

UNITED STATES PATENT OFFICE.

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CONCENTRATION OF ORES.

No Drawing.

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To all whom it may concern:

Be it known that I, CHARLES K. McARTHUR, Jr., a subject of the King of Great Britain, residing at Butte, in the county of Silver Bow, State of Montana, have invented certain new and useful Improvements in the Concentration of Ores; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to the concentration of ores by flotation and, more particularly, to the differential flotation of mixed sulfide ores. The invention has for its object the provision of an improved method of concentrating mixed or complex sulfide ores by differential flotation. More particularly, the invention aims to provide an improved method of concentrating by differential flotation a mixed or complex sulfide ore containing lead and/or copper and/or silver sulfides associated with zinc and/or iron sulfides.

Throughout this specification and the appended claims the term "ore" includes ores, concentrates, tailings, slimes, and other products containing metalliferous sulfides. The process of the invention is especially adapted for the differential separation by flotation of sulfide minerals in an oiled flotation concentrate or in other mixed sulfide flotation products.

The present invention involves treating the mixed or complex sulfide ore with a halogen, such as chlorine, bromine or iodine, and with a cyanide, such as an alkali, alkaline earth or metallic cyanide, and thereafter subjecting the so treated ore to a flotation operation in the presence of an appropriate flotation agent. The treatment of the ore with the halogen and cyanide is preferably a time treatment, that is to say, the mixed sulfide ore is preferably subjected to the action of the halogen and cyanide for a substantial period of time, say thirty minutes. This treatment is preferably carried out as a preparatory or preliminary step to the differential flotation operation, although it will be understood that the preparatory aspect as well as the time element feature may be modified or dispensed with according to the requirements of the particular mixed sulfide ore undergoing treatment.

The mixed sulfide ore to be treated is re-

duced to a flotatable size, usually by grinding to the desired degree of fineness in a ball mill. In treating crude ores and the like, I prefer to introduce the halogen and the cyanide into the ball mill whereby intimate contact of these agents with the sulfide minerals is effected in the course of the grinding. In treating mixed sulfide concentrates or the like, the halogen and cyanide may be added in any appropriate manner to the concentrate. After the ore has been subjected for the required period of time to the action of the halogen and cyanide, the ore pulp is conducted to a flotation apparatus of any of the well-known types and subjected therein to differential flotation. An appropriate flotation agent is added to the ore pulp for the flotation operation, and this may be advantageously done by adding the flotation agent to the ore during grinding.

The treatment of the ore with the halogen and cyanide should take place under neutral (that is non-acid) or slightly alkaline pulp conditions, and the differential-flotation operation should similarly be conducted with a neutral or slightly alkaline pulp. As a result of the treatment of the ore with a halogen and cyanide, the lead, copper and silver sulfides become readily amenable to flotation while flotation of the zinc sulfide is to a large extent inhibited. The flotation of the iron sulfide may be appreciably effected with the lead, copper and silver sulfides, or appreciably inhibited with the zinc sulfide, according to the relative amounts of halogen and cyanide used. In general, the greater the ratio of the amount of halogen to cyanide the greater the amount of iron sulfide floated with the lead sulfide.

After the removal of the lead and/or copper and/or silver froth concentrate, the flotation of the zinc sulfide in the remaining pulp may be in large part effected in a second flotation operation, in which the iron is in large part inhibited with or without the addition of an alkali, alkaline earth salt, alkaline salt, or a hydroxide, and with or without the addition of copper sulfate, and with the addition of an appropriate frothing and collecting agent. The iron in the tailings of the second flotation operation may be in a large part recovered by a further flotation operation.

In applying the present invention to the treatment of a mixed or combined flotation

concentrate containing lead and/or copper and/or silver sulfides and zinc and/or iron sulfides, of such fineness that the sulfide particles are free, or to a very great extent free, the concentrate is taken from a convenient point in the flotation circuit, either prior to or after dewatering, and passed into a suitable container large enough and so constructed as to give a thorough mixing of the concentrate and reagents with the necessary time treatment. One or more halogens and a cyanide in sufficient quantities to condition the oil or other flotation agent in the concentrate are added to the container or to the concentrate prior to the introduction of the concentrate into the container. The amount of these reagents may be varied to meet any conditions that may arise. A hydroxide, such, for example, as sodium hydroxide may if desired or necessary be employed in conjunction with the halogen and cyanide for appropriately conditioning the oil or other flotation agent present in the concentrate. After this treatment, the concentrate is appropriately conveyed to any suitable type of flotation machine, in which the flotation of the lead and/or copper and/or silver sulfides is in large part effected and the flotation of the zinc sulfide is in large part inhibited. This flotation operation may be promoted by the addition of a suitable flotation agent, depending upon the condition of the concentrate pulp. According to the relative amounts of halogen and cyanide used, the iron sulfide may be floated with the lead to an appreciable extent or appreciably inhibited, as desired.

The practice of the invention will be further illustrated by the following examples:

(1) 1500 grs. of ore (thru 10 mesh) assaying 5.1 ozs. Ag, 5.0% Pb, 10.3% Zn, and 7.4% Fe, to which was added 750 cc. of water, 0.8 lb. of bromine per ton of ore, and 0.4 lb. of sodium cyanide per ton of ore, was placed in a ball mill and ground until the sulphides particles were free and of a size suitable for flotation. The ore was then placed in a laboratory flotation machine, where, with the addition of 0.4 lb. of Barrett #4 oil, a silver lead float, carrying with it an appreciable amount of the iron, and assaying 30.0 ozs. Ag, 40.1% Pb, 14.5% Zn, and 11.4% Fe, was made. 1.0 lb. of copper sulphate, 4.0 lbs. of sodium carbonate and 0.2 lb. of Barrett #634 oil was then added to the contents of the flotation machine, where a zinc float assaying 3.6 ozs. Ag, 1.9% Pb, 57.6% Zn, and 3.0% Fe, was made. The tailing from this test assayed 1.0 oz. Ag, 0.1% Pb, 0.5% Zn, and 6.4% Fe.

In the above test, by using a relatively large amount of bromine, namely eight tenths (0.8) lb. per ton of ore, and at the same time a relatively small amount of cyanide, the flotation of the iron is appreciably

effectuated with the flotation of the lead.

(2) 1500 grs. of ore (thru 10 mesh) assaying 11.3 ozs. Ag, 7.7% Pb, 9.7% Zn, and 5.1% Fe, to which was added 750 cc. of water, 0.4 lb. of bromine per ton of ore, and 1.0 lb. of sodium cyanide per ton of ore, was placed in a ball mill and ground until the sulphide particles were free and of a size suitable for flotation. The ore was then placed in a laboratory flotation machine, where with the addition of 0.3 lb. of Barrett #4 oil, a silver-lead float, very free from iron, assaying 71.2 ozs. Ag, 68.1% Pb, 9.5% Zn, and 2.6% Fe, was made. 1.0 lb. of copper sulphate, 3.0 lbs. of sodium carbonate, and 0.3 lb. of Barrett #634 oil per ton of ore was then added to the contents of the flotation machine, where a zinc float assaying 13.4 ozs. Ag, 2.8% Pb, 52.0% Zn, and 4.6% Fe, was made. The tailings from this test assayed 1.4 oz. Ag, 0.1% Pb, 0.7% Zn, and 5.6% Fe.

In the above test, the extent to which the iron was inhibited from floating with the lead, is due to the relatively small amount of bromine, and relatively large amount of cyanide.

(3) 1500 grs. of a mixed or combined flotation concentrate, with a density of 35% solids, assaying 16.2 ozs. Ag, 4.0% Pb, 55.5% Zn, and 2.2% Fe, was placed in a square glass mixing jar, mechanically driven, with an amount of bromine equivalent to one (1.0) lb. per ton of dry concentrates, and sodium cyanide equivalent to two (2.0) lbs. per ton of dry concentrates, and subjected to a time treatment of thirty (30) minutes. The concentrate was then removed from the jar and placed in a callow laboratory flotation machine, where, without the addition of further reagents, a float assaying 24.4 ozs. Ag, 44.5% Pb, 16.2% Zn, and 11.0% Fe, and a residue assaying 15.4 ozs. Ag, 0.7% Pb, 60.1% Zn, and 1.0% Fe, was made.

In the above test, by using a relatively large amount of bromine, namely, one (1.0) lb. per ton of dry concentrates, and a relatively small amount of cyanide, the flotation of the iron is in a large part effected with the flotation of the lead.

(4) 1500 grs. of a mixed or combined flotation concentrate, with a density of 35% solids, assaying 17.1 ozs. Ag, 5.9% Pb, 56.0% Zn, and 1.78% Fe, was placed in a square glass mixing jar, mechanically driven, with an amount of bromine equivalent to three-tenths (0.3) lb. per ton of dry concentrates, and amounts of sodium cyanide equivalent to two and five-tenths (2.5) lbs. per ton of dry concentrates, and subjected to a time treatment of thirty (30) minutes. The concentrate was then removed from the jar, and without the addition of further reagents, placed in a callow laboratory flotation ma-

chine, where a float assaying 27.4 ozs. Ag, 55.0% Pb, 18.0% Zn, and 2.4% Fe, and a residue assaying 14.6 ozs. Ag, 0.3% Pb, 60.4% Zn, and 1.6% Fe, was made.

5 In the above test, the extent to which the iron was inhibited from floating with the lead, is due to the relatively small amount of bromine and the relatively large amount of cyanide.

10 I claim:—

1. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between different sulfide minerals in the ore, and subjecting the so-treated ore to a flotation operation whereby the flotation of one sulfide mineral is in large part effected while the flotation of another sulfide mineral is in large part inhibited.

2. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing lead and zinc sulfides, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between the lead and zinc sulfides, and subjecting the so-treated ore to a flotation operation whereby the flotation of the lead sulfide is in large part effected while the flotation of the zinc sulfide is in large part inhibited.

3. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing lead sulfide, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between the lead sulfide and another sulfide mineral in the ore, and subjecting the so-treated ore to a flotation operation whereby the flotation of the lead sulfide is in large part effected while the flotation of another sulfide mineral is in large part inhibited.

4. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing zinc sulfide, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between the zinc sulfide and another sulfide mineral in the ore, and subjecting the so-treated ore to a flotation operation whereby the flotation of one sulfide mineral is in large part effected while the flotation of the zinc sulfide is in large part inhibited.

5. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing iron sulfide, which comprises treating the ore with a free halogen and a cyanide and thereby effecting

a marked difference in the amenability to flotation between different sulfide minerals in the ore, the ratio of the amounts of halogen and cyanide employed being relatively large or small according as it is desired to promote or inhibit the flotation of the iron sulfide, and subjecting the so-treated ore to a flotation operation whereby the flotation of one sulfide mineral is in large part effected while the flotation of another sulfide mineral is in large part inhibited and the iron sulfide is in large part associated with one or the other of said sulfide minerals according to the ratio of the amounts of halogen and cyanide employed.

6. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing lead, copper and silver sulfides together with zinc sulfide, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between the lead, copper and silver sulfides and the zinc sulfide, and subjecting the so-treated ore to a flotation operation whereby the flotation of the lead, copper and silver sulfides is in large part effected while the flotation of the zinc sulfide is in large part inhibited.

7. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing lead, copper and silver sulfides together with zinc and iron sulfides, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between the lead, copper and silver sulfides and the zinc sulfide, the ratio of the amounts of halogen and cyanide employed being relatively large or small according as it is desired to promote or inhibit the flotation of the iron sulfide, and subjecting the so-treated ore to a flotation operation whereby the flotation of the lead, copper and silver sulfides is in large part effected while the flotation of the zinc sulfide is in large part inhibited and the iron sulfide is in large part associated with the zinc sulfide or the other sulfides according to the ratio of the amounts of halogen and cyanide employed.

8. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing lead, copper and silver sulfides together with zinc and iron sulfides, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between the lead, copper and silver sulfides and the zinc and iron sulfides, subjecting the so-treated ore to a flotation operation whereby the flotation of the lead, copper and silver sulfides is in large part effected while the flotation of the zinc and iron sulfides is in large part

inhibited, treating the remaining ore pulp with an alkaline agent, and subjecting the so-treated remaining ore pulp to another flotation operation and thereby effecting in
 5 large part the flotation of the zinc sulfide and inhibiting in large part the flotation of the iron sulfide.

9. A process of differentially separating by flotation different sulfide minerals in a
 10 mixed sulfide ore containing copper sulfide, which comprises treating the ore with a free halogen and cyanide and thereby effecting a marked difference in the amenability to flotation between the copper sulfide and another sulfide mineral in the ore, and sub-
 15 jecting the so-treated ore to a flotation operation whereby the flotation of the copper sulfide is in large part effected while the flotation of another sulfide mineral is in
 20 large part inhibited.

10. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing silver sulfide, which comprises treating the ore with a free
 25 halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between the silver sulfide and another sulfide mineral in the ore, and subjecting the so-treated ore to a flotation operation where-
 30 by the flotation of the silver sulfide is in large part effected while the flotation of another sulfide mineral is in large part inhibited.

11. A process of differentially separating
 35 by flotation different sulfide minerals in a mixed sulfide ore containing copper and iron sulfides, which comprises treating the ore with a free halogen and a cyanide and there-
 40 by effecting a marked difference in the amenability to flotation between the copper and iron sulfides, and subjecting the so-treated ore to a flotation operation where-
 45 by the flotation of the copper sulfide is in large part effected while the flotation of the iron sulfide is in large part inhibited.

12. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing lead, zinc and
 50 iron sulfides, which comprises treating the ore with a free halogen and a cyanide and

thereby effecting a marked difference in the amenability to flotation between the lead sulfide and the zinc and iron sulfides, subject-
 55 ing the so-treated ore to a flotation operation whereby the flotation of the lead sulfide is in large part effected while the flota-
 60 tion of the zinc and iron sulfides is in large part inhibited, treating the remaining ore pulp with an alkaline agent, and subjecting the so-treated remaining ore pulp to another flotation operation and thereby effect-
 65 ing in large part the flotation of the zinc sulfide and inhibiting in large part the flotation of the iron sulfide.

13. A process of differentially separating
 65 by flotation different sulfide minerals in a mixed sulfide ore containing zinc sulfide, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to
 70 flotation between the zinc sulfide and another sulfide mineral in the ore, subjecting the so-treated ore to a flotation operation whereby the flotation of one sulfide mineral
 75 is in large part effected while the flotation of the zinc sulfide is in large part inhibited, treating the remaining ore pulp with an alkaline agent, and subjecting the so-treated remaining ore pulp to another flotation op-
 80 eration and thereby effecting in large part the flotation of the zinc sulfide.

14. A process of differentially separating by flotation different sulfide minerals in a mixed sulfide ore containing lead and zinc
 85 sulfides, which comprises treating the ore with a free halogen and a cyanide and thereby effecting a marked difference in the amenability to flotation between the lead and zinc sulfides, subjecting the so-treated ore to a flotation operation whereby the flo-
 90 tation of the lead sulfide is in large part effected while the flotation of the zinc sulfide is in large part inhibited, treating the remaining ore pulp with an alkaline agent, and subjecting the so-treated remaining ore
 95 pulp to another flotation operation and thereby effecting in large part the flotation of the zinc sulfide.

In testimony whereof I affix my signature.

CHARLES KENNETH McARTHUR, Jr.