate the invention, a preferred embodiment is described below as it was applied to the treatment of a bulk mineral sulfide flotation concentrate. The bulk mineral sulfide concentrate was isolated from a complex copper ore by a conventional initial sulfidic flotation in the presence of lime, potassium ethyl xanthate (a sulfhydric collector) and amyl alcohol (a frothing agent). This concentrate contained approximately 0.15 percent by weight of molybdenum sulfide together with from 25 to 30 percent by weight each of copper and iron sulfides, the remainder being silica and other insolubles.

The pulp density of this cleaner concentrate was adjusted to about 50 percent solids, and the pulp conditioned for 1 minute in a rougher conditioner with the addition of 0.13 pound per ton of concentrate of an oil-in-water type emulsion containing about 30 percent by weight of a dimethylpolysiloxane having a viscosity of about 450 centipoises at 25° C., and 3.5 pounds per ton of concentrate of "Nokes' reagent" prepared by reacting 13 parts by weight of sodium hydroxide (in 20 percent aqueous solution) together with 10 parts by weight of phosphorus pentasulfide and spray drying the resultant product.

Following the rougher conditioning, the pulp was introduced into a bank of flotation cells where it was held for a flotation time of 3 to 5 minutes. The tailings from this rougher flotation, amounting to over 97 percent of the heads, contained only about 0.01 percent by weight of molybdenite.

The rougher concentrate, having a molybdenite concentration of about 2.5 percent, was next subjected to a first cleaner flotation, and the resultant concentrate was immediately transferred to a bank of flotation cells for a second cleaner flotation. The only reagent added in the first and second cleaner flotations was 0.5 and 0.25 pound per ton of concentrate, respectively, of the "Nokes' reagent."

The concentrate recovered from the second cleaner flotation contained about 20 percent by weight of molybdenite. This concentrate was reground in a ball mill to separate the molybdenite from gangue, and the reground concentrate was then conditioned for approximately 5 to 6 minutes, with a further addition of 0.25 pound per ton of concentrate of the "Nokes' reagent." After adjusting the pulp density to 5 percent solids, it was then subjected to a third cleaner flotation operation. The third cleaner concentrate contributed only about 0.2 percent of the original heads and contained about 30 percent by weight of molybdenite.

Prior to conducting a fourth cleaner flotation, the concentrate of the third cleaner step was conditioned for approximately 5 minutes with 0.25 pound per ton of concentrate of the "Nokes' reagent" as the sole additive, and the pulp density adjusted to 3 percent solids. The conditioned pulp was then subjected to the fourth cleaner flotation, which yielded a concentrate containing 51 percent by weight of molybdenite.

Next, after conditioning in the presence of about 0.5

pound per ton of sodium silicate cyanide and a further addition of 0.25 pound per ton of the "Nokes' reagent," the concentrate recovered from the fourth cleaner flotation was subjected to the final cleaner flotation. The concentrate obtained was leached with a hot 20 percent solution of sodium cyanide to remove residual copper. The resultant molybdenite concentrate contained 56 percent by weight of molybdenite, 0.6 percent by weight of iron and less than 0.3 percent by weight of copper.

I claim:

1. A process for recovering molydenite from a flotation concentrate containing copper sulfide and molybdenite which comprises subjecting an aqueous pulp of the concentrate to froth flotation in the presence of a frothing agent, from 0.1 to 0.5 pound per ton of concentrate of an aqueous emulsion containing from 5 to 30 percent by weight of a dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and from 2 to 5 pounds per ton of concentrate of an inorganic compound of an element selected from the group consisting of phosphorus, arsenic, and antimony, said inorganic compound containing bivalent sulfur and an inorganic cation.

2. A process for recovering molybdenite from a flotation concentrate containing copper sulfide and molybdenite which comprises subjecting an aqueous pulp of the concentrate to froth flotation in the presence of a frothing agent, from 0.1 to 0.5 pound per ton of concentrate of an aqueous emulsion containing from 5 to 30 percent by weight of a dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and from 2 to 5 pounds per ton of concentrate of an inorganic compound of phosphorus, said inorganic compound containing bivalent sulfur and an inorganic cation.

3. A process for recovering molybdenite from a flotation concentrate containing copper sulfide and molybdenite which comprises subjecting an aqueous pulp of the concentrate to froth flotation in the presence of a frothing agent, from 0.1 to 0.5 pound per ton of concentrate of an aqueous emulsion containing from 5 to 30 percent by weight of a dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and the inorganic reaction product of approximately 13 parts by weight of sodium hydroxide with approximately 10 parts by weight of phosphorus pentasulfide in aqueous solution.

4. A process for recovering molybdenite from a flotation concentrate containing copper sulfide and molybdenite isolated from a complex cupriferous ore and contaminated with a sulfhydric collector and a frother, which comprises subjecting an aqueous pulp of the concentrate to rougher flotation in the presence of (*a*) from 0.1 to 0.5 pound per ton of concentrate of an aqueous emulsion containing from about 5 to 30 percent by weight of a dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and (*b*) from 2 to 5 pounds per ton of concentrate of the inorganic reaction product of approximately 13 parts by weight of sodium hydroxide with approximately 10 parts by weight of phosphorus pentasulfide in aqueous solution.

5. A process for recovering molybdenite from a flotation concentrate containing copper sulfide and molybdenite which comprises first subjecting an aqueous pulp of the concentrate to a rougher flotation operation in the presence of a frothing agent, from 0.1 to 0.5 pound per ton of concentrate of an aqueous emulsion containing from 5 to 30 percent by weight of a dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and from 2 to 5 pounds per ton of concentrate of an inorganic compound of phosphorus containing bivalent sulfur and an inorganic cation, and then subjecting an aqueous pulp of the rougher concentrate to at least one cleaner flotation in the presence of a further addition of said inorganic compound.

6. A process for recovering molybdenite from a flotation concentrate containing copper sulfide and molybdenite isolated from a complex cupriferous ore and contaminated with a sulfhydric collector and a frother, which comprises first subjecting an aqueous pulp of the concentrate to a rougher flotation operation in the presence of (*a*) from 0.1 to 0.5 pound per ton of concentrate of an aqueous emulsion containing from about 5 to 30 percent by weight of a dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and (*b*) from 2 to 5 pounds per ton of concentrate of the inorganic reaction product of approximately 13 parts by weight of sodium hydroxide with approximately 10 parts by weight of phosphorus pentasulfide in aqueous solution, and then subjecting an aqueous pulp of the rougher concentrate to at least one cleaner flotation operation in the presence of a further addition of from 0.25 to 0.5 pound per ton of concentrate of said inorganic reaction product.

7. A process for recovering molybdenite from a flotation concentrate containing copper sulfide and molybdenite which comprises subjecting an aqueous pulp of the concentrate to a rougher flotation operation in the presence of a frothing agent, from 0.1 to 0.5 pound per ton of concentrate of an aqueous emulsion containing from 5 to 30 percent by weight of a dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and from 2 to 5 pounds per ton of concentrate of an inorganic compound of phosphorus containing bivalent sulfur and an inorganic cation, then subjecting an aqueous pulp of the rougher concentrate to successive cleaner flotation operations each in the presence of said inorganic compound, and leaching the final cleaner concentrate with a hot aqueous solution of an alkali metal cyanide to dissolve substantially all of the remaining copper sulfide from the molybdenite.

8. A process for recovering molybdenite from a flotation concentrate containing copper sufide and molybdenite isolated from a complex cupriferous ore and contaminated with a sulfhydric collector and a frother, which comprises subjecting an aqueous pulp of the concentrate to a rougher flotation operation in the presence of (*a*) from 0.1 to 0.5 pound per ton of concentrate of an aqueous emulsion containing from about 5 to 30 percent by weight of dimethylpolysiloxane having a viscosity of at least 200 centipoises at 25° C., and (*b*) from 2 to 5 pounds per ton of concentrate of the inorganic reaction product of approximately 13 parts by weight of sodium hydroxide with approximately 10 parts by weight of phosphorus pentasulfide in aqueous solution, subjecting an aqueous pulp of the rougher concentrate to successive cleaner flotation operations each in the presence of a further addition of from 0.25 to 0.5 pound per ton of concentrate of said inorganic reaction product, and leaching the final cleaner concentrate with a hot aqueous solution of an alkali metal cyanide to dissolve substantially all of the remaining copper sulfide from the molybdenite.

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