

1

3,363,758

USE OF PRIMARY ALIPHATIC ETHER AMINE ACID SALTS IN FROTH FLOTATION PROCESS

Alvin D. Cronberg, Bloomington, Clarence N. Impola, Prior Lake, and Thomas H. Lentz, Hopkins, Minn., assignors to Ashland Oil & Refining Company, Ashland, Ky., a corporation of Kentucky
No Drawing. Filed Dec. 8, 1966, Ser. No. 600,054
8 Claims. (Cl. 209—166)

ABSTRACT OF THE DISCLOSURE

Acid salts of primary aliphatic ether amines, e.g., 3-isodecoxypropylamine acetate and N-tridecoxypropyl-1,3-propylene diamine monoacetate, are used as silica collectors in the concentration of minerals by froth flotation.

This invention relates to the use of acid salts of primary aliphatic ether amines as silica collectors in the concentration of minerals by the froth flotation process. In a further aspect, it relates to the use of acid salts of primary aliphatic ether amines, such as 3-isodecoxypropylamine acetate and N-tridecoxypropyl-1,3-propylene diamine monoacetate, as cationic silica collectors in froth flotation of iron ore.

Froth flotation is a common process applied in the art of separating or concentrating minerals from ore or the like. Briefly, the flotation process usually comprises grinding crushed ore, classifying the ground ore in water, treating the classified ore by flotation to concentrate one or more minerals while the remainder of the minerals of the ore remain behind in the water pulp, thickening and filtering the separated concentrate and thereafter treating the same for ultimate use of the separated minerals. In carrying out the flotation step, a collector is added to the ore dispersed in the water and air is introduced into the pulp to form a froth, and the froth, containing those minerals that are not wetted and have an affinity for air bubbles, is withdrawn.

A host of selective collecting agents have been developed that are used for forming water-repellent, air-aid surfaces on one mineral or a class of minerals. These collectors are anionic or cationic, and while many of them have been used satisfactorily, they often are limited by their solubility and handling characteristics, selectivity, effectiveness, stability, cost, etc.

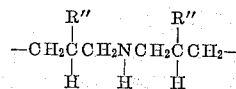
Accordingly, an object of this invention is to use acid salts of primary aliphatic ether amines as collectors in the concentration of minerals by the froth flotation process. Another object is to use acid salts of primary aliphatic ether amines, such as 3-isodecoxypropylamine acetate, as cationic silica collectors in froth flotation of iron ore. Further objects and advantages of this invention will become apparent to those skilled in the art from the following description and accompanying claims.

Briefly, we have discovered that acid salts of primary aliphatic ether amines are useful collectors or reagents in concentrating or separating minerals from ores by the froth flotation process. For example, we have found that the acetate of 3-isodecoxypropylamine (prepared by hydrogenating the reaction product of isodecyl alcohol and

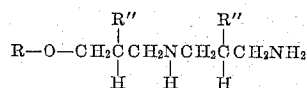
2

acrylonitrile) is an excellent cationic collector for the separation of silica and/or other siliceous materials from iron ore such as magnetite in the froth flotation process.

The primary aliphatic ether amines useful in the practice of this invention (as salts) can be represented by the general formula $R-O-R'-NH_2$, where R is a straight or branched chain aliphatic radical, preferably an alkyl radical, and R' is a straight or branched chain alkylene group or linkage or R' is the divalent radical:



where R'' is a hydrogen atom or a methyl group. Where R' is said alkylene linkage, the primary aliphatic ether amines are ether monoamines (and occasionally referred to as such hereinafter) having the subgenus formula $R-O-R'''-NH_2$, where R is as defined above and has 6 to 22 carbon atoms, preferably 8 to 12 carbon atoms, and R''' is said alkylene linkage, preferably having 2 to 6 carbon atoms and more preferably 3 carbon atoms. Where R' in the above general formula is said divalent radical, the primary aliphatic ether amines are ether diamines (and occasionally referred to as such hereinafter or as N-aliphatic ether alkylene diamines) having the subgenus formula:



where R and R'' are as defined above. The R in this subgenus formula has 1 to 13 or more carbon atoms and preferably 7 to 13 carbon atoms, and this R preferably is an alkyl group with 1 to 4 methyl branches, such as the alkyl group derived from an oxo alcohol or mixtures of such alcohols, e.g., isooctyl alcohol, 3,4,4-trimethyl 1-hexanol, decyl alcohol, and tridecyl alcohol.

The ether monoamine acid salts used as collectors in this invention are water-soluble (or water-dispersible) compounds which are liquid at room temperature or are solids with low melting points, properties which make them particularly suitable as reagents in the froth flotation process. The acid salts of these ether monoamines can be represented by the general formula:



where R and R''' are as defined above, A is a solubilizing salt-forming anion of an acid, and n is an integer (preferably 1, as will be the case where monobasic acids are used) equal to the valence of said anion. Representative anions of such salts include acetate, halides (such as chloride, bromide, and iodide), sulfate, nitrate, borate, carbonate, oxalate, sulfamate, phosphate, salicylate, and the like. Sufficient acid is used in neutralizing the ether monoamines to render them water dispersible. In some cases, only 25% neutralization will render the monoamines water dispersible. The acetate salts are preferred because they are less corrosive and have better water solubility.

Representative ether monoamines which can be used

3

(as acid salts) in the practice of this invention and used as reagents in froth flotation include:

3-n-hexoxypropylamine,
3-(3-methylpentoxy) propylamine,
3-isohexoxypropylamine,
3-(2,3-dimethylbutoxy) propylamine,
3-n-heptoxypropylamine,
3-n-octoxypropylamine,
3-n-octoxy (2-methyl) propylamine,
3-isooctoxypropylamine,
3-n-nonoxypopylamine,
3-n-decoxypropylamine,
3-n-dodecoxypropylamine,
3-n-tetradecoxypropylamine,
3-n-pentadecoxypropylamine,
3-n-hexadecoxypropylamine,
3-n-octadecoxypropylamine,
3-(9-n-octadecenoxy) propylamine,
3-(12-n-octadecenoxy) propylamine,
3-n-eicosoxypropylamine,
3-n-docosoxypropylamine,
3-isodecoxypropylamine,
4-n-hexoxy-n-butylamine,
5-(4,6-diethyloctoxy)-3-methylamylamine,
4-(3-methyl-8-propyldodecoxy)-2-ethyl butylamine,
3-n-tridecoxypropylamine,
3-isodecoxypropylamine,
3-(3,4-dimethylhexoxy) propylamine,
3-(3,5-dimethylhexoxy) propylamine,
3-(4,5-dimethylhexoxy) propylamine,
3-(3-methylheptoxy) propylamine,
3-(5-methylheptoxy) propylamine,
5-(3-n-butyl-5-isooctylnonoxy) pentylamine,
4-(2,4,6-trimethyl-3-ethyltetradecoxy) butylamine,
6-(3-n-pentyl-4-diethylhexoxy) hexylamine,
3-lauroleyloxypropylamine,
3-myrestoleyloxypropylamine,
3-palmitoleyloxypropylamine,
3-oleyloxypropylamine,
3-ricinoleyloxypropylamine,
3-linoleyloxypropylamine,
3-linolenyloxypropylamine,
3-eleostearlyloxypropylamine,
3-eiconyloxypropylamine,
3-gadoleyloxypropylamine,
3-arachidonyloxypropylamine,

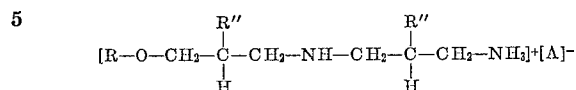
and the like, including mixtures thereof, and their acid salts.

The ether monoamines can be prepared by known methods of cyanoethylation of a primary aliphatic alcohol (ROH), or mixtures of such alcohols, including oxo alcohols, to prepare the corresponding ether nitriles and then hydrogenating the latter to prepare the corresponding ether amines.

The ether diamines used in this invention are liquids and have extremely low cloud points, generally below 0° C. They have relatively high nitrogen or amine content and low combining weight. They can be readily neutralized and used as acid salts, many of which salts are liquids and soluble or dispersible and stable in hard or soft water. Since the ether diamines contain two amine nitrogens, i.e., they contain a primary amine group and a secondary amine group, each ether diamine molecule can combine with one or two monovalent acid anions. So, in neutralizing the ether diamines with an acid having a monovalent anion, one to two moles of acid can be used per mole of ether diamine. In some cases, as low as 25% neutralization will render the diamines water dispersible. In any event, sufficient acid is used in neutralizing the diamine to render the same water dispersible, and preferably enough so that the salts are liquids. Where the diamine is to be 50% neutralized with an acid having a monovalent acid anion, one mole of the acid will be

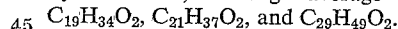
4

used per mole of ether diamine and the resulting salt will have the general formula:



10 where R and R'' are as defined above, and A is a solubilizing salt-forming monovalent acid anion, such as chloride, acetate, benzoate, etc. (The above salt formula is the theoretical formula; actually, some of the secondary amine group is also neutralized to some extent.) Monoacetates of these ether diamines are preferred because they will be liquid at room temperature in addition to being readily dispersible or soluble in aqueous systems.

Inorganic or organic acids can be used in forming the salts from the free base ether amines. Common inorganic acids which can be used include phosphoric, nitric, boric, hydrochloric, hydrobromic and sulfuric acids. Organic acids which can be used include aliphatic mono- di- or tri-carboxylic acids; lower alkyl carboxylic acids; mono- or dihydroxy lower alkyl carboxylic acids and amino-substituted compounds thereof; and unsaturated aliphatic acids. Examples of these organic acids include formic, acetic, hydroxy acetic, propionic, butyric, isovaleric, glycolic, lactic, gluconic, amino acetic, protonic, malonic, succinic, glutaric, adipic, malic, tartaric, glutaric, maleic, fumaric, citric, isocitric aconitic, oxalic, salicylic, sulfonic, carbonic, benzoic and naphthenic acids, and the like. Particularly useful, commercially available acids which can be used include fatty acids, either saturated or unsaturated with 14 to 18 carbon atoms, such as those derived from naturally occurring fats, and oils, such as soybean oil, coconut oil, tallow, tall oil, etc., as well as polymerized fatty acids such as dimer fatty acids (which are usually mixtures of dimer and trimer acids obtained by polymerizing linoleic acids, tall oil acids or soybean acids). Another useful commercially available group of acids which can be used are the Sunaptic Acids, which are monocarboxylic derivatives of naphthalene hydrocarbons, having average molecular formulas



Representative ether diamines which can be used in the practice of this invention include:

N-(methoxy-n-propyl)-1,3-propylene diamine;
N-(ethoxy-n-propyl)-1,3-propylene diamine;
50 N-(n-propoxy-n-propyl)-1,3 propylene diamine;
N-(isobutoxy-n-propyl)-1,3-propylene diamine;
N-(n-pentoxy-n-propyl)-1,3-propylene diamine;
N-(n-hexoxy-n-propyl)-1,3-propylene diamine;
N-(n-heptoxy-n-propyl)-1,3-propylene diamine;
55 N - (3,4 - dimethylhexoxy - n - propyl) - 1,3 - (2-methyl)-propylene diamine;
N-(n-heptenoxy-2-methylpropyl)-1,3-propylene diamine;
N - (4 - methyl - 3 - hexenoxy - n - propyl) - 1,3 - (2-methyl)-propylene diamine;
60 N-(n-octoxy-n-propyl)-1,3-propylene diamine;
N - (3,4 - dimethyl - hexoxy - n - propyl) - 1,3 - (2-methyl)-propylene diamine;
N-(4-ethyl-hexenoxy-2-methylpropyl-1,3-(2-methyl)-propylene diamine;
65 N-(1-methylheptoxy-n-propyl)-1,3-propylene diamine;
N-(4,4-dimethylhexoxy-n-propyl)-1,3-propylene diamine;
N-(6-methylheptoxy-n-propyl)-1,3-propylene diamine;
N-7-octenoxy-n-propyl)-1,3-(2-methyl)-propylene diamine;
70 N-(3-methyl-5-heptenoxy-n-propyl)-1,3-propylene diamine;
N-(n-nonoxyn-propyl)-1,3-propylene diamine;
N - (4 - methyl - 3 - ethyl - hexoxy - n - propyl) - 1,3-propylene diamine;
75

N - (2,3 - dimethyl - 4 - heptenoxy - 2 - methylpropyl)-
1,3-propylene diamine;
N-(n-decoxy-n-propyl)-1,3-propylene diamine;
N - (3,4,5 - trimethylheptoxy - n - propyl) - 1,3 - (2-
methyl)-propylene diamine;
N-(9-decenoxy-2-methylpropyl)-1,3-propylene diamine;
N - (9 - methyl - 4,5 - nonadienoxy - n - propyl) - 1,3-
propylene diamine;
N-(n-hendecoxy-n-propyl)-1,3-propylene diamine;
N-9-methyl-decoxy-2-methylpropyl)-1,3-propylene
diamine;
N - (9 - hendecenoxy - n - propyl) - 1,3 - (2 - methyl)-
propylene diamine;
N-(3-n-propyl-octoxy-n-propyl)-1,3-propylene diamine;
N-(n-dodecoxy-n-propyl)-1,3-propylene diamine;
N - (10-methylhendecoxy - 2 - methylpropyl) - 1,3-
propylene diamine;
N - (8 - methyl - 6 - ethylnonoxy - n - propyl) - 1,3 - (2-
methyl)-propylene diamine;
N-(10-dodecenoxy-n-propyl)-1,3-propylene diamine;
N-(n-tridecoxy-n-propyl)-1,3-propylene diamine;
N - (4,7,9 - trimethyldecoxy - n - propyl) - 1,3 - (2-
methyl)-propylene diamine;
N - (3,5,7,8 - tetramethylnonoxy - 2 - methylpropyl)-
1,3-propylene diamine;
N-(10-tridecenoxy-n-propyl)-1,3-propylene diamine;
N - (4,8,12 - trimethyl - 11 - decenoxy - n - propyl) - 1,3-
propylene diamine;
N - (8 - n - propyl - 5,9 - decadienoxy - 2 - methyl-
propyl)-1,3-propylene diamine;

and the like. Mixtures of said ether diamine acid salts can be used, especially where the alcohol used to form the ether diamines is a mixture of alcohols, as will be the case where commercial oxo alcohols are used.

The ether diamines used in this invention can be prepared by reacting an aliphatic ether primary amine with acrylonitrile or methacrylonitrile and then hydrogenating the resulting aliphatic ether amine nitrile to produce the ether diamine. The aliphatic ether primary amines can themselves be prepared by hydrogenating the aliphatic ether nitriles produced by the reaction of a primary and/or secondary aliphatic alcohol with acrylonitrile or methacrylonitrile. Alcohols which can be used for this purpose include methanol, isobutanol, etc. and higher alcohols. Particularly useful alcohols which can be used are the higher oxo alcohols produced by hydrogenation of oxoaldehydes which in turn are prepared by the oxonation reaction between an olefin, carbon-monoxide and hydrogen. The disclosure of the preparation of these ether diamines will be omitted in the interest of brevity, and further detail on such preparation is disclosed in copending application Ser. No. 519,531, filed Jan. 10, 1966, incorporated herein by reference.

The amount of ether amine acid salt reagent used in the froth flotation process will vary and be dependent upon such factors as the type of ore being treated, the amount of mineral to be collected, the degree of subdivision of such minerals, the degree of separation desired, and the particular ether amines used. Functionally expressed, the amount of ether amine acid salt reagent used in such froth flotation process will be that sufficient to achieve a desirable separation. Generally, the amount of ether amine acid salt used will be 0.05 to 2 pounds, preferably 0.1 to 0.3 pound, per ton of ore.

The ether amine acid salt reagent can be employed as a solution or dispersion in water or other solvent and introduced into the ore pulp as such without prior conditioning or can be conditioned with the ore pulp prior to the actual concentration operation. In addition, the reagents of this invention can be used in conjunction with other conventional treating agents such as activators, frothing agents, depressing agents, dispersing agents, etc. One particular advantage of this invention is that when it is prac-

ticed to separate silica from iron ore, such as magnetite, effective separation can be obtained without the necessity of using an iron depressant such as starch.

In carrying out the practice of my invention, the general well known technique of the froth flotation process is used. Briefly, the ore, or a concentrate of the ore, is ground and mixed with water to form a pulp. The pulp is placed in a suitable flotation cell or vessel provided with an agitator. Air is introduced into the pulp by means of a sparger and passes through the pulp. The froth that is formed is skimmed off or allowed to overflow. The silica floats away with the froth, leaving the mineral concentrate behind. In this manner, the silica or siliceous material is separated from the desired mineral. Although this invention is particularly applicable in removing silica from iron ore, such as magnetite, it can be used in concentrating any silica-containing minerals or ores, such as hematite, goethite, phosphate rock, etc.

The following examples further illustrate the advantages and objects of this invention, but the various reagents, conditions of treatment, and other details recited in these examples should not be construed to unduly limit this invention.

Examples

Several ether amine acid salts of this invention were evaluated as silica collector reagents in the froth flotation of magnetic iron concentrate obtained from the Mesabi Iron Range. The iron concentrate or feed used in Runs 1, 2 and 3 was ground so that 80% passed through a 325 mesh standard sieve, and it contained about 63.5 weight percent iron and 10 weight percent silica. The iron concentrate feed used in Runs 4, 5 and 6 was ground so that 90% passed through a 325 mesh standard sieve, and it contained 67.2 weight percent iron and 5.1 weight percent silica.

In Runs 1, 2 and 3, 500 grams of the concentrate was placed in a Fagergren Mineral Master laboratory flotation cell and diluted with sufficient water to provide a water mixture containing 20 weight percent of the iron concentrate. The mixture was allowed to agitate in the cell for one minute, using an impeller speed of 1500 r.p.m. The reagent to be evaluated was then added to the agitating pulp in the cell, using in all cases 2 ml. of a 2½ percent solution of the reagent in water (0.2 lb./ton of iron concentrate). Twenty-five seconds after the reagent was added, 0.05 pound of methyl isobutyl carbinol per ton of feed was added as a frothing agent. Thirty seconds after the reagent was added, the air valve of the cell was opened, injecting air at the bottom of the cell and thus starting the flotation process, the pH of the pulp being 7.5-8. The froth product or tailings (containing the silica) was skimmed off. The tailings and concentrate products were then filtered in a filter press and baked overnight in a 300° F. oven. The dried products were then weighed and analyzed to determine the amount of iron and the amount of silica in each product. Runs 4, 5 and 6 were made in the same manner as described above, except that only 1 ml. of the 2½ percent reagent solution was added to the pulp and 0.06 lb. of pine oil per ton of feed was used as the frothing agent. Results are summarized in the following Table II.

The reagent used in Runs 1 and 5 comprised a primary C₈-C₁₀ propyl ether amine acetate, having a total amine nitrogen (TAN) content of 6.68%, the sum of secondary and tertiary amine nitrogen in the material being 0.26%. In preparing this reagent, 20.97 grams of the ether amine was 50% neutralized with 3 grams of glacial acetic acid. Five grams of this neutralized ether amine was diluted with 195 grams of water to prepare a 2.5% reagent dispersion. The reagents used in the other runs were prepared in the same manner, and the compositions of all of the reagents used are shown in Table I.

TABLE I

Run	Amine used	Analysis			Percent Neutralized with acetic acid
		TAN, percent	Sec. and tert. amine N, percent	Equivalent weight	
1-----	C ₈ -C ₁₀ propyl ether diamine..	6.68	0.26	209.7	50
2-----	3-isodecoxypropyl amine	6.04	0.09	229.7	50
3-----	do.....	5.56	0.06	252.0	50
4-----	C ₈ -C ₁₀ propyl ether diamine..	6.68	0.26	209.7	100
5-----	do.....	6.68	0.26	209.7	50
6-----	N-tridecoxypropyl-1,3-propylene diamine.	7.93	*3.75	176.5	50

*This figure is for secondary amine nitrogen only.

TABLE II

Run	Collector used	Product	Amt. of product, wt. percent	Assay		Units		Fe recovery, wt. percent
				HCl insol., wt. percent	Fe, wt. percent	HCl insol.	Fe	
1-----	{C ₈ -C ₁₀ propyl ether amine acetate (50% neutralized).	{Concentrate.....	87.78	7.12	65.67	6.25	57.65	90.82
		{Tailings.....	12.22	31.10	47.68	3.80	5.83	
						10.05	63.48	
2-----	{3-isodecoxypropyl amine acetate (50% neutralized).	{Concentrate.....	79.74	6.19	66.25	4.94	52.84	83.45
		{Tailings.....	20.26	26.02	51.78	5.27	10.48	
						10.21	63.32	
3-----	{3-isodecoxypropyl amine acetate (50% neutralized).	{Concentrate.....	80.06	6.45	66.25	5.16	53.04	83.59
		{Tailings.....	19.94	24.42	52.22	4.87	10.41	
						10.03	63.45	
4-----	{C ₈ -C ₁₀ propyl ether amine acetate (100% neutralized).	{Concentrate.....	90.97	3.79	68.12	3.45	61.97	92.20
		{Tailings.....	9.03	19.65	56.89	1.77	5.24	
						5.22	67.21	
5-----	{C ₈ -C ₁₀ propyl ether amine acetate (50% neutralized).	{Concentrate.....	87.45	3.13	68.59	2.74	60.00	89.32
		{Tailings.....	12.55	19.13	57.26	2.40	7.18	
						5.14	67.18	
6-----	{N-tridecoxypropyl-1,3-propylene diamine monoacetate.	{Concentrate.....	89.51	3.54	68.28	3.17	61.12	91.10
		{Tailings.....	10.49	19.65	56.88	2.06	5.97	
						5.23	67.09	

The data of Table II show that the ether amine salts of this invention are generally strong silica collectors with good selectivity. In the case of Run 1, the collector exhibited good selectivity and high iron recovery, though by using greater amounts of the collector the silica content in the concentrate could be reduced. In the case of Run 2, the collector exhibited good selectivity, good iron recovery, and strong collecting power. In the case of Run 3, though the selectivity was not as high, the collector exhibited good iron recovery and strong collecting power. In similar runs with secondary aliphatic ether amine and primary amine acetates, the concentrate was too high in silica content or the selectivity was lower, showing that the primary aliphatic ether amines of this invention are superior.

The results of Runs 4 and 5 show that the neutralization level of the amine has a significant effect on flotation performance. The 50% neutralized amine salt was a stronger collector than the 100% neutralized amine salt.

Since all of the collectors listed are readily dispersible in water as 50% acetate salts, these collectors have advantages and more versatility than conventional lauryl primary amines which are not readily dispersible in water unless completely or 100% neutralized with acetic acid.

Run 6 shows that N-tridecoxypropyl-1,3-propylene diamine monoacetate is also an effective silica flotation collector, its use resulting in good silica reduction with a high iron recovery.

Another series of runs was made in which a conventional distilled primary lauryl amine 100% neutralized with acetic acid was compared with the C₈-C₁₀ propyl ether amine 100% neutralized with acetic acid (used in Run 4). These runs were made with varying reagent levels using the aforementioned procedure on an ore containing 10.3 weight percent silica and 64.5 weight percent iron. Table III shows the flotation concentrate grades and recoveries.

TABLE III

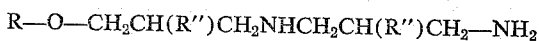
Run	Collector used	Amt. of collector used, lb./ton conc.	Amt. of iron in conc., wt. percent	HCl insol. wt. percent	Iron recovery, percent
7-----	Primary lauryl amine acetate	0.05	63.85	7.06	83.2
8-----	do.....	0.10	68.36	5.26	66.1
9-----	C ₈ -C ₁₀ propyl ether amine acetate.....	0.05	65.43	8.44	92.6
10-----	do.....	0.10	67.03	6.73	83.8
11-----	do.....	0.20	63.15	5.28	69.2

If a plot is made of the percent silica remaining in the concentrate versus the percent Fe recovery, using the data of Table III, it would show that the C₈-C₁₀ propyl ether amine acetate of this invention is significantly more selective than the primary lauryl amine acetate. That is, the ether amine acetate of this invention will result in a concentrate lower in silica at an equal iron recovery, or a higher iron recovery at an equal silica content. The primary lauryl amine acetate is a stronger collector but not as selective as the ether amine acetate. In addition, the primary lauryl amine must be completely neutralized to make it readily dispersible in water, and even then it is a solid rather than a liquid salt and cannot be handled as easily.

Various modifications and alterations of this invention will become apparent to those skilled in the art without departing from the scope and spirit of this invention.

We claim:

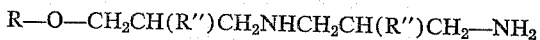
1. A froth flotation process for separating silica from an ore, which comprises frothing said ore in the presence of an aqueous medium containing a water dispersible acid salt of an aliphatic ether diamine having the general formula



where R is an aliphatic radical having 1-13 carbon atoms, and R'' is a hydrogen atom or a methyl group and floating off the silica from said ore.

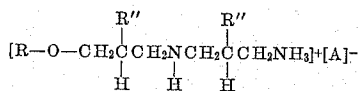
2. The process according to claim 1, wherein said ether diamine is used in the form of its acetate salt.

3. The process according to claim 1, wherein said ether diamine has the general formula



where R is an alkyl radical having 7 to 13 carbon atoms and 1-4 methyl branches, and R'' is a hydrogen atom or a methyl group.

4. A froth flotation process for separating silica from iron ore, which comprises frothing said ore in an aqueous medium in the presence of 0.1 to 2 pounds per ton of said ore of a water-dispersible, liquid aliphatic ether diamine salt having the general formula



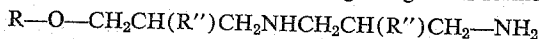
where R is an aliphatic radical having 7-13 carbon atoms, R'' is hydrogen or methyl, and A is a solubilizing salt-forming anion of monobasic acid and floating off the silica from said ore.

5. The process according to claim 4, wherein said iron ore is magnetite.

6. The process according to claim 5, wherein said anion is acetate.

7. The process according to claim 6, wherein said ether diamine salt is N-tridecoxypropyl-1,3-propylene diamine monoacetate.

8. In a froth flotation process for separating silica from an ore by subjecting said ore to froth flotation in the presence of a collecting agent to float off said silica, the improvement comprising using as the collecting agent an acid salt of an ether diamine having the general formula



where R is an aliphatic radical having 1-13 carbon atoms and R'' is a hydrogen atom or a methyl group.

References Cited

UNITED STATES PATENTS

2,166,150	7/1939	Howk	209-166 X
2,177,985	10/1939	Harris	209-166
2,214,352	9/1940	Schoeller	209-166 X
2,222,728	11/1940	Tartaron	209-166
2,307,397	1/1943	Falloner	209-166
2,372,624	3/1945	Carpenter	260-584
2,450,720	10/1948	De Vaney	209-166
2,839,131	6/1958	Monson	209-166
3,076,819	2/1963	Heise	260-584 X
3,251,852	5/1966	De Groote	260-584

HARRY B. THORNTON, *Primary Examiner*.

R. HALPER, *Assistant Examiner*.