

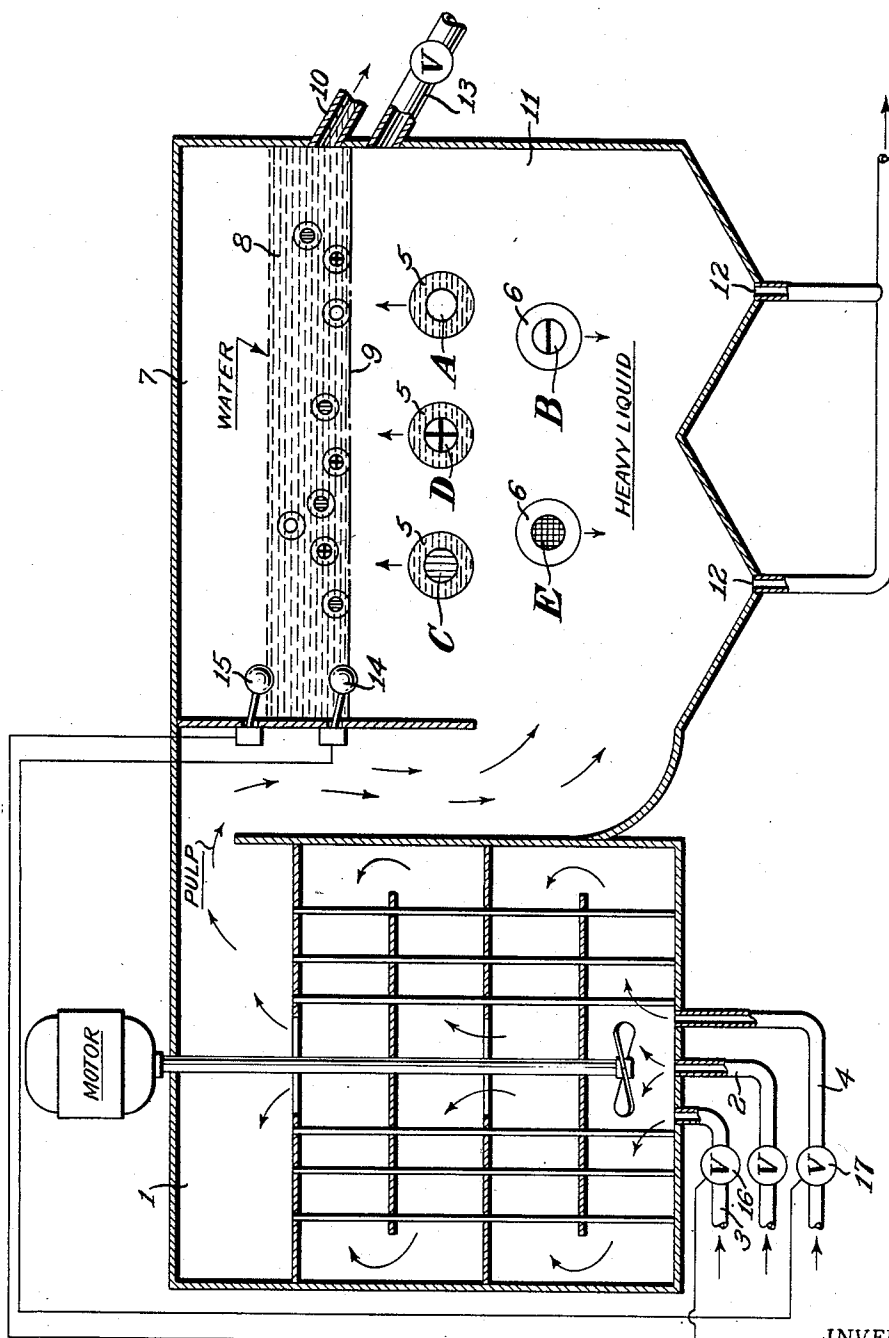
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PROCESS FOR SEPARATING MINERALS

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PROCESS FOR SEPARATING MINERALS

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This invention relates to a new process for separating the mineral components in ores, sludges and the like. More specifically, it relates to the forced separation of selected mineral components regardless of their specific gravity, by means of two immiscible liquids of different specific gravity.

Hitherto it has been well known to separate the mineral components of ores by means of a liquid medium having a specific gravity intermediate the specific gravities of the components being separated. This sink-float method may be successfully used in many separations but possesses a number of disadvantages. Frequently there is no available liquid having a specific gravity intermediate the particular specific gravity of the specific minerals to be separated so that the requisite specific gravity must be obtained by modifying the liquid either by dilution with other liquids, or by the addition of heavy salts, or the like. Liquid media of high specific gravity are almost prohibitively expensive. The highest practical specific gravity presently obtainable in liquids suitable for mineral separation is about 5. However, many ores contain two or more mineral components having specific gravities of 5 or over, so that it is virtually impossible to separate these minerals by the sink-float method. Furthermore, it cannot be used very successfully to separate mineral components having substantially the same or very close specific gravity. In the event that the valuable component of the ore has a specific gravity intermediate that of several other relatively worthless components, it is necessary to subject the ore to at least two expensive separations, using liquids of successively different intermediate specific gravity in order to isolate the desired concentrate. Another disadvantage of this method lies in the fact that it is difficult to obtain a separation of the smaller particles. Since the force of gravity is small to negligible on small or colloidal particles, the time required for the separation is prohibitive.

The object of this invention is to provide a process for separating minerals which comprises a selective separation of minerals independent of the specific gravity of said minerals, by means of two immiscible liquids of different specific gravity.

Another object is to provide a method for separating from each other minerals of relatively high specific gravity, as for example, minerals having specific gravities of 5 or greater, by means of liquids having lower specific gravity than said minerals.

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Another object is to provide a liquid separation method which permits the isolation in a single step of a desired mineral concentrate regardless of the specific gravity of the other components of the ore or sludge, even though the specific gravity of the desired component is intermediate those of the remaining components, and which substantially reduces the number of separation steps hitherto required by liquid sink-float methods.

Still another object of the invention is to provide a simple method for separating minerals having very close or substantially similar specific gravities.

Still other objects and advantages of my invention will become apparent from the following detailed description and accompanying drawing, in which:

The figure in the drawing comprises a diagrammatic representation of a mineral separation according to my process.

A film of water adhering to a mineral particle of greater specific gravity than water tends, in effect, to reduce its specific gravity. The effective decrease in specific gravity becomes progressively greater as the particle size becomes smaller, until a critical particle size is reached where the particle with an adhering film of water will not break through the liquid interface between a water layer within which it is contained and a heavier immiscible liquid even though the actual specific gravity of the mineral itself may be higher than the specific gravity of each liquid.

Apparently the cohesion of the water for the adhering aqueous film and its interfacial tension at the liquid interface are sufficient to keep the particle from penetrating the liquid interface.

To accomplish separations according to my process, substantially all of the mineral particles must be of sufficiently small size so that when water-wetted they will be retained within a water layer regardless of the actual specific gravity of any of the mineral components. The critical particle size at which this will occur varies somewhat according to the specific gravity of the particular mineral components, with the heavier minerals requiring somewhat finer subdivision. In general, reduction to a mesh size of about 60 to 80 is sufficient for most ores, but the ore may be reduced to still finer particles if any of the mineral components require it. Reduction to the requisite particle size may be accomplished in any well known fashion, as in a ball mill or the like.

The ore is preferably wet ground as is the usual procedure, although it may be ground dry and

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subsequently admixed with water. In any case the finely divided ore particles should be thoroughly wetted with water. Since normally substantially all minerals are water-wettable, all of the ore particles thus acquire an adhering aqueous film. Selected reagents are added to the water used either in the grinding operation or in the subsequent wetting treatment, which serve to condition the surfaces of selected mineral components and which shall hereinafter be more fully described.

The aqueous slurry containing the finely divided water wetted mineral particles is then thoroughly agitated with additional water if necessary, to reduce the pulp density, and a liquid which is immiscible with and heavier than water. Additional quantities of the aforementioned surface conditioning reagents may be added at this point.

By treating the ore particles with selected surface conditioning reagents which I shall henceforth call adapters, the adhering water film may be replaced by a film of the heavy liquid from selected mineral components in the ore, sludge or the like being processed. The particular adapter reagent employed is determined by the specific mineral component selected for film replacement. The mechanism involved is obscure but apparently the adapter reagent is either adsorbed on the surface or reacts with the surface of the mineral particle so as to decrease its affinity for water and/or increase its affinity for the non-aqueous liquid, with resulting replacement of the aqueous film by an adhering film of the heavy liquid.

In general, I have found that the flotation reagents or promoters employed in the ore flotation art for floating specific classes of minerals, are effective adapters for substantially the same classes in my process. Some illustrative examples of such reagents are the various xanthates such as the ethyl, iso-propyl, butyl and amyl xanthate derivatives which are generally effective for sulfides as a class and the precious metals, such as gold; the various organic thio-phosphate reagents, generally referred to as aerofloat reagents, which are effective for specific sulfides and the precious metals; the mercapto-benzothiazole derivatives which are variously effective for specific sulfides and non-sulfide base metals; the thiocarbonyl derivatives which are effective for specific sulfides, such as lead and copper sulfide and the precious metals; various fatty acids and soaps which are effective for use with metallic oxides and non-metallic minerals, and the like. Within a group of adapter reagents suitable for a given mineral, certain ones may be more effective than others under the particular conditions of the separation. For example, the particular heavy liquid employed in the separation may have an excessively solvent effect on a given adapter reagent, thus removing it from the mineral surface being conditioned and rendering the adapter ineffective. In such a case a different separating liquid must be employed or a less soluble adapter used.

In some cases where the adapter reagent is too weak in its action on a given mineral component to accomplish replacement of the aqueous film by the non-aqueous liquid, it may be necessary to employ additional reagents which activate the surfaces of the particular mineral and increase its adsorption of the adapter. Some illustrative examples of these reagents are copper sulfate, activator for sphalerite, sodium sulfide which is

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an activator for lead oxide minerals, and the like.

Frequently, the adapter reagent employed to cause replacement of the aqueous film on a selected mineral component will similarly condition another mineral component on which it is desired to retain the water film. For example, this is usually the case when a mixture of sulfide minerals are to be separated with the aid of a xanthate adapter. This may be counteracted by the use of a reagent, which I shall call an inhibitor, to condition the surface of the second mineral particle so that it retains its aqueous film despite the presence of the adapter. The particular inhibitor employed, of course, varies according to the specific mineral since a reagent which is effective for a given mineral will be inert with respect to another mineral having different surface properties. As in the case of adapters the mechanism involved is obscure, but apparently the mineral, though reactive toward both the adapter and inhibitor reagents present, has a greater affinity for the latter, which conditions the surface of the mineral particle so that it adheres to the water.

In general, the reagents which are classified as depressors in the ore flotation art, are suitable as inhibitors in my process. Illustrative examples of such reagents are the following: lime which inhibits pyrite; the sodium and calcium sulfites and hyposulfites which inhibit pyrite and sphalerite; zinc sulfate which in conjunction with ferro and ferricyanides, inhibits sphalerite; quebracho and tannic acid which inhibit calcite and dolomite in the presence of fatty acid adapters for fluorite and scheelite; sodium silicate which inhibits quartz; starch and glue which inhibit mica, talc and sulfur; ferro and ferricyanides which inhibit cobalt and nickel sulfides in the presence of copper sulfide; caustic soda which inhibits stibnite, and the like.

My process, as aforementioned, involves the use of two liquids as the separating means, one of the liquids being water. Any non-aqueous liquid which possesses the following properties may be used as the second liquid. The liquid must be chemically very stable. It must be immiscible with and of different specific gravity than water so that a mixture of the two readily separates into two layers with a clearly defined interface. The specific gravity of the second separating liquid need bear no relation to the specific gravity of any of the mineral components to be separated and may, in fact, be less than that of the lightest component. The liquid should not have a high solvent action with respect to the adapter reagents employed to cause the adherence of the liquid to the selected mineral particles. If the liquid dissolves the adapter, thus removing it from or preventing its adsorption on the adapted particle, the particle is likely to preferentially readhere to the water present. By way of illustration, I have found the following liquids particularly suitable for use in my process: tetrabromomethane, specific gravity 2.97; tri-bromomethane-1,1,2, specific gravity 2.58; ethylidene bromide, specific gravity 2.09. Carbon tetrachloride, specific gravity 1.59 and tetrachloroethylene, specific gravity 1.62 may be used but are limited in their applicability because of their high solvent action on a number of the adapter reagents. Many liquids of higher specific gravity than the aforementioned may be used but it is obviously more economical to employ the less costly separating media of relatively low specific gravity.

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The mixture comprising the finely divided ore or sludge, the two immiscible liquid separating media and the selected conditioning reagents should be well agitated to ensure thorough treatment of the particles. The selected mineral component or components because of the use of the appropriate adapter reagent then carry an adhering film of the non-aqueous liquid. The remaining components, if necessary with the aid of suitable inhibitor reagents, are water wetted.

The pulp mixture is then transferred to a suitable settling tank where the two immiscible liquids separate into layers with a well defined liquid interface. The mineral particles separate into the two layers in accordance with the character of their wetting films. The water wetted particles are retained within the water layer and the adapted particles, namely, those selectively wetted with the non-aqueous liquid, are retained in the non-aqueous liquid layer regardless of the specific gravity of the various mineral components. This phenomenon can perhaps best be explained in the terms of an illustrative example of an ore separation accomplished according to my process.

Example I

The ore being treated contains the following mineral components:

	Specific gravity
Quartz -----	2.6
Sphalerite -----	4.0
Pyrolusite -----	4.8
Pyrite -----	5.0
Galena -----	7.5

It is desired to make a concentrate of sphalerite and galena and a tailing of quartz, pyrolusite and pyrite in a single separation step.

The ore is ground in water containing the conditioning reagents required for the separation to a mesh size of about 80 or less. The wet pulp is led into agitator 1 as diagrammatically shown in the figure through inlet pipe 2. Additional water is piped in at 3 to reduce the density of the pulp, and a second immiscible liquid, which in this case is ethylidene bromide having a specific gravity of 2.09, is piped in at 4.

The conditioning reagents employed in this case are as follows:

Copper sulfate which activates the surface of the sphalerite for the adapter.

Lime which acts as an inhibitor for the pyrite so that it retains a water film. The xanthate adapter would otherwise cause the replacement of the aqueous film on the pyrite by the ethylidene bromide.

Potassium isopropyl xanthate (marketed under the trade name of Reagent 322, by the American Cyanamid Company), an adapter reagent which selectively conditions the surface of both the sphalerite and galena particles so that they preferentially adhere to a film of ethylidene bromide.

Pyrolusite and quartz are inert towards these reagents and preferentially adhere to an aqueous film.

After thorough agitation, the various mineral components are selectively coated with liquid films as diagrammatically represented in the figure.

The quartz particles A carry an adhering film of water 5.

The sphalerite particles B, because of the conditioning effect of the copper sulfate activator and xanthate adapter preferentially adhere to a film of ethylidene bromides 6.

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The pyrolusite particles C are coated with an adhering water film 5.

The pyrite particles D, because of the conditioning effect of the lime inhibitor, are preferentially wetted by water 5.

The galena particles E, because of the conditioning effect of the xanthate adapter, are preferentially wetted by ethylidene bromide 6.

The treated ore and liquid mixture flows from the agitator into the lower portion of settling tank 7 so that the water separates from the heavier ethylidene bromide in an upward stream. The water carries with it into the water layer the water wetted particles, in this case the quartz, pyrolusite and pyrite, despite the fact that the actual specific gravity of pyrolusite and of pyrite are considerably greater than that of ethylidene bromide. Because of the small particle size of the minerals, the adhering water film reduces the effective specific gravity to the point where the cohesive forces of the water with respect to the water film adhering to the mineral particle are sufficient to counteract gravitational forces which tend to pull the particles down out of the water and to carry the water wetted particles up into the water layer.

The adhering water film, furthermore, reduces the effective specific gravity of the small particles to the point where the particle as a whole is in effect lighter than the heavy liquid. This is an added factor forcing an upward streaming of the water wetted particles. After being forced into the upper water layer the water wetted particles collect at the bottom of the layer above the liquid interface 9. The surface tension of the water at the liquid interface in addition to its cohesive forces, prevents downward penetration of the interface by the particles and also tends to draw the particles up into the water layer as they stream upwardly and come in contact with the aqueous interface. The collected particles are drawn off at outlet 10, preferably in a continuous flow to prevent excessive clumping of the particles above the interface, since coalescence of the particles may increase the effective specific gravity of the mass to the point where it drops through the interface.

The sphalerite and galena particles which have been selectively coated with ethylidene bromide are retained in the heavy liquid layer 11. Being of greater specific gravity than ethylidene bromide, they sink to the bottom and are drawn off through outlets 12 at the bottom of the tank. For this particular separation outlet 13 may be closed since none of the mineral components collect below the liquid interface. However, in some separations it may be desired to separate from the water tailings a mineral component which is lighter than the heavy liquid. In such case the particular component is selectively coated with the heavy liquid so that it is trapped in the heavy liquid layer wherein it floats beneath the liquid interface. This mineral component is then drawn off through outlet 13.

The liquid levels are regulated by means of suitable controls such as floats 14 and 15 which control the respective liquid intakes into the agitator by means of suitable control valves 16 and 17.

Since the ordinary sink-float processes as hitherto practiced require for separation purposes a liquid having a specific gravity intermediate the specific gravities of the components to be separated, it will be noted that the ethylidene bromide employed in the foregoing example could not be

employed to separate any of the mineral components from the particular ore mixture in view of the fact that its specific gravity is less than that of the lightest component, namely, the quartz. According to my process it is possible not only to separate heavy minerals by means of a lighter liquid, but also to separate the mineral components without regard to their specific gravity, as can be seen from the foregoing example, where minerals having specific gravity, respectively, of 2.6, 4.8 and 5 were cleanly separated from minerals having specific gravity, respectively, of 4 and 7.5 in a single operation.

Furthermore, it is a practical impossibility to obtain separation of pyrite, specific gravity 5, and galena, specific gravity 7.5, by the ordinary sink-float methods even without regard to cost, since there is presently no known liquid having a specific gravity greater than about 4.35 which may be employed when sulfides are present.

My process results in a clean, substantially positive separation of the mineral components. I have found for the most part that a somewhat cleaner separation results from an upward separation of the liquid layers. However, in some cases a downward separation gives slightly better results.

My process permits the separation of mineral particles of substantially the same, or very close, specific gravity which cannot be readily separated by the ordinary sink-float methods. The separation is readily accomplished, according to my process, by grinding the ore into sufficiently small particles so that they are substantially all retained within a water layer when water wetted and then selectively coating the mineral components having substantially the same or very close specific gravity, respectively, with water and an immiscible liquid of different specific gravity. In the settling tank, the water wetted component is retained in the water and the other component is retained in the immiscible liquid with which it is coated.

The following detailed examples are illustrative of my invention, but, it will be understood, do not limit the scope of the invention in any way:

Example II

It is desired to obtain a gold concentrate from an ore comprising:

	Specific gravity
Gold -----	17.5
Pyrite -----	5.0
Hematite -----	5.1
Quartz -----	2.6

The ore is wet ground in a ball mill to a mesh size of about 60 or less. The following surface conditioning reagents are added with the water:

Reagent 301 (American Cyanamid Co.), sodium sec-butyl xanthate—adapter for the gold.

Reagent 404 (American Cyanamid Co.), a mercapto-benzothiazole—adapter for the gold which supplements action of Reagent 301 if gold is tarnished.

Lime—inhibitor for pyrite which would otherwise be adapted by Reagent 301.

The quartz and hematite are unaffected by the above reagents and retain a water film. The water wet pulp is then thoroughly agitated with additional water and tetrabromoethane, specific gravity 2.97. The tetrabromoethane replaces the water film on the gold particles because of the action of the adapter reagents. The other mineral components retain a water film. The treated

pulp mixture is passed into a settling tank where the liquids separate. The water wetted pyrite, hematite and quartz separate into the upper water layer and the gold is retained in the lower tetrabromoethane layer. It is possible to obtain from many gold ores gold concentrates ranging from 200 to 500 fine by this method.

Example III

It is desired to obtain a concentrate of gold and galena from an ore comprising:

	Specific gravity
Gold -----	17.5
Galena -----	7.5
Sphalerite -----	4.0
Pyrite -----	5.0
Barite -----	4.5
Quartz -----	2.6

The ore was ground to a mesh size of about 60 or less in water containing the following surface conditioning reagents:

Sodium sec-butyl xanthate (Reagent 301)—adapter for gold and galena;

Sodium ferro cyanide and zinc sulfate—inhibitors for sphalerite which would otherwise be adapted by Reagent 301;

Lime—inhibitor for pyrite which would otherwise be adapted by Reagent 301.

Barite and quartz are unaffected by the above reagents and retain a water film.

The water wetted pulp is then thoroughly agitated with additional water and tetrabromoethane, specific gravity 2.97. The aqueous films adhering to the gold and galena are replaced by the tetrabromoethane because of the action of the adapter reagent. The other components retain water films. In the settling tank the sphalerite, pyrite, barite and quartz separate with the water and the gold and galena are retained in the tetrabromoethane.

The galena may be separated from the gold concentrate in a second separation by including a chromate inhibiting reagent for the galena in addition to the xanthate adapter so that the galena is forced into the water layer and the gold is separated into the tetrabromoethane layer. Prior to this separation, however, the tetrabromoethane coating must first be removed, as for example by volatilization, in order to permit access of the water soluble chromate inhibitor to the galena surface.

A sphalerite concentrate may be obtained from the water tailings of the first separation by mixing them in an agitator with tetrabromoethane and the following surface conditioning reagents:

Lime sufficient to raise the pH to about 9 to 10 to inhibit the pyrite.

Copper sulfate to enhance the activity of the adapter on the sphalerite.

Sodium sec-butyl xanthate (Reagent 301) and potassium isopropyl xanthate (Reagent 322) to adapt the sphalerite.

In the settling tank the water wetted pyrite, barite and quartz are separated into the water layer and the sphalerite, which now carries an adhering film of the tetrabromoethane, is retained in the heavy liquid layer.

Example IV

My process may be employed to recover the diamond residue in arter grinder sludge. Typical sludges contain organic materials, such as oils and resins, free metals, such as copper filings, iron filings and zinc, silicon carbide (carborundum),

specific gravity 3.23, aluminum oxide (corundum), specific gravity 4, diamonds, specific gravity 3.52 and traces of other impurities.

The organic components, particularly the oils, and the metals are removed since they hamper the separation process by treating the sludge with sulfuric acid, washing and then treating with sodium hydroxide. The residue is washed and dried. Complete dissolution of the metals is not necessary but complete removal of the oil is essential since it acts as a substantially universal adapter, preferentially coating all of the sludge components.

The residue, which is of a mesh size of about 30, is added to a wet grinding machine or ball mill with sufficient water to make a paste comprising about 50% solids. The following surface conditioning reagents are added with the water:

Glycerine and mineral oil in proportions of about 1:1 to adapt the diamonds;

Lime to inhibit the silicon carbide and corundum which otherwise would be adapted to some extent by the adapter reagents. By adding the reagents to the grinder, the effectiveness of the reagents is increased.

The pulp is agitated with additional water and tetrabromoethane, specific gravity 2.97. The diamonds are selectively coated with tetrabromoethane, the carborundum, other impurities and corundum with water. In the settling tank, the particles separate into the liquid layers according to the character of their adhering films. The diamonds carry with them some minor contaminants which may be removed by treatment of the filtered or centrifuged diamonds with sodium hydrogen sulfate and acid.

Although I have described my process in terms of a non-aqueous separating liquid of greater specific gravity than the water, which is the preferred embodiment, it will be understood that my invention may be practiced with a non-aqueous immiscible liquid of lesser specific gravity, such as kerosene, in which case the adapter reagents employed cause replacement of the aqueous film adhering to selected mineral components by the non-aqueous liquid of lesser specific gravity than the water with inhibitor reagents, if necessary, causing retention of water films by other mineral components. However, lighter fluids can be conveniently used only with relatively light minerals, such as graphite, since for heavier minerals the grind must be excessively fine in order to retain the selected mineral components within the low specific gravity medium.

It will also be understood that although the specific embodiments heretofore described relate to the use of water as one of the two immiscible liquids since water is the liquid commonly employed in grinding operations and is, of course, most economical, the water may be replaced by another liquid which is stable and immiscible with the second liquid of different specific gravity.

Although this invention has been described with reference to illustrative embodiments thereof, it will be apparent to those skilled in the art that the principles of this invention may be embodied in other forms but within the scope of the appended claims.

Having thus described my invention, I claim:

1. A process for separating minerals by means of water and a second immiscible liquid of higher specific gravity than water comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being

retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to particles of one mineral by a film of said second liquid and permit retention of water films by particles of another mineral having a higher specific gravity than the second liquid, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted mineral particles, including particles of said mineral of higher specific gravity than the second liquid, from the upper water layer and removing the particles of selected mineral wetted by the second liquid from said second liquid layer.

2. A process for separating minerals by means of water and a second immiscible liquid of higher specific gravity than water comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the retention of a water film by particles of one mineral having a higher specific gravity than the second liquid and other selected surface conditioning reagents which cause the replacement of the water film adhering to particles of another mineral by a film of said second liquid, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted mineral particles, including particles of said mineral of higher specific gravity than the second liquid, from the upper water layer and removing the particles of selected mineral wetted by the second liquid from said second liquid layer.

3. A process for separating minerals by means of water and a second immiscible liquid of higher specific gravity than water but of substantially lower specific gravity than at least certain of the mineral components being separated, comprising finely reducing said mineral components to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to particles of at least one selected mineral component of greater specific gravity than said second immiscible liquid and permit retention of water films by particles of at least one other selected mineral component of greater specific gravity than said second immiscible liquid, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the

selected water-wetted particles, including particles of said mineral of higher specific gravity than the second liquid, from the upper water layer and removing the particles wetted by said second liquid, including particles of said other selected mineral of greater specific gravity than the second liquid, from said second liquid layer.

4. A process for separating minerals by means of water and a second immiscible liquid of higher specific gravity than water but of substantially lower specific gravity than at least certain of the mineral components being separated, comprising finely reducing said mineral components to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to particles of at least one selected mineral component of greater specific gravity than said second immiscible liquid, and other selected surface conditioning reagents which cause retention of water films by particles of at least one other selected mineral component of greater specific gravity than said second immiscible liquid, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including particles of said mineral of higher specific gravity than the second liquid, from the upper water layer and removing the particles wetted by said second liquid, including particles of said other selected mineral of greater specific gravity than the second liquid, from said second liquid layer.

5. The process of separating minerals by means of water and a second immiscible liquid of higher specific gravity comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to selected mineral component particles by a film of said second immiscible liquid and permit retention of water films by the other selected mineral component particles, at least one of said water wetted mineral components being of higher true specific gravity than at least one of the mineral components wetted by said second immiscible liquid, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including particles of said water-wetted mineral component of higher specific gravity than said other mineral component wetted by the second liquid, from the upper water layer and removing the particles wetted by said second liquid, including particles of said other mineral component of lesser specific gravity than said water-wetted mineral component removed in the water layer, from said second liquid layer.

6. The process of separating minerals by means of water and a second immiscible liquid of higher specific gravity comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to selected mineral component particles by a film of said second immiscible liquid and other selected surface conditioning reagents which cause retention of water films by the other selected mineral component particles, at least one of said water wetted mineral components being of higher specific gravity than at least one of the mineral components wetted by said second immiscible liquid, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including particles of said water-wetted mineral component of higher specific gravity than said other mineral component wetted by the second liquid, from the upper water layer and removing the particles wetted by said second liquid, including particles of said other mineral component of lesser specific gravity than said water-wetted mineral component removed in the water layer, from said second liquid layer.

7. The process for separating minerals having two mineral components of substantially the same specific gravity by means of water and a second immiscible liquid of higher specific gravity than water but of lower specific gravity than said two mineral components, comprising finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to the particles of one of said mineral components having substantially the same specific gravity as one other mineral component by a film of said second immiscible liquid and which permit retention of water films by the particles of the other of said mineral components having substantially the same specific gravity, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including the water-wetted particles of the mineral component having substantially the same specific gravity as one other mineral component, from the upper water layer and removing the particles wetted by the second liquid, including the particles of said other mineral component of substantially the same specific gravity, from said second liquid layer.

8. The process for separating minerals having two mineral components of substantially the same specific gravity by means of water and a second immiscible liquid of higher specific gravity than

water but of lower specific gravity than said two mineral components comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to the particles of one of said mineral components having substantially the same specific gravity as one other mineral component by a film of said second immiscible liquid and other selected surface conditioning reagents which cause retention of water films by the particles of the other of said mineral components having substantially the same specific gravity, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including the water-wetted particles of the mineral component having substantially the same specific gravity as one other mineral component, from the upper water layer and removing the particles wetted by the second liquid, including the particles of said other mineral component of substantially the same specific gravity, from said second liquid layer.

9. A process for separating a mineral component having a specific gravity intermediate the specific gravity of at least two other mineral components from said two other components by means of water and a second immiscible liquid of higher specific gravity than water but of lower specific gravity than said mineral component of intermediate specific gravity comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to the particles of said mineral component of intermediate specific gravity by a film of said second immiscible liquid and which permit the retention of water films by the particles of said other two mineral components of respectively higher and lower specific gravity, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including the water-wetted particles of said mineral components of respectively higher and lower specific gravity than said component of intermediate specific gravity, from said upper water layer and removing the particles wetted by the second liquid, including the particles of said mineral component of intermediate specific gravity from said second liquid layer.

10. A process for separating a mineral component having specific gravity intermediate the specific gravity of at least two other mineral components from said two other components by means of water and a second immiscible liquid of higher

specific gravity than water but of lower specific gravity than said mineral component of intermediate specific gravity comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to the particles of said mineral component of intermediate specific gravity by a film of said second immiscible liquid and other selected surface conditioning reagents which cause the retention of water films by the particles of said other two mineral components of respectively higher and lower specific gravity, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including the water-wetted particles of said mineral components of respectively higher and lower specific gravity than said component of intermediate specific gravity, from said upper water layer and removing the particles wetted by the second liquid, including the particles of said mineral component of intermediate specific gravity, from said second liquid layer.

11. A process for separating a mineral component having a specific gravity intermediate the specific gravity of at least two other mineral components from said two other components by means of water and a second immiscible liquid of higher specific gravity than water but of lower specific gravity than said mineral component of intermediate specific gravity comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to the particles of said two mineral components of respectively lower and higher specific gravity by a film of said second immiscible liquid and which permit the retention of a water film by the particles of said mineral component of intermediate specific gravity, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including the water-wetted particles of said mineral component of intermediate specific gravity, from the upper water layer and removing the particles wetted by the second liquid, including the particles of said two mineral components of respectively higher and lower specific gravity, from said second liquid layer.

12. A process for separating a mineral component having a specific gravity intermediate the specific gravity of at least two other mineral components from said two other components by means of water and a second immiscible liquid of higher specific gravity than water but of lower specific gravity than said mineral component of inter-

mediate specific gravity, comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and said second immiscible liquid in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to the particles of said two mineral components of respectively lower and higher specific gravity by a film of said second immiscible liquid and other selected surface conditioning reagents which cause the retention of a water film by the particles of said mineral component of intermediate specific gravity, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of said second immiscible liquid, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including the water-wetted particles of said mineral component of intermediate specific gravity, from the upper water layer and removing the particles wetted by the second liquid, including the particles of said two mineral components of respectively higher and lower specific gravity, from said second liquid layer.

13. A process for separating minerals by means of water and tetrabromoethane comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and tetrabromoethane in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to particles of one mineral by a film of tetrabromoethane and permit retention of water films by particles of another mineral having a higher specific gravity than tetrabromoethane, said surface conditioning reagents being incorporated into the mineral mixture prior to addition of the tetrabromoethane, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted mineral particles, including particles of said mineral of higher specific gravity than tetrabromoethane, from the upper water layer and removing the particles of selected mineral wetted by the tetrabromoethane from said tetrabromoethane layer.

14. A process for separating minerals by means of water and ethylidene bromide comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and ethylidene bromide in the presence of selected

surface conditioning reagents which cause the replacement of the water film adhering to particles of one mineral by a film of ethylidene bromide and permit retention of water films by particles of another mineral having a higher specific gravity than ethylidene bromide, said surface conditioning reagents being incorporated into the mineral mixture prior to the addition of the ethylidene bromide, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including particles of said mineral of higher specific gravity than ethylidene bromide, from the upper water layer and removing the particles of selected mineral wetted by the ethylidene bromide from said ethylidene bromide layer.

15. A process for separating minerals by means of water and tribromoethane-1,1,2 comprising, finely reducing said minerals to a maximum particle size of about 60 mesh so that substantially all of said particles when water wetted are capable of being retained within a water layer despite the true specific gravity of said particles, water wetting said particles, intimately admixing said water wetted particles with water and tribromoethane-1,1,2 in the presence of selected surface conditioning reagents which cause the replacement of the water film adhering to particles of one mineral by a film of tribromoethane-1,1,2 and permit retention of water films by particles of another mineral having a higher specific gravity than tribromoethane-1,1,2, said surface conditioning reagents being incorporated into the mineral mixture prior to the addition of the tribromoethane-1,1,2, permitting the two immiscible liquids to separate into layers under the influence of gravity, removing the selected water-wetted particles, including particles of said mineral of higher specific gravity than tribromoethane-1,1,2, from the upper water layer and removing the particles of selected mineral wetted by the tribromoethane-1,1,2 from said tribromoethane-1,1,2 layer.

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