

TB 108



DEPARTMENT OF
ENERGY, MINES AND RESOURCES
MINES BRANCH
OTTAWA

*THE FLOATABILITY OF TEN
NON-METALLIC MINERALS
(A SUPPLEMENT TO TB 108)*

R. A. WYMAN AND J. H. COLBORNE

MINERAL PROCESSING DIVISION

MARCH 1974

01 7991360

© Crown Copyrights reserved

Available by mail from Information Canada, Ottawa, K1A 0S9
and at the following Information Canada bookshops:

HALIFAX

1683 Barrington Street

MONTREAL

640 St. Catherine Street West

OTTAWA

171 Slater Street

TORONTO

221 Yonge Street

WINNIPEG

393 Portage Avenue

VANCOUVER

800 Granville Street

or through your bookseller

Price: .75 cents Catalogue No. M34-20/186

Price subject to change without notice

Information Canada
Ottawa, 1974

Mines Branch Technical Bulletin 186

THE FLOATABILITY OF TEN NON-METALLIC MINERALS

(A Supplement to TB 108)

by

R. A. Wyman* and J. H. Colborne**

- - -

ABSTRACT

The work reported is part of a long-range study intended to fill a continuing demand for information on industrial mineral flotation. Previous work, already reported, covered about 14,000 trials. The present work covers about 7,000 additional trials.

The experimental procedure involves a simple, bubble pick-up method applied in acid, neutral and basic conditions under the influence of thirty-one different collectors and six common modifiers. The trade names and general chemical names for collectors and modifiers are listed in the report.

The method of assessing results includes comparison on a weighted average basis and a graphical form of presentation which conforms with earlier presentations. The present work includes the data derived for amblygonite, aragonite, brucite, diopside, graphite, nepheline syenite, scheelite, tremolite, zeolite, and zircon.

*Head, and **Technician, Industrial Minerals Milling Section, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

Bulletin Technique de la Direction des Mines BT 186

LA FLOTTABILITE DE DIX MINERAUX NON-METALLIQUES

(Un supplément de BT 108)

par

R. A. Wyman* et J. H. Colborne**

- - -

RESUME

Le travail rapporté dans ce bulletin fait partie d'une étude à longue portée destinée à satisfaire une demande continuelle d'information sur la flottation des minéraux industriels. Des travaux antérieurs, qui ont déjà été rapportés, englobaient environ 14,000 essais. Le travail présent comprend environ 7,000 essais additionnels.

Le procédé expérimental utilisé comporte une méthode à bulle collectrice appliquée dans des conditions acides, neutres et basiques sous l'influence de trente et un agents collecteurs différents et de six réactifs activants ou déprimants d'usage courant. Les appellations commerciales et chimiques pour les agents collecteurs et réactifs sont données dans le rapport.

La méthode d'évaluation des résultats comporte une comparaison basée sur la moyenne pondérée ainsi qu'une forme graphique de présentation laquelle se conforme avec les présentations antérieures. Le travail présent comprend les données obtenues sur les minéraux suivants: amblygonite, aragonite, brucite, diopside, graphite, néphéline syénite, scheelite, trémolite, zéolite et zircon.

*Chef, et **Technicien, Section du Traitement des Minéraux Industriels, Division du Traitement des Minéraux, Direction des Mines, Département de l'Energie, des Mines et des Ressources, Ottawa, Canada.

CONTENTS

	<u>Page</u>
Abstract	i
Résumé	ii
Introduction	1
Experimental Procedure	2
Minerals Investigated	4
Collectors Investigated	5
Modifiers Investigated	7
Results	8
Data Sheets: (Response to Collectors; Effect of Modifiers)	
Amblygonite	11
Aragonite	13
Brucite (granular)	15
Brucite (fibrous)	17
Diopside	19
Graphite	21
Nepheline Syenite	23
Scheelite	25
Tremolite	27
Zeolite	29
Zircon	31
Conclusion	33
References	33

INTRODUCTION

For a number of years the Industrial Minerals Milling Section employed a small-scale test to aid in solving flotation problems. The test method was simple and direct. It was intended to be indicative rather than definitive, a guide rather than a solution.

Because the information obtained had proven helpful in solving a number of flotation problems, it was decided to publish the results. Technical Bulletin TB 70⁽¹⁾ was issued in 1965 and presented the results of approximately 4000 of the small-scale experiments, designed to indicate the flotability of eleven non-metallic minerals under a variety of conditions. Its purpose was to point out possible new approaches for the separation of non-metallic minerals by flotation, particularly where separation was difficult, and to suggest possible methods of separation for minerals for which no effective system was known.

By 1969, the work had been extended to cover approximately 14,000 of the small-scale experiments, showing flotation for twenty-one non-metallic minerals (the original 11, plus 10 more) in response to thirty-one collectors as well as the influence of six common modifiers. These results were reported in Technical Bulletin TB 108⁽²⁾.

Because of continuing wide demand for information in this field, well over 7,000 additional small-scale trials have been completed since TB 108 was published. These cover the flotation response of ten additional non-metallic minerals and form the subject of the present report.

EXPERIMENTAL PROCEDURE

Minerals to be investigated are obtained in the purest form available, as crystals where possible. Each mineral is pulverized, and the 28 to 325 mesh fraction is isolated. This fraction is selected because most flotation is done within this size range and a rough visual estimation of the number of particles picked up by a bubble can be made.

These individual fractions are rinsed lightly with dilute HCl and then washed with distilled water to neutral pH. The intent is to clean the surfaces without etching or altering them significantly. Each mineral is stored in distilled water.

The apparatus used consists of a small turntable, a beaker, a stirring rod, and a glass tube with a rubber eyedropper bulb and screw clamp at its top. Before an experiment, the beaker, stirring rod and glass tube are rinsed with chromic-acid cleaning solution and washed thoroughly with distilled water. Measuring devices such as graduates and pipettes are similarly cleaned once or twice per day.

A single experiment consists of the following steps:

- (1) About 100 ml of distilled water is put into the beaker.
- (2) A small quantity (about 0.01 g) of the particular mineral to be examined is added.
- (3) The pH regulator, if used, is added and mixed by stirring rod.
- (4) Modifier (to give 0.05 g/l concentration), if used, is added and mixed by stirring rod.
- (5) Collector to give 0.1 g/l concentration is added and mixed by stirring rod.

- (6) The beaker is placed on the turntable. The tube with eyedropper is lowered vertically until its open end is about one half inch above the mineral.
- (7) The screw clamp on the rubber bulb is turned to produce a bubble at the lower end of the glass tube.
- (8) The beaker and turntable are raised until the bubble makes contact with the mineral.
- (9) The beaker is lowered until the bubble and adhering particles are surrounded by the liquid.
- (10) Particles adhering to the bubble are estimated (none, one, two, ten, fifteen, etc.).
- (11) The glass tube is lightly tapped and the tenacity with which the particles cling to the bubble (i.e., poor, fair, or good) is estimated.
- (12) These estimations are recorded on a standard form.

The experiments progress from simple to more complex. The first step for each mineral is to run a blank, i.e., the bubble is placed in contact with the mineral in distilled water only. With many minerals, several particles will be picked up but may drop off as soon as the tube is tapped lightly. Each mineral is then tested for response to each collector in turn, under acidic, neutral and basic conditions. In the neutral case, the system consists only of the mineral and the collector in distilled water. For acidic conditions, 1 ml of H_2SO_4 of a predetermined concentration is added from a 1-ml dispensing bottle. The acid is of such a concentration that when 1 ml is added to 100 ml of distilled water, a pH of 3.0 will result. Similarly, for basic conditions, 1 ml of Na_2CO_3 of predetermined concentration is added from a 1-ml dispensing bottle, producing a pH of 10.0 in 100 ml of distilled water. For both the

acidic and basic experiments the regulator is mixed-in by stirring and the collector is added and also mixed-in by stirring, before bubble contact is made.

The pH will vary slightly during the experiment, owing to the presence of the mineral and the other reagents. However, the quantity of both mineral and reagents is comparatively small and the operations are conducted rapidly. It has been found that the pH varies little from that of the acid or base in distilled water. The maximum change in pH is observed when ionizing modifiers are used. Since the general acidic or basic nature of the system is not altered, however, and the total variation is rarely beyond one pH point, it is considered preferable not to readjust the pH to the specified points. This would add greatly to the time required to perform an individual acidic or basic experiment. Moreover, since the observations are not absolute, the over-all results must be considered as relative only. The one operation with any significant bias is that for "neutral" when HF is used as a modifier. The pH in this case is always slightly on the acid side. However, this would also be the case in larger-scale flotation practice.

In experiments with modifiers, each system - mineral, collector, and pH control - is repeated with each modifier. The modifier is added before the collector and mixed by stirring.

MINERALS INVESTIGATED

The criteria for selecting minerals for this study were that they come from natural occurrences and be nearly pure. Minerals reported upon are as follows:

<u>Mineral</u>	<u>Colour</u>	<u>Origin</u>
1. Amblygonite	White	Manitoba
2. Aragonite	White	B.C.
3. Brucite (granular)	Buff	Quebec
" (fibrous)	White	Quebec
4. Diopside	White	Quebec
5. Graphite	Black	Quebec
6. Nepheline Syenite	White	B.C.
7. Scheelite	Buff	N.W.T.
8. Tremolite	White	Ontario
9. Zeolite	Brownish grey	N.B.
10. Zircon	Pink	Australia

COLLECTORS INVESTIGATED

The principle of collection in flotation is simple - to render hydrophobic the surfaces of the mineral to be floated, thus allowing attachment to an air bubble and elevation to the surface. In theory this should be possible with any mineral. In practice there are many complicating factors, and finding a chemical that will be selective for one specific mineral in a mixture of minerals is by no means easy.

Since the mineral surface is the site of the action, the chemicals involved are the so-called surface-active agents (or surfactants). Broadly, these agents fall into three classes according to their activity - non-ionic, anionic, and cationic. Non-ionic agents do not ionize in solution. When anionic agents are dissolved, the negative ions, or anions, are active, and when cationic agents are dissolved, the positive ions, or cations, are active.

Although fatty acids are anionic, they are widely used in non-metallic mineral flotation and, for the purpose of this report, have been considered as a fourth class.

There are many thousands of surfactants available, and the list is continually increasing and changing. The older, stable types are rapidly being replaced by biodegradable ones. For the purpose of flotation, these can be narrowed into a comparatively small number of general types, with an even narrower grouping applicable to non-metallics. Reagents that are in more or less common use as flotation collectors have been included as well as newcomers.

The collectors used are listed below according to their class, trade name, and general chemical name.

NON-IONIC, Ethanol

Igepal CTA	Alkyl phenoxy poly- (ethyleneoxy) ethanol
Rexol 25J	Nonyl phenol polyethoxy ethanol

ANIONIC, Petroleum sulphonate

Reagent 801	"Green acid"-type petroleum sulphonate
Petroflote 462	Sodium alkyl-aryl petroleum sulphonic acid
Leonal SA	Naphthalene sulphonic acid derivative

ANIONIC, Fatty acid sulphonate

Emcol 4150	Fatty acid aliphatic sulphonate
Sulphonated castor oil	Sulphonated castor oil (60% fats)
Prestabit oil V	Sulphonated fatty acids

ANIONIC, Alkyl sulphate

Duponol 80	Sodium octyl sulphate
Nutrapon WAC	Sodium lauryl sulphate
Duponol OS	Diethyl cyclohexylamine lauryl sulphate

ANIONIC, Sodium taurate

Igepon TE 42	Sodium-N-methyl-N-tallow acid taurate
Igepon T 33	Sodium-N-methyl-N-oleoyl taurate
Igepon TN 74	Sodium-N-methyl-N-palmitoyl taurate

CATIONIC, Primary amine

Adogen 170A	Technical tallow amine acetate
Armac C	Coco amine acetate
Armeen L-9	Primary beta amine

CATIONIC, Diamine

Duomac T	Tallow diamine di-acetate
Duomac C	Coco diamine di-acetate
Duomeen L-11	Beta diamine

CATIONIC, Tertiary amine

Nalcamine G 11	Hydroxyethyl alkyl imidazoline (glyoxalidine)
Armeen 12 D	Lauryl amine
Armeen DLM 11	Beta tertiary amine

CATIONIC, Quaternary ammonium compounds

Emcol E 607-40	N (lauroyl-colamino-formly-methyl) pyridinium chloride
ARQUAD 12	n-alkyl trimethyl ammonium chloride
Retarder LA	Cetyl trimethyl ammonium bromide
Ammonyx T	Cetyl trimethyl benzyl ammonium chloride

FATTY ACID, Tall oil

Neofat 42-12	Tall oil base fatty acid
Actinol FA 2	Tall oil fatty acid

FATTY ACID, Oleic

Harfat 231	Oleic acid blend
Distilled oleic acid	Oleic acid

MODIFIERS INVESTIGATED

As pointed out in the previous section, Flotation is effected by the action of a collector, causing the surface of a mineral to become hydrophobic. In many cases, however, it is necessary to use, as well, modifying agents to achieve this. Such agents simply aid in getting the collector onto the surface of the mineral to be floated. This action is called activation. On the other hand, a modifying agent may prevent a collector from getting

onto the surface of unwanted minerals. This action is called depression. These are probably the most important functions of modifiers.

The regulation of pH is itself a form of modifying: as indicated earlier, all the experiments were done at three pH levels. The cleaning of surfaces, dispersion of ultra-fine solids, precipitation of dissolved salts, and other functions, are handled by modifying agents. Some agents serve more than one purpose - e.g., sodium carbonate may act as a dispersant, activator, depressant, or means of pH control. Metal ions are believed to alter the mineral surfaces by being adsorbed on these surfaces. Organic colloids are thought to blank off surfaces. Organic acids may aid in activation, depression, or cleaning surfaces.

The pH-controlling agents employed have been described under EXPERIMENTAL PROCEDURE. Other modifiers used in the experiments are: (1) three to provide ion resurfacing - FeSO_4 for iron, $\text{Al}_2(\text{SO}_4)_3$ for aluminum, and HF for fluorine; (2) two organic colloids to blank mineral surfaces - starch and dextrin; and (3) one organic acid - citric acid.

RESULTS

The object in the method of presenting the results is usability. Ready comparison of the results for individual minerals is necessary in order to facilitate selection of the liquid systems in which separations would be likely to take place. In this report, the estimations for each mineral have been condensed so that they will fit onto the front and back of a single sheet. Each sheet may be removed from the report so that it may be laid beside another, or so that two or more may be overlapped, for easier comparison.

For each mineral, flotation is estimated according to collectors

on the front of a page, and according to modifiers on the back of a page. To make comparison as easy as possible, the flotability is depicted by four symbols - black for excellent, cross-hatched for good, stippled for fair, and blank for poor. Thus the darker areas, black and cross-hatched, generally indicate acceptable flotation, whereas the lighter areas, stippled and white, indicate unsatisfactory flotation at best.

In the initial recording of observations as described under EXPERIMENTAL PROCEDURE, the number of particles adhering to the bubble and the strength of the bond were indicated. Thus, 15G stood for about 15 particles picked up and firmly held by the bubble (good bond). If the record was 15F, then some or most of the particles could be dislodged by a light tapping on the bubble tube (fair bond). A record such as 3P would indicate that 3 particles were picked up and either dropped from the bubble after a moment or two or dropped after a light tap on the bubble tube (poor bond).

In assessing the results for this method of presentation, one has to use a form of weighted average. This consists of arbitrarily allotting the number 1 to poor bond, 2 to fair bond and 3 to good bond, then multiplying the number of particles by these numbers. The aggregate of all cases divided by the number of cases is then used to determine the average flotability. An average below 10 is considered to be poor, between 10 and 25 fair, 25 to 40 good, and above 40 excellent. In the occasional doubtful case between poor and fair, or between fair and good, flotability has been indicated by using both symbols. Results which differ greatly from the average have not been used in the calculation but are pointed out as exceptions.

Results are presented for the various minerals in alphabetical order, and each sheet is dated so that, with subsequent extensions of the work, the latest and most up-to-date sheets will be retained.

RESPONSE TO COLLECTORS

Amblygonite

KEY: Excellent Flotation



Fair Flotation



Good Flotation



Poor Flotation



<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

Date January, 1974

Amblygonite

EFFECT OF MODIFIERS

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
NON-IONIC Ethanol							
Acid							
Neutral							
Basic							
ANIONIC Petroleum Sulphonate							
Acid							
Neutral							
Basic							
ANIONIC Fatty Acid Sulphonate							
Acid							
Neutral							
Basic							
ANIONIC Alkyl Sulphate							
Acid							
Neutral							
Basic							
ANIONIC Sodium Taurate							
Acid							
Neutral							
Basic							
CATIONIC Primary Amine 1							
Acid							
Neutral							
Basic							
CATIONIC Diamine 2							
Acid							
Neutral							
Basic							
CATIONIC Tertiary Amine 3							
Acid							
Neutral							
Basic							
CATIONIC Quaternary							
Acid							
Neutral							
Basic							
FATTY ACID Tall Oil							
Acid							
Neutral							
Basic							
FATTY ACID Oleic							
Acid							
Neutral							
Basic							

1. Poor flotation with Armeen L-9

2. " " Duomac T

3. Excellent flotation with Nalcamine G11

KEY: Excellent Flotation



Fair Flotation



Good Flotation



Poor Flotation



<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

Aragonite

EFFECT OF MODIFIERS













	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
Acid Neutral Basic	NON-IONIC		Ethanol				
Acid Neutral Basic	ANIONIC		Petroleum Sulphonate				
Acid Neutral Basic	ANIONIC		Fatty Acid Sulphonate				
Acid Neutral Basic	ANIONIC		Alkyl Sulphate				
Acid Neutral Basic	ANIONIC		Sodium Taurate				
Acid Neutral Basic	CATIONIC		Primary Amine	1	1	1	1
Acid Neutral Basic	CATIONIC	2	Diamine	2	3	3	2
Acid Neutral Basic	CATIONIC		Tertiary Amine				
Acid Neutral Basic	CATIONIC		Quaternary				
Acid Neutral Basic	FATTY ACID		Tall Oil				
Acid Neutral Basic	FATTY ACID		Oleic				


































1. Poor flotation with Armeen L-9
 2. Excellent " " Duomac T
 3. Poor " " Duomeen L-11

- 15 -
RESPONSE TO COLLECTORS

Brucite
(granular)

KEY:	Excellent Flotation		Fair Flotation	
	Good Flotation		Poor Flotation	

<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
Acid Neutral Basic	NON-IONIC		Ethanol				
Acid Neutral Basic	ANIONIC	1	Petroleum Sulphonate	1	1	1	1
Acid Neutral Basic	ANIONIC		Fatty Acid Sulphonate				
Acid Neutral Basic	ANIONIC		Alkyl Sulphate				
Acid Neutral Basic	ANIONIC	3 2	Sodium Taurate	2	2		2 2
Acid Neutral Basic	CATIONIC		Primary Amine	4			
Acid Neutral Basic	CATIONIC		Diamine				
Acid Neutral Basic	CATIONIC		Tertiary Amine				
Acid Neutral Basic	CATIONIC		Quaternary	5			
Acid Neutral Basic	FATTY ACID		Tall Oil				
Acid Neutral Basic	FATTY ACID		Oleic				

1. Poor flotation with Leonal SA
2. Excellent " " Igepon T-33
3. Poor " " Igepon TN-74
4. " " " Adogen 170A
5. Excellent " " Ammonyx T

KEY: Excellent Flotation



Fair Flotation



Good Flotation



Poor Flotation



<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Anionic	12	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cationic	13	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fatty acid	4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Anionic	Petroleum sulphonate	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
"	Fatty acid sulphonate	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
"	Alkyl sulphate	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
"	Sodium taurate	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cationic	Primary amine	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
"	Diamine	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
"	Tertiary amine	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
"	Quaternary	4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fatty acid	Tall oil	2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
"	Oleic	2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

No flotation obtained.

Date January, 1974













Brucite
(fibrous)


































EFFECT OF MODIFIERS

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
	NON-IONIC		Ethanol				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	ANIONIC		Petroleum Sulphonate				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	ANIONIC		Fatty Acid Sulphonate				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	ANIONIC		Alkyl Sulphate				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	ANIONIC		Sodium Taurate				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	CATIONIC		Primary Amine				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	CATIONIC		Diamine				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	CATIONIC		Tertiary Amine				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	CATIONIC		Quaternary				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	FATTY ACID		Tall Oil				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	FATTY ACID		Oleic				
Acid	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Neutral	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Basic	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>

No flotation obtained.

KEY:	Excellent Flotation		Fair Flotation	
	Good Flotation		Poor Flotation	

<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

Diopside

EFFECT OF MODIFIERS













	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
	NON-IONIC		Ethanol				
Acid							
Neutral							
Basic							
	ANIONIC		Petroleum Sulphonate				
Acid							
Neutral							
Basic							
	ANIONIC		Fatty Acid Sulphonate				
Acid							
Neutral							
Basic							
	ANIONIC		Alkyl Sulphate				
Acid							
Neutral							
Basic							
	ANIONIC		Sodium Taurate				
Acid							
Neutral							
Basic							
	CATIONIC		Primary Amine				
Acid							
Neutral							
Basic							
	CATIONIC		Diamine				
Acid							
Neutral							
Basic							
	CATIONIC		Tertiary Amine				
Acid							
Neutral							
Basic							
	CATIONIC		Quaternary				
Acid							
Neutral							
Basic							
	FATTY ACID		Tall Oil				
Acid							
Neutral							
Basic							
	FATTY ACID		Oleic				
Acid							
Neutral							
Basic							












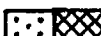





















1. Excellent flotation with Duomac T
2. Poor " " Duomeen L-11
3. Excellent " " Nalcamine G11

RESPONSE TO COLLECTORS

Graphite

KEY:	Excellent Flotation		Fair Flotation	
	Good Flotation		Poor Flotation	

<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

Graphite

EFFECT OF MODIFIERS

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
Acid Neutral Basic	NON-IONIC		Ethanol				
Acid Neutral Basic	ANIONIC	Petroleum Sulphonate					
Acid Neutral Basic	ANIONIC	Fatty Acid Sulphonate					
Acid Neutral Basic	ANIONIC	Alkyl Sulphate					
Acid Neutral Basic	ANIONIC	Sodium Taurate					
Acid Neutral Basic	CATIONIC	Primary Amine					
Acid Neutral Basic	CATIONIC	Diamine					
Acid Neutral Basic	CATIONIC	Tertiary Amine					
Acid Neutral Basic	CATIONIC	Quaternary					
Acid Neutral Basic	FATTY ACID	Tall Oil					
Acid Neutral Basic	FATTY ACID	Oleic					

1. Poor flotation with Leonal SA
2. Excellent " " Igepon TE 42
3. Poor " " Duomac C
4. Excellent " " Duomac T
5. Poor " " Nalcamine G 11
6. Excellent " " ARQUAD 12
7. Poor " " Retarder LA
8. Poor " " Ammonyx T

Date ... January, 1974

RESPONSE TO COLLECTORS

Nepheline Syenite

KEY: Excellent Flotation



Fair Flotation



Good Flotation



Poor Flotation



<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			



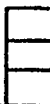

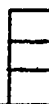
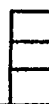



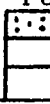
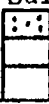
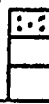
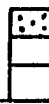
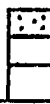






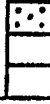












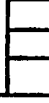



















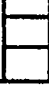
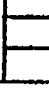









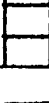












<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

January, 1974

Date

Nepheline Syenite

EFFECT OF MODIFIERS

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
Acid Neutral Basic	NON-IONIC 		Ethanol 				
Acid Neutral Basic	ANIONIC 		Petroleum Sulphonate 				
Acid Neutral Basic	ANIONIC 		Fatty Acid Sulphonate 			1 	
Acid Neutral Basic	ANIONIC 		Alkyl Sulphate 				
Acid Neutral Basic	ANIONIC 		Sodium Taurate 				
Acid Neutral Basic	CATIONIC 		Primary Amine 				
Acid Neutral Basic	CATIONIC 		Diamine 	2 			
Acid Neutral Basic	CATIONIC 		Tertiary Amine 	3 			
Acid Neutral Basic	CATIONIC 		Quaternary 				
Acid Neutral Basic	FATTY ACID 		Tall Oil 				
Acid Neutral Basic	FATTY ACID 		Oleic 				

1. Excellent flotation with Sulphonated Castor Oil
2. " " " Duomac T
3. " " " Armeen DLM 11

KEY: Excellent Flotation



Fair Flotation



Good Flotation



Poor Flotation



<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

EFFECT OF MODIFIERS

Scheelite

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
Acid Neutral Basic	NON-IONIC		Ethanol				
Acid Neutral Basic	ANIONIC	Petroleum Sulphonate					
Acid Neutral Basic	ANIONIC	Fatty Acid Sulphonate					
Acid Neutral Basic	ANIONIC	Alkyl Sulphate					
Acid Neutral Basic	ANIONIC	Sodium Taurate					
Acid Neutral Basic	CATIONIC	Primary Amine					
Acid Neutral Basic	CATIONIC	Diamine					
Acid Neutral Basic	CATIONIC	Tertiary Amine					
Acid Neutral Basic	CATIONIC	Quaternary					
Acid Neutral Basic	FATTY ACID	Tall Oil					
Acid Neutral Basic	FATTY ACID	Oleic					

1. Excellent flotation with Nalcamine G11

RESPONSE TO COLLECTORS

Tremolite

KEY: Excellent Flotation



Fair Flotation



Good Flotation



Poor Flotation



<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

Date January, 1974

Tremolite

EFFECT OF MODIFIERS

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
Acid Neutral Basic	NON-IONIC		Ethanol				
Acid Neutral Basic	ANIONIC		Petroleum Sulphonate				
Acid Neutral Basic	ANIONIC		Fatty Acid Sulphonate				
Acid Neutral Basic	ANIONIC		Alkyl Sulphate				
Acid Neutral Basic	ANIONIC		Sodium Taurate				
Acid Neutral Basic	CATIONIC		Primary Amine				
Acid Neutral Basic	CATIONIC		Diamine				
Acid Neutral Basic	CATIONIC		Tertiary Amine				
Acid Neutral Basic	CATIONIC		Quaternary				
Acid Neutral Basic	FATTY ACID		Tall Oil				
Acid Neutral Basic	FATTY ACID		Oleic				

1. Poor flotation with Armeen L-9

2. Excellent flotation with Duomac T

RESPONSE TO COLLECTORS

Zeolite

KEY: Excellent Flotation



Fair Flotation



Good Flotation



Poor Flotation



<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

Zeolite

EFFECT OF MODIFIERS

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
Acid Neutral Basic	NON-IONIC		Ethanol				
Acid Neutral Basic	ANIONIC		Petroleum Sulphonate				
Acid Neutral Basic	ANIONIC		Fatty Acid Sulphonate				
Acid Neutral Basic	ANIONIC		Alkyl Sulphate				
Acid Neutral Basic	ANIONIC		Sodium Taurate				
Acid Neutral Basic	CATIONIC		Primary Amine				
Acid Neutral Basic	CATIONIC		Diamine				1
Acid Neutral Basic	CATIONIC		Tertiary Amine			2	
Acid Neutral Basic	CATIONIC		Quaternary				
Acid Neutral Basic	FATTY ACID		Tall Oil				
Acid Neutral Basic	FATTY ACID		Oleic				

1. Excellent flotation with Duomac T.

2. " " " Nalcamine G11.

January, 1974

Date

RESPONSE TO COLLECTORS

Zircon

KEY: Excellent Flotation



Fair Flotation



Good Flotation



Poor Flotation



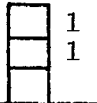


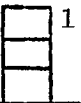

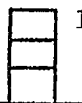
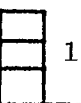






































































<u>CLASS</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	2			
Anionic	12			
Cationic	13			
Fatty acid	4			

<u>Class</u>	<u>TYPE</u>	<u>No. Tested</u>	<u>Acid</u>	<u>Neutral</u>	<u>Basic</u>
Non-ionic	Ethanol	2			
Anionic	Petroleum sulphonate	3			
"	Fatty acid sulphonate	3			
"	Alkyl sulphate	3			
"	Sodium taurate	3			
Cationic	Primary amine	3			
"	Diamine	3			
"	Tertiary amine	3			
"	Quaternary	4			
Fatty acid	Tall oil	2			
"	Oleic	2			

Date January, 1974

Zircon

EFFECT OF MODIFIERS

	No Modifier	Fe	Al	F	Starch	Dextrin	Citric Acid
Acid Neutral Basic	NON-IONIC  1 1			 1		 1	 1
Acid Neutral Basic	ANIONIC 		Petroleum Sulphonate 				
Acid Neutral Basic	ANIONIC 	 2	Fatty Acid Sulphonate 			 2	
Acid Neutral Basic	ANIONIC 		Alkyl Sulphate 				
Acid Neutral Basic	ANIONIC 		Sodium Taurate 	 3			 3
Acid Neutral Basic	CATIONIC 		Primary Amine 				
Acid Neutral Basic	CATIONIC 		Diamine 				
Acid Neutral Basic	CATIONIC 		Tertiary Amine 				
Acid Neutral Basic	CATIONIC 		Quaternary  4			 4	
Acid Neutral Basic	FATTY ACID 	 5	Tall Oil 	 5	 5	 5	 5
Acid Neutral Basic	FATTY ACID 		Oleic 				

1. Fair flotation with Rexol 25J
2. Excellent " " Prestabilt Oil V
3. Poor " " Igepon T-33
4. " " Ammonyx T
5. " " Actinol FA 2

CONCLUSION

The graphical method of presenting results provides a ready comparison of the effects of similar liquid systems on different minerals, and indicates areas for possible selective flotation.

When used in conjunction with data presented in TB 108⁽²⁾, comparison may be made between the flotation characteristics of thirty-one non-metallic minerals.

REFERENCES

1. Wyman, R. A., "The Floatability of Eleven Common Non-Metallic Minerals", Mines Branch Technical Bulletin No. TB 70, April 1965, Department of Energy, Mines and Resources, Ottawa.
2. Wyman, R. A., "The Floatability of Twenty-One Non-Metallic Minerals", Mines Branch Technical Bulletin No. TB 108, January 1969, Department of Energy, Mines and Resources, Ottawa.

