Mines Branch Technical Bulletin TB 70

PROJECT NO. MP-IM R-1

THE FLOATABILITY OF ELEVEN COMMON NON-METALLIC MINERALS

by

R.A. Wyman*

ABSTRACT

The aqueous systems, including pH regulators and collectors, that affect the floatability of eleven common non-metallic minerals are outlined. The effect of six common modifiers on the floatability of these minerals in the aqueous systems employed is also outlined. Results are presented graphically for ease of comparison.

As the work is extended to include other minerals, similar minerals from different sources and additional aqueous systems, further reports will be issued.

The project is intended to assist workers in the solution of problems involving non-metallic mineral flotation.

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Etude n^{o} MP-IM-R-1

LA FLOTTABILITÉ DE ONZE MINÉRAUX COMMUNS NON MÉTALLIQUES

par

R.A. Wyman*

RÉSUMÉ

L'auteur trace les grandes lignes de l'action de diverses solutions aqueuses, des régulateurs de pH et des agents collecteurs sur la flottabilité de onze minéraux non métalliques communs, ainsi que de l'effet de six agents modificateurs d'usage courant sur la flottabilité de ces minéraux en solution aqueuse. Les résultats sont présentés graphiquement pour faciliter les comparaisons.

Au fur et à mesure de l'extension des études à d'autres minéraux et à des minéraux similaires mais d'origines différentes, et à d'autres solutions aqueuses, les rapports pertinents paraîtront.

Ces travaux ont été entrepris en vue d'aider les chercheurs à trouver des solutions aux problèmes posés par la flottation des minéraux non métalliques.

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INTRODUCTION

Although advances are being made in the isolation and control of phenomena that produce flotation, no direct routes have been found to the solution of flotation problems, particularly with non-metallic minerals. The same non-metallic mineral originating from two different sources rarely reacts to flotation in precisely the same way. In some cases minerals from different parts of the same deposit require variations of treatment. In general, a comprehensive study is required for each instance and a great deal of time and effort is consumed.

More or less "standard" approaches to the flotation of many non-metallic minerals have already been worked out, and there is a tendency to apply variations of these systems to new cases. It is quite possible that more efficient results could be obtained by other systems, if the proper approach was known. Moreover, the separation of certain non-metallic minerals has never been satisfactorily achieved. Such separations should be possible if the correct type of approach was known.

The intent of the present study is to outline such approaches. This and subsequent reports should become a suitable reference for starting new non-metallic flotation problems, pointing out new systems where effective separations may take place, and suggesting methods for the separation of minerals that now present difficult problems.

SCOPE

The study is intended to embrace as many non-metallic minerals as can be obtained in a relatively pure natural form, and, if possible, two or more representatives of each mineral obtained from different locations. The floatability of each will be observed under acid, neutral and basic conditions with representative collectors from each class, preferably with two or more of each type. The effect of representative modifiers will also be observed.

Since it is a comprehensive project that will require many years to complete, a report will be issued whenever sufficient, useful information has been developed. The work reported herein is believed to constitute such a body of information. Eleven well known non-metallic minerals to which flotation is commonly applied are reported upon. The response of these minerals to seventeen different collectors under acid, neutral and basic conditions is indicated, and the effect of six different modifiers is shown.

EXPERIMENTAL PROCEDURE

The underlying principle is a simple experimental procedure that is positive but requires only a short time to perform. Most bench-scale flotation methods allow only one or two experiments per day and require some time-consuming form of assessment, usually chemical analysis. A great deal of time and effort is thus involved as well as the services of several people. Bench-scale experiments are, however, an essential step in process development. Any reduction in the number of such experiments for developing a process is an advantage. The procedure employed in this study was worked out originally to aid in reducing the time and effort involved in the bench-scale development of a process. Its success in doing so encouraged elaboration into the present extensive project.

Minerals to be investigated are obtained in the purest form available; where possible, as crystals. Each mineral is pulverized and the minus 28 plus 325 mesh fraction is isolated. Each is then washed thoroughly in dilute HCl and rinsed with distilled water to neutral pH. Each is stored in a separate clean bottle in distilled water. The minus 28 plus 325 mesh fraction was selected for two reasons: It is within the size range to which flotation is usually applied; and a rough visual estimation of the number of particles picked up by a bubble can be made.

The approach used is extremely simple. The apparatus 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. In performing an individual 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, measured quantity of a particular mineral (about 0.01 g) is added.
3) The pH regulator, if used, is added and mixed with the stirring rod.
4) Modifier (to give 0.05 gpl concentration), if used, is added and mixed with the stirring rod.
5) Collector to give 0.1 gpl concentration is added and mixed with the stirring rod.
6) The beaker is placed on the turntable. The bubble tube is lowered until its tip is about ½ in. above the mineral at the bottom of the beaker.
7) The screw clamp on the rubber ball is turned to produce a bubble at

the lower end of the glass tube.

8) The beaker is raised with the turntable until the bubble makes contact with the mineral.

9) The beaker is lowered until the bubble is well up into the liquid.

10) Approximately the number of particles adhering to the bubble (i.e., none, 1 or 2, approximately 5, 10, 15, etc.) are observed.

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 observed.

12) These observations 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 they will usually 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. With acid, 1 ml of H_2SO_4 of a predetermined strength is added from a 1-ml dispensing bottle. Similarly, for basic conditions, 1 ml of Na_2CO_3 of predetermined strength is added from a 1-ml dispensing bottle. For both the acid and basic experiments the regulator is mixed in by stirring, the collector is added and also mixed in by stirring, before bubble contact is made.

In the acid case, the H_2SO_4 in the dispensing bottle is of such a strength that when 1 ml is added to 100 ml of distilled water a pH of 3.0 will result. 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 in distilled water.

Similarly with the basic conditions, the Na_2CO_3 is of a strength to produce a pH of 10.0 when 1 ml is added to 100 ml of distilled water. This has also been found to hold closely after the addition of mineral and other reagents.

The maximum change in pH is observed when ionizing modifiers are used. Since the general acid 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 acid or basic experiment. Moreover, since the observations are not absolute, the overall results must be considered as relative only. Nevertheless, they are sufficiently accurate and informative to be of importance. 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 on the acid side. However, as this would also be the case in larger scale flotation practice, adjustments should not be made.

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

MINERALS INVESTIGATED

In order to get this program started, a canvass was made of minerals available in the Division. Wherever a suitable mineral was found, in older collections, more recent collections, or large crystals, a sample was obtained for inclusion in the study. Because of this, the geographical origin of many of the minerals is not known with certainty. However, each one is in itself of good quality and representative of a natural mineral occurrence.

The minerals currently reported upon are as follows:

1. APATITE
2. BARITE
3. BERYL
4. BIOTITE
5. CALCITE
6. FLUORITE
7. MUSCOVITE
8. ORTHOCLASE
9. QUARTZ
10. SPODUMENE
11. TOPAZ

COLLECTORS INVESTIGATED

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

Since the mineral surfaces are the sites 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. The first do not ionize in solution. In the second, the negative, or anion, is the active member, and in the third the positive, or cation, is the active member. 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 distinct class in themselves.

At the present time there are many thousands of surfactants available and the list is rapidly increasing. For the purposes of flotation these can be narrowed into a comparatively small number of general types with an even narrower grouping as applied to non-metallics. An effort was made to select reagents that are in more or less common use as flotation collectors and would represent the principal types.

The collectors tested are listed below according to their activity, type and composition.

CLASS	TYPE	COMPOSITION
Non-ionic	Ethanol	Alkyl phenoxypoly-(ethyleneoxy) ethanol
"	"	Nonyl phenol polyethoxy ethanol
Anionic	Petroleum sulphonate	(Not available)
"	"	Sodium alkyl-aryl petroleum sulphonic acid
"	"	Naphthalene sulphonic acid derivative
"	Fatty acid sulphonate	Fatty acid aliphatic sulphonate
"	Alkyl sulphate	Sodium octyl sulphate
"	Sodium taurate	Sodium N-methyl-N-"tallow-acid" taurate
Cationic	Primary amine	Technical tallow amine acetate
"	Diamine	Tallow diamine acetate
"	Tertiary amine	Hydroxyethyl alkyl imidazoline (glyoxalidine)
"	Quaternary	N(lauroyl-colamino-formyl-methyl) pyridinium chloride
"	"	n-alkyl trimethyl ammonium chloride

CLASS	TYPE	COMPOSITION
Cationic	Quaternary	Cetyl trimethyl ammonium bromide
"	"	Cetyl trimethyl benzyl ammonium chloride
Fatty acid	Tall oil	Tall oil base
"	Oleic	Oleic acid blend

MODIFIERS INVESTIGATED

As pointed out in the previous section, flotation is effected by causing the surface of a mineral to become hydrophobic by the action of a collector agent. In most cases, however, it is necessary to use modifying agents to achieve this. Such agents simply aid in getting the collector onto the surface of the mineral to be floated by altering the conditions in a suitable manner. 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 modification. As indicated earlier, all the experiments cover three pH levels. The cleaning of surfaces, dispersion of ultra-fine solids, precipitation of dissolved salts, and other factors 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 adsorption. Organic colloids are thought to blank off surfaces. Organic acids may aid in activation or depression or as surface cleansers.

The pH-controlling agents employed have been described under EXPERIMENTAL PROCEDURE. Other modifiers used in the experiments are: 1) three to provide metal ion resurfacing - $FeSO_4$ for iron, $Al_2(SO_4)_3$ 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 results 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 that two or more may be overlapped, for easier comparison.

On the front of each sheet the flotation is given by collector class at the top and by type at the bottom. On the reverse the effect of the modifiers is shown. To make comparison as easy as possible, the floatability 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 ± 15 particles picked up and dislodged from the bubble only with some difficulty (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 3 particles picked up and either dropping from the bubble after a moment or two on their own or dropping on the initial light tap of the bubble tube (poor bond). In making the assessments reported herein, excellent flotation for individual cases is considered to be 15 or more particles picked up and adhering with a good bond. Good flotation is 10 to 15 particles picked up and adhering with a good bond. Fair flotation indicates 5 to 10 particles picked up and a fair bond. Poor flotation is less than 5 particles with a poor bond. The only "grey" area is between good and fair flotation. In certain cases a pick-up of more than 10 particles is classed as fair if the bond is not good. Similarly, certain cases of less than 10 particles picked up are classed as good when the bond is strong.

In assessing groups of collectors (such as the 4 quaternaries), or the results for a class (such as the 6 anionics), a form of weighted average has been adopted. 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 has then been used to determine the average floatability. The occasional doubtful situation between fair and good flotation has been indicated by using both symbols.

The name of each mineral has been placed in the upper right hand corner for facing pages and the upper left for reverse pages, to allow ready identification. The minerals are recorded in alphabetical order, and each is dated so that with following reports and included extensions of the work the latest and most up-to-date sheets may be retained.

RESPONSE TO COLLECTORS

KEY:			
Excellent Flotation	■	Fair Flotation	⊡
Good Flotation	▩	Poor Flotation	□

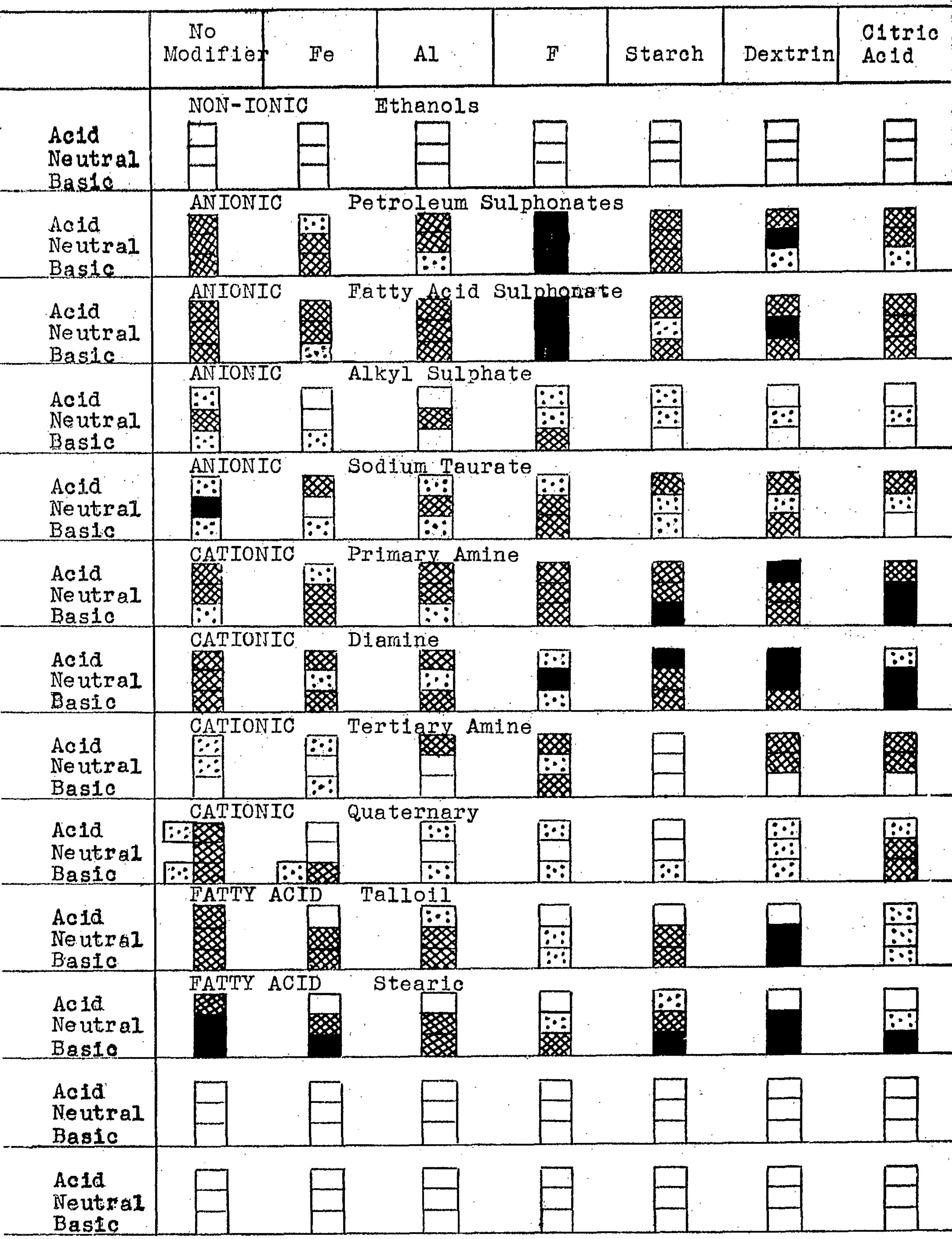
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	▩	■	▩
Cationic	7	▩	▩	⊡▩
Fatty acid	2	▩	■	▩

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	▩	▩	▩
Fatty acid sulphonate	"	1	▩	▩	▩
Alkyl sulphate	"	1	⊡	▩	⊡
Sodium taurate	"	1	⊡	■	⊡
Primary amine	Cationic	1	▩	▩	⊡
Diamine	"	1	▩	▩	▩
Tertiary amine	"	1	⊡	⊡	□
Quaternary	"	4	⊡▩	▩	⊡▩
Talloil	Fatty acid	1	▩	▩	▩
Oleic	"	1	▩	■	■

Date.....April,1965.......

APATITE

EFFECT OF MODIFIERS



Date ..April, 1965...

RESPONSE TO COLLECTORS

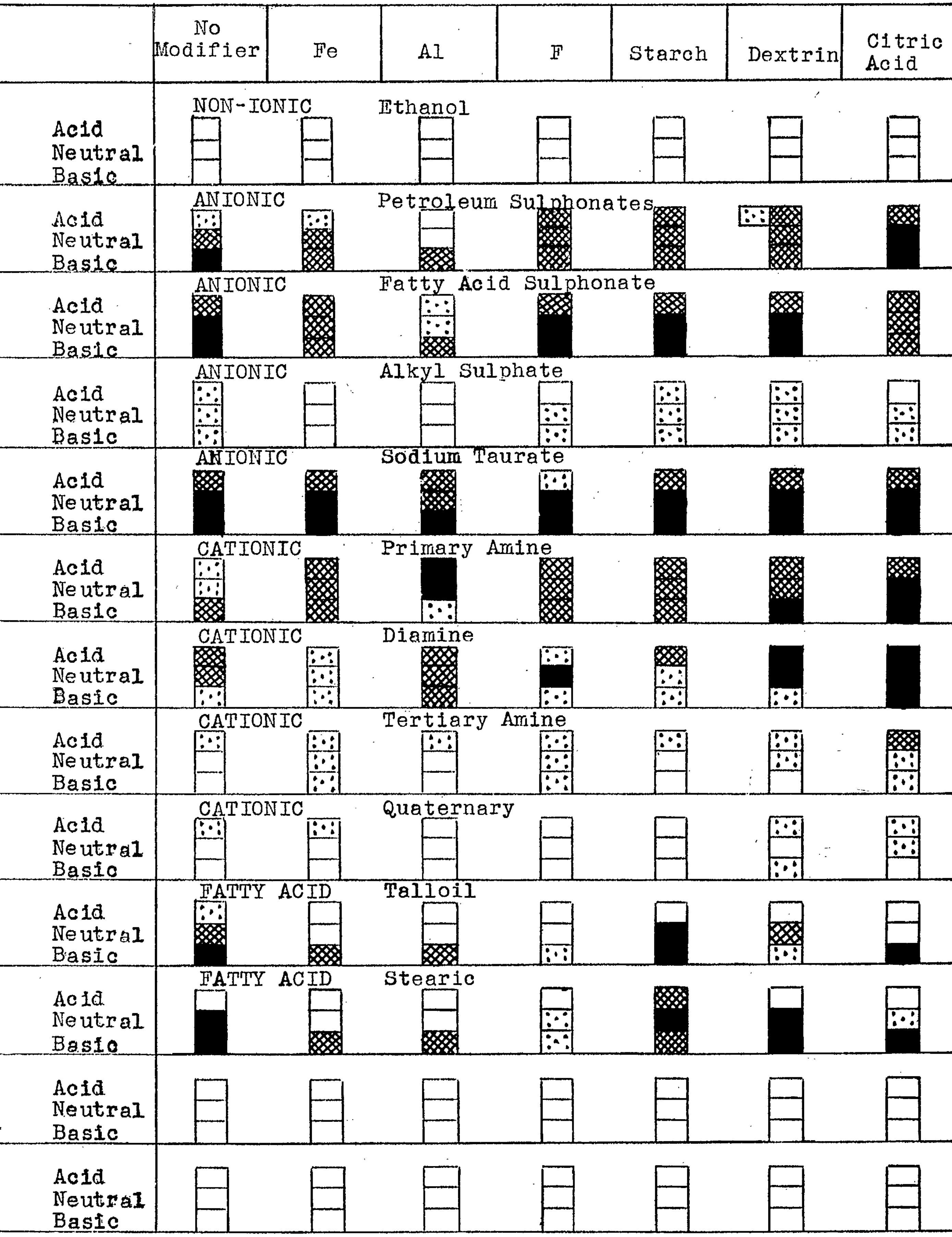
KEY:			
Excellent Flotation	■	Fair Flotation	⁙
Good Flotation	▩	Poor Flotation	□

Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	▩	▩	■
Cationic	7	⁙	⁙	⁙
Fatty acid	2	□	■	■

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	⁙	▩	■
Fatty acid sulphonate	"	1	▩	■	■
Alkyl sulphate	"	1	⁙	⁙	⁙
Sodium taurate	"	1	▩	■	■
Primary amine	Cationic	1	⁙	⁙	▩
Diamine	"	1	▩	▩	⁙
Tertiary amine	"	1	⁙	□	□
Quaternary	"	4	⁙	□	□
Talloil	Fatty acid	1	⁙	▩	■
Oleic	"	1	□	■	■

Date....April, 1965....

EFFECT OF MODIFIERS



Date ..April, 1965........

RESPONSE TO COLLECTORS

KEY: Excellent Flotation ■ Fair Flotation ⊡
Good Flotation ▩ Poor Flotation □

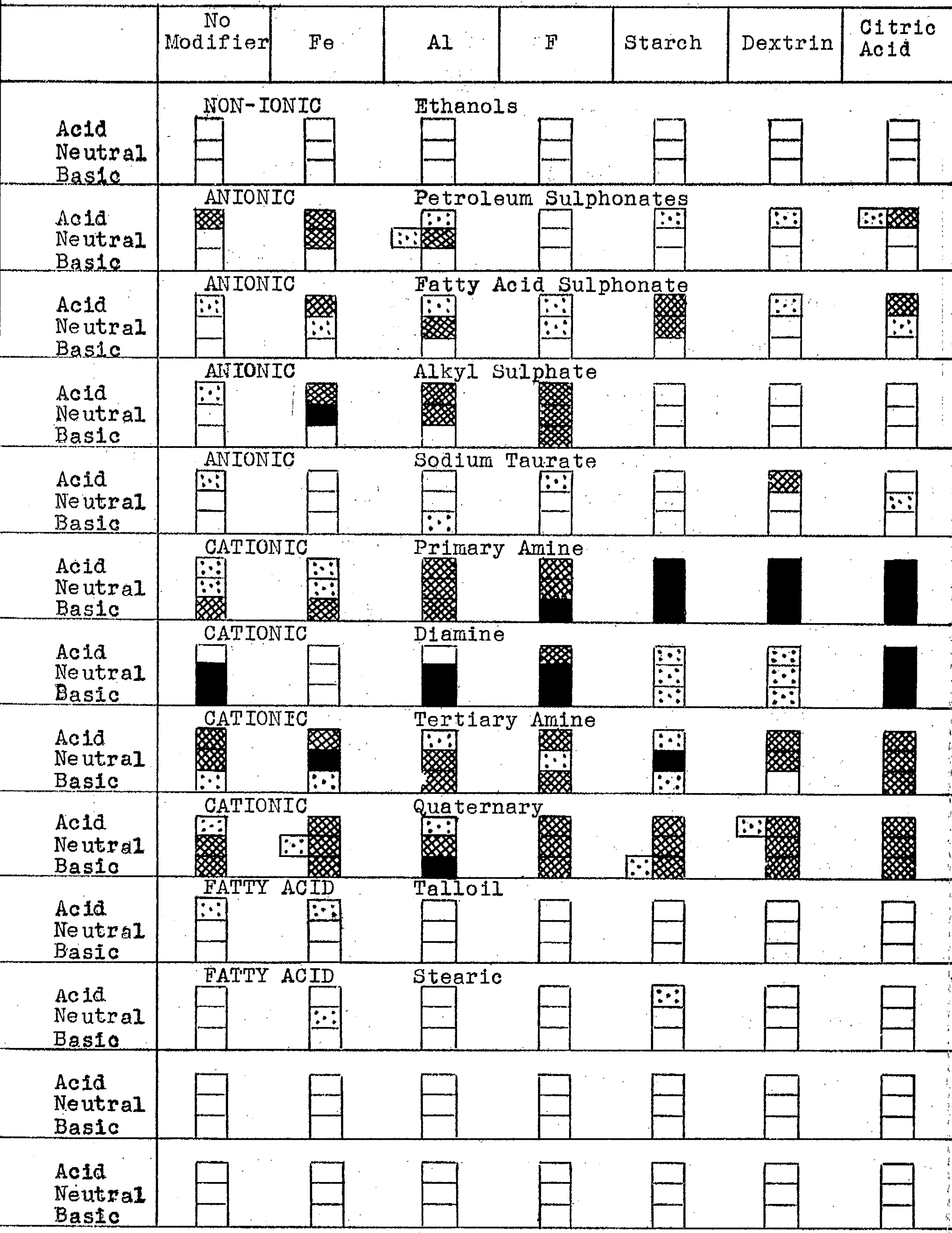
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	⊡	□	□
Cationic	7	⊡	▩	▩
Fatty acid	2	□	□	□

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	▩	□	□
Fatty acid sulphonate	"	1	⊡	□	□
Alkyl sulphate	"	1	⊡	□	□
Sodium taurate	"	1	⊡	□	□
Primary amine	Cationic	1	⊡	⊡	▩
Diamine	"	1	□	■	■
Tertiary amine	"	1	▩	▩	⊡
Quaternary	"	4	⊡	▩	▩
Talloil	Fatty acid	1	⊡	□	□
Oleic	"	1	□	□	□

Date ..April, 1965..........

BERYL

EFFECT OF MODIFIERS



Date ... April, 1965 ...

RESPONSE TO COLLECTORS

KEY: Excellent Flotation ■ Fair Flotation ⁙

Good Flotation ▩ Poor Flotation □

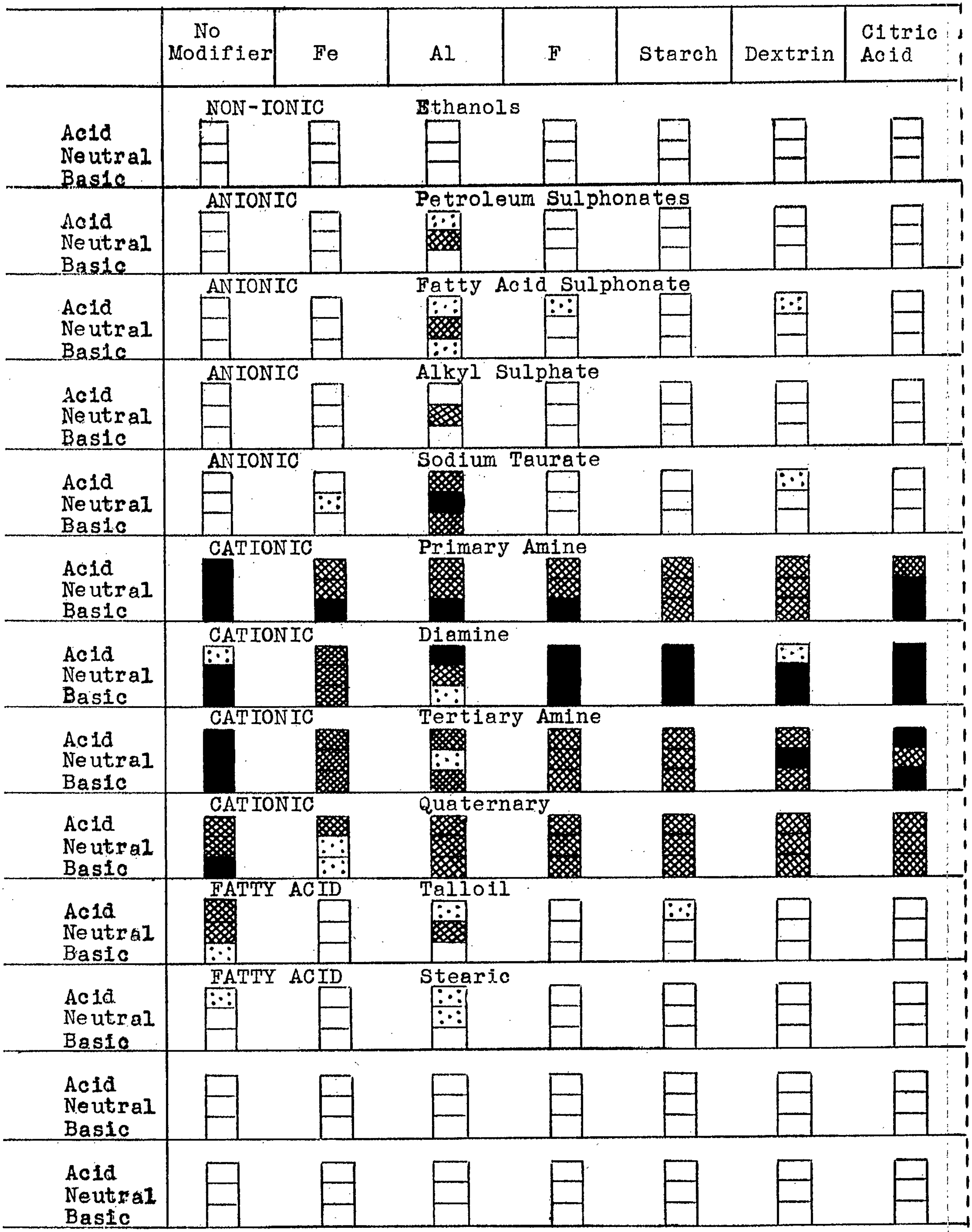
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	□	□	□
Cationic	7	▩	■	■
Fatty acid	2	⁙	⁙	□

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	□	□	□
Fatty acid sulphonate	"	1	□	□	□
Alkyl sulphate	"	1	□	□	□
Sodium taurate	"	1	□	□	□
Primary amine	Cationic	1	■	■	■
Diamine	"	1	⁙	■	■
Tertiary amine	"	1	■	■	■
Quaternary	"	4	▩	▩	■
Talloil	Fatty acid	1	▩	▩	⁙
Oleic	"	1	⁙	□	□

Date: April, 1965

BIOTITE

EFFECT OF MODIFIERS



Date April, 1965.....

CALCITE

RESPONSE TO COLLECTORS

KEY: Excellent Flotation ■ Fair Flotation ⬚

Good Flotation ▩ Poor Flotation □

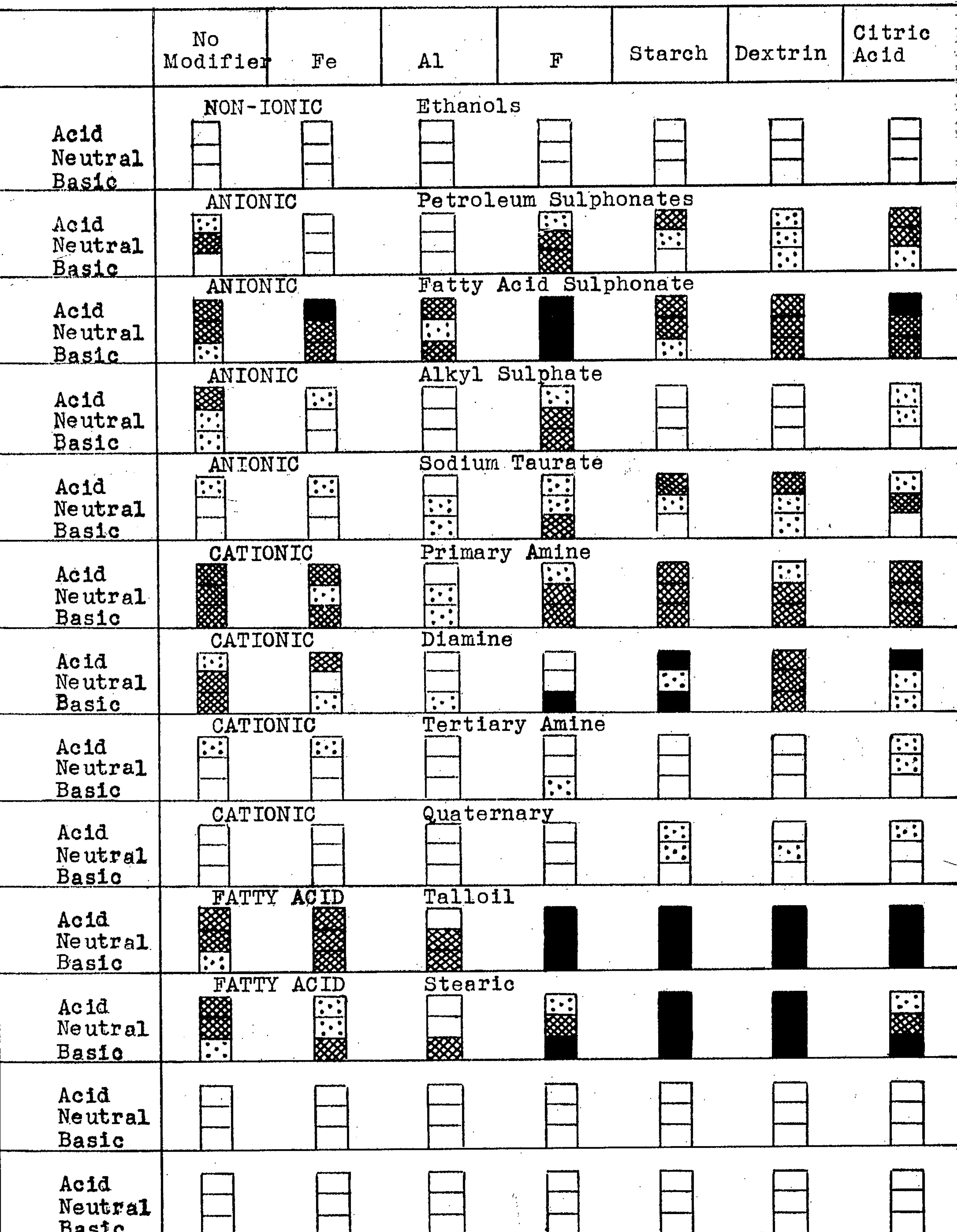
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	⬚▩	⬚▩	⬚
Cationic	7	⬚	⬚	⬚
Fatty acid	2	▩	▩	⬚

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	⬚	▩	□
Fatty acid sulphonate	"	1	▩	▩	⬚
Alkyl sulphate	"	1	▩	⬚	⬚
Sodium taurate	"	1	⬚	□	□
Primary amine	Cationic	1	▩	▩	▩
Diamine	"	1	⬚	▩	▩
Tertiary amine	"	1	⬚	□	□
Quaternary	"	4	□	□	□
Talloil	Fatty acid	1	▩	▩	⬚
Oleic	"	1	▩	▩	⬚

Date ....April..1965...

CALCITE

EFFECT OF MODIFIERS



Date ..April, 1965...

RESPONSE TO COLLECTORS

KEY: Excellent Flotation ■ Fair Flotation ⁙ Good Flotation ▩ Poor Flotation □

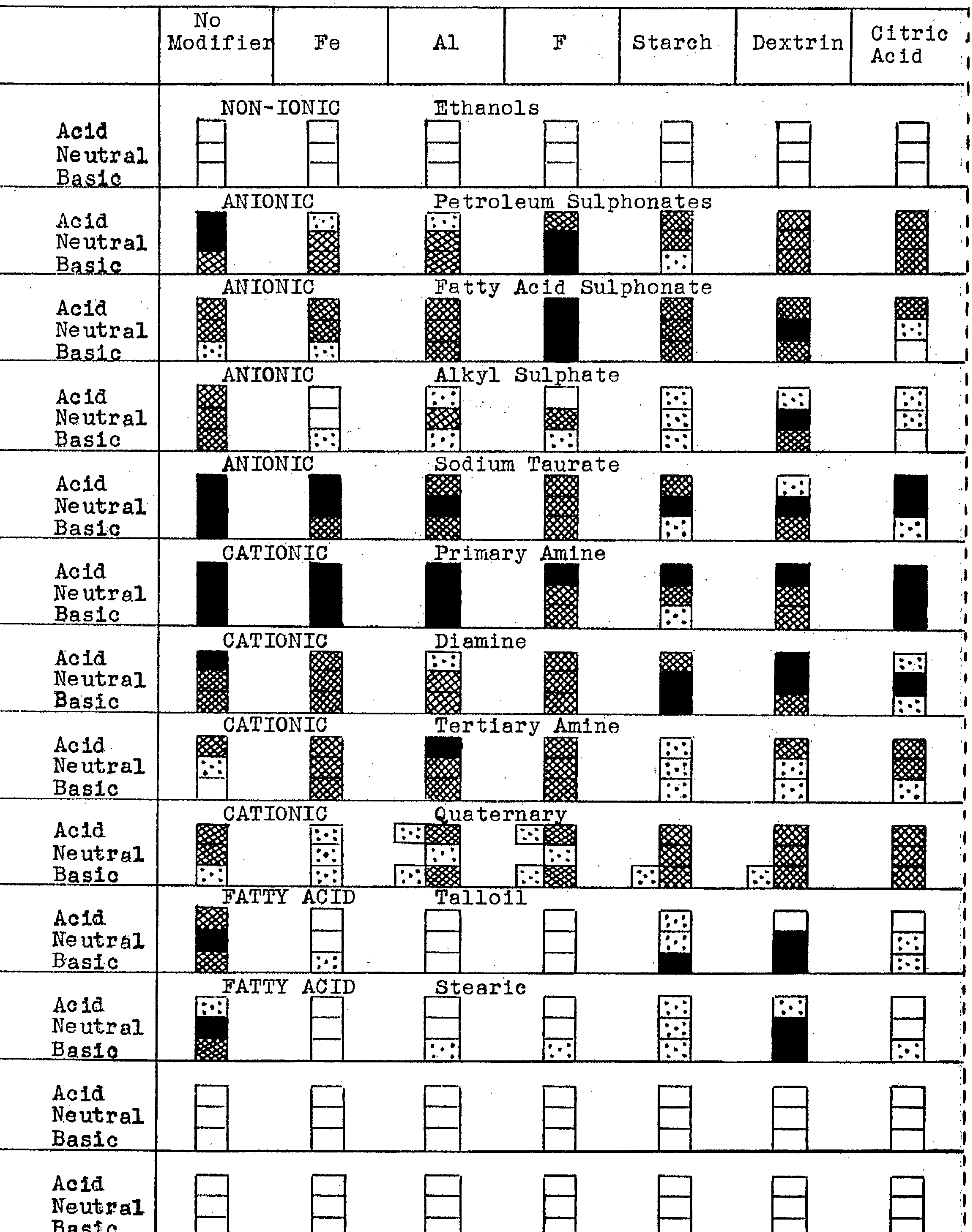
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	Poor	Poor	Poor
Anionic	6	Excellent	Excellent	Good
Cationic	7	Good	Good	Fair / Good
Fatty acid	2	Good	Excellent	Good

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	Poor	Poor	Poor
Petroleum sulphonate	Anionic	3	Excellent	Excellent	Good
Fatty acid sulphonate	"	1	Good	Good	Fair
Alkyl sulphate	"	1	Good	Good	Good
Sodium taurate	"	1	Excellent	Excellent	Excellent
Primary amine	Cationic	1	Excellent	Excellent	Excellent
Diamine	"	1	Excellent	Good	Good
Tertiary amine	"	1	Good	Fair	Poor
Quaternary	"	4	Good	Good	Fair
Talloil	Fatty acid	1	Good	Excellent	Good
Oleic	"	1	Fair	Excellent	Good

Date ....April, 1965....

FLUORITE

EFFECT OF MODIFIERS



Date ..April, 1965...

RESPONSE TO COLLECTORS

KEY: Excellent Flotation ■ Fair Flotation ⬚

Good Flotation ▩ Poor Flotation □

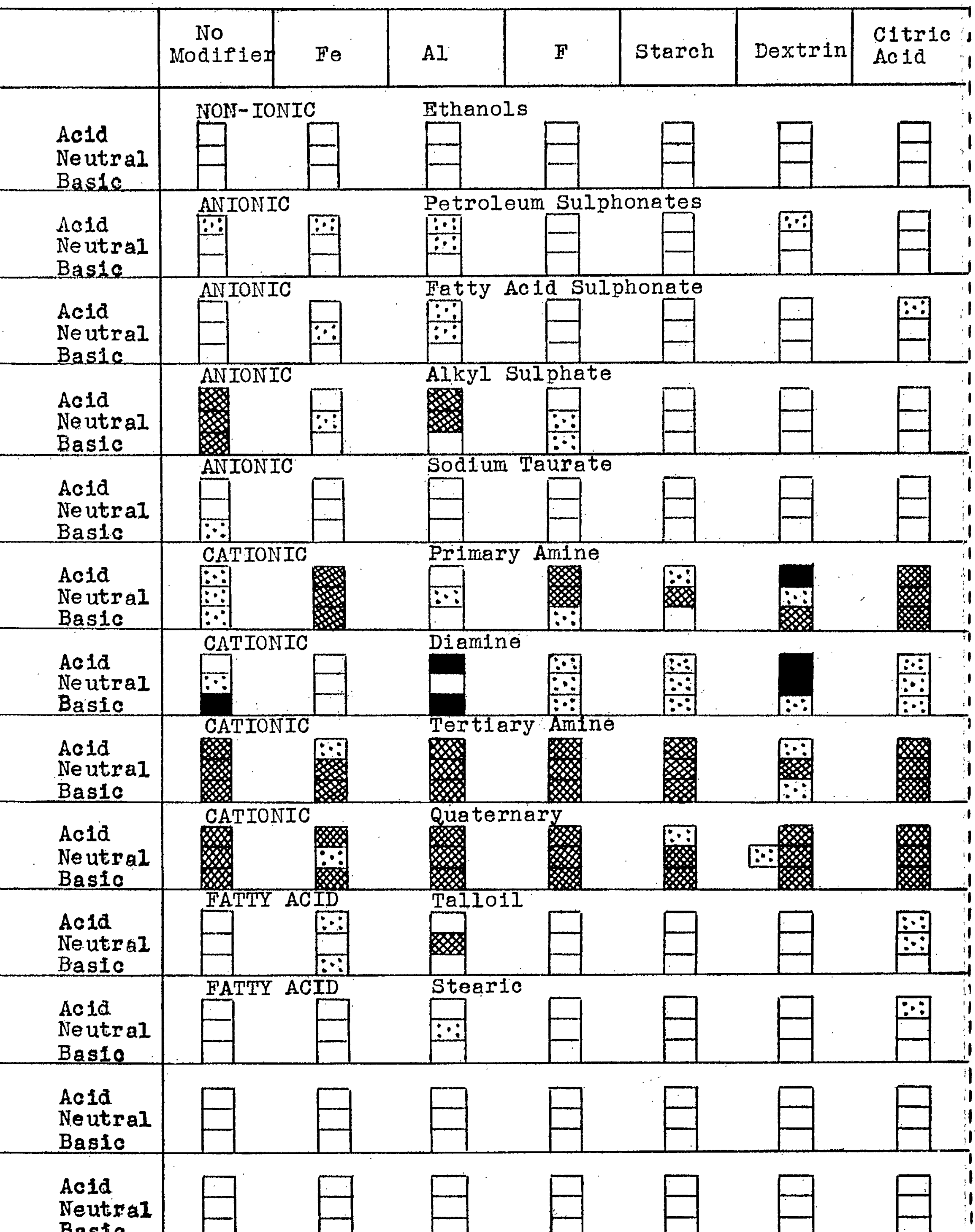
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	⬚	□	□
Cationic	7	▩	▩	▩
Fatty acid	2	□	□	□

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	⬚	□	□
Fatty acid sulphonate	"	1	□	□	□
Alkyl sulphate	"	1	▩	▩	▩
Sodium taurate	"	1	□	□	⬚
Primary amine	Cationic	1	⬚	⬚	⬚
Diamine	"	1	□	⬚	■
Tertiary amine	"	1	▩	▩	▩
Quaternary	"	4	▩	▩	▩
Talloil	Fatty acid	1	□	□	□
Oleic	"	1	□	□	□

Date....April, 1965.......

MUSCOVITE

EFFECT OF MODIFIERS



Date ..April., 1965...

ORTHOCLASE

RESPONSE TO COLLECTORS

KEY: Excellent Flotation ■ Good Flotation ▩ Fair Flotation ⊡ Poor Flotation □

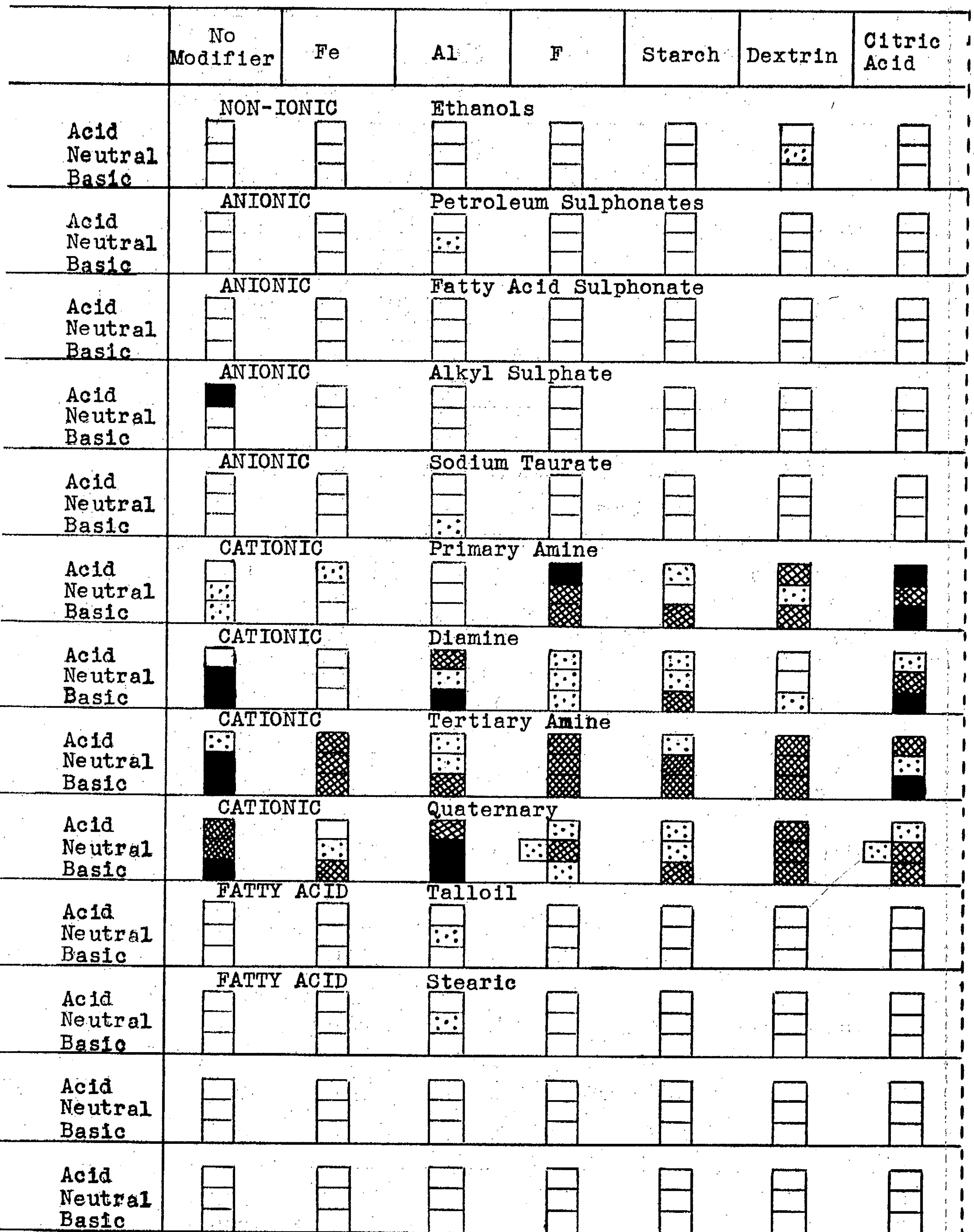
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	□	□	□
Cationic	7	⊡▩	▩	■
Fatty acid	2	□	□	□

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	□	□	□
Fatty acid sulphonate	"	1	□	□	□
Alkyl sulphate	"	1	■	□	□
Sodium taurate	"	1	□	□	□
Primary amine	Cationic	1	□	⊡	⊡
Diamine	"	1	□	■	■
Tertiary amine	"	1	⊡	■	■
Quaternary	"	4	▩	▩	■
Talloil	Fatty acid	1	□	□	□
Oleic	"	1	□	□	□

Date...April, 1965.....

ORTHOCLASE

EFFECT OF MODIFIERS



Date ...April, 1965.......

RESPONSE TO COLLECTORS

KEY: Excellent Flotation ■ Fair Flotation ⁙

Good Flotation ▒ Poor Flotation □

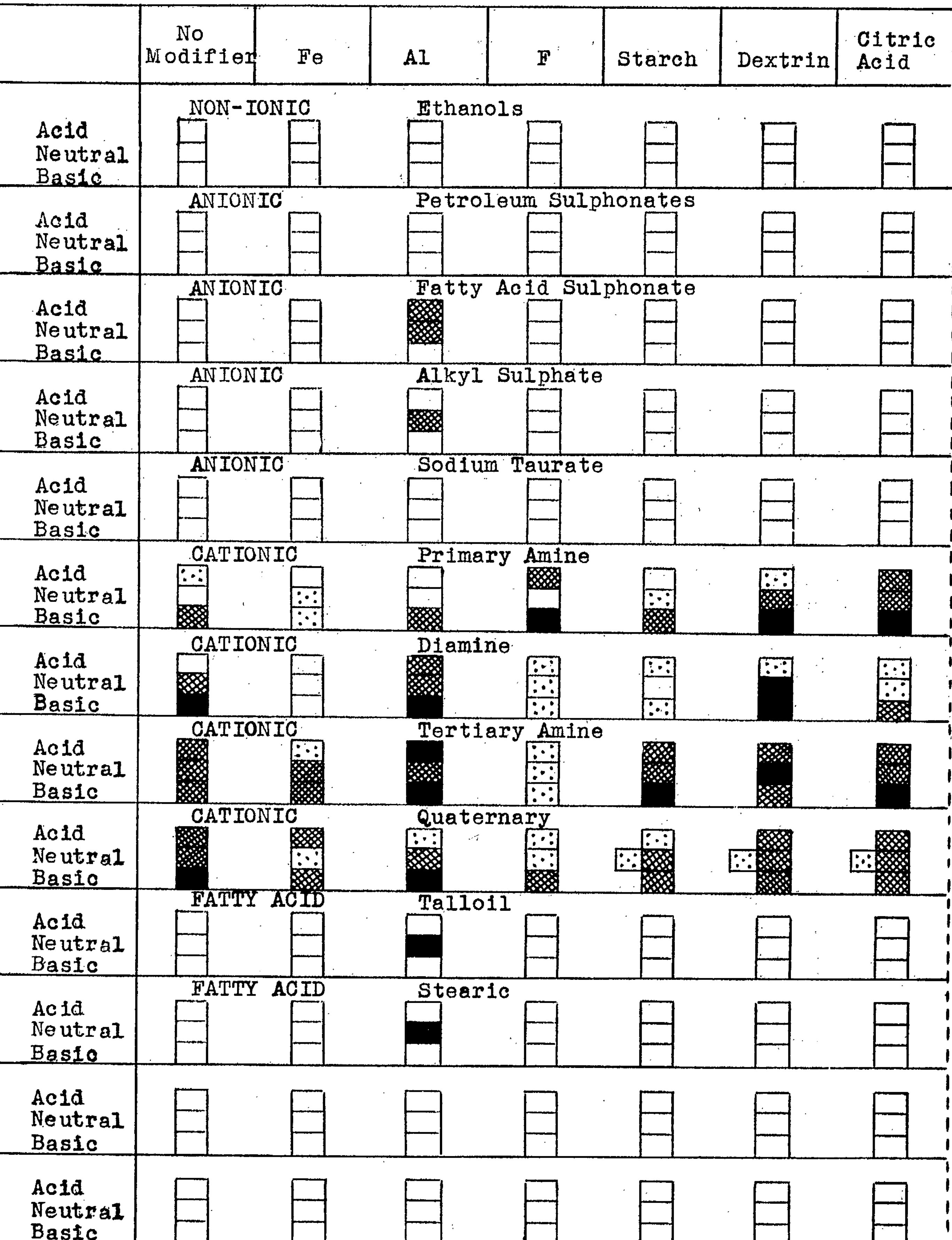
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	□	□	□
Cationic	7	⁙	▒	■
Fatty acid	2	□	□	□

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	□	□	□
Fatty acid sulphonate	"	1	□	□	□
Alkyl sulphate	"	1	□	□	□
Sodium taurate	"	1	□	□	□
Primary amine	Cationic	1	⁙	□	▒
Diamine	"	1	□	▒	■
Tertiary amine	"	1	⁙	▒	▒
Quaternary	"	4	▒	▒	■
Talloil	Fatty acid	1	□	□	□
Oleic	"	1	□	□	□

Date ...April, 1965.......

QUARTZ

EFFECT OF MODIFIERS



Date ..April, 1965........

RESPONSE TO COLLECTORS

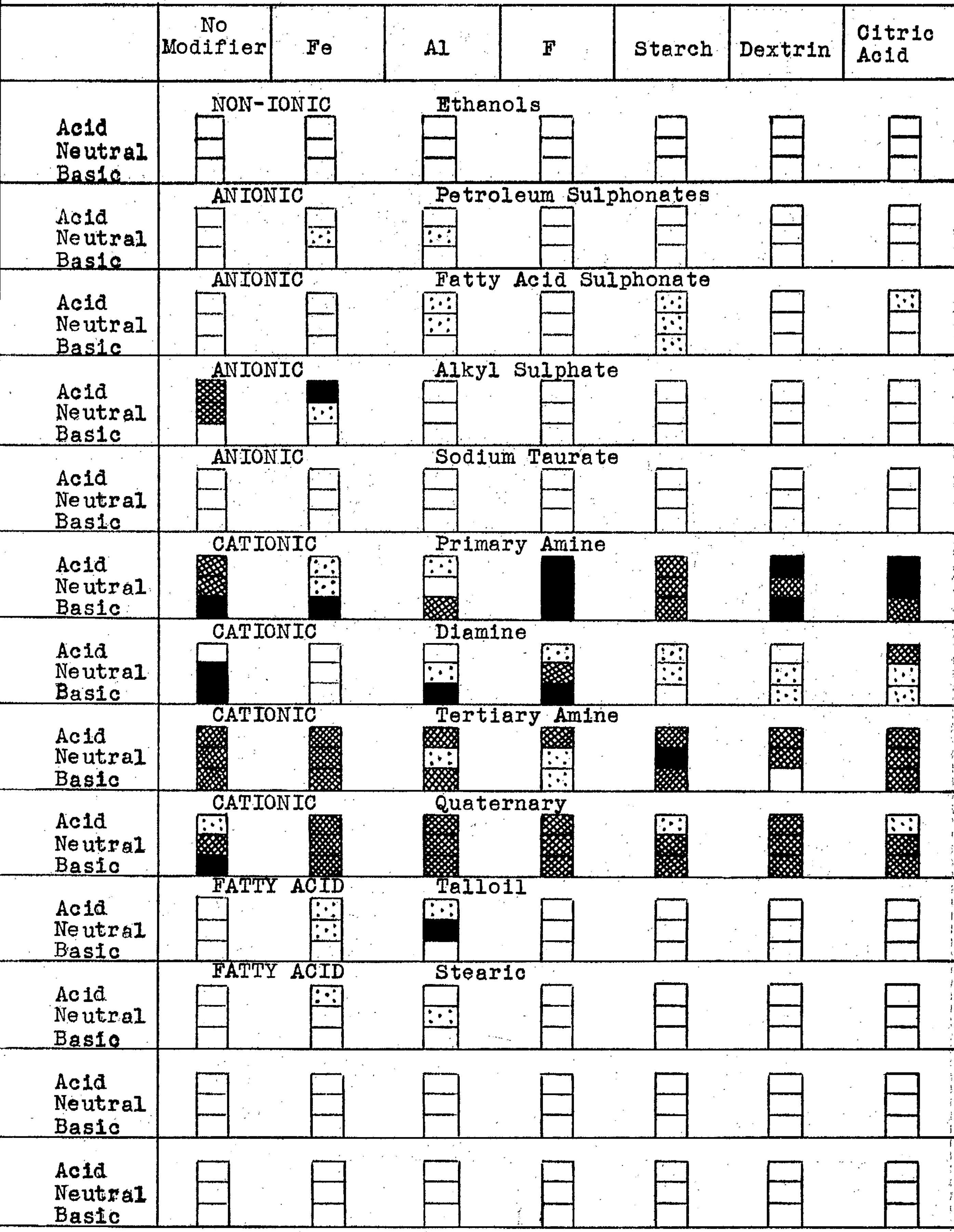
KEY:			
Excellent Flotation	■	Fair Flotation	⬚
Good Flotation	▩	Poor Flotation	□

Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	□	□
Anionic	6	□	□	□
Cationic	7	⬚	▩	■
Fatty acid	2	□	□	□

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	□	□
Petroleum sulphonate	Anionic	3	□	□	□
Fatty acid sulphonate	"	1	□	□	□
Alkyl sulphate	"	1	▩	▩	□
Sodium taurate	"	1	□	□	□
Primary amine	Cationic	1	▩	▩	■
Diamine	"	1	□	■	■
Tertiary amine	"	1	▩	▩	▩
Quaternary	"	4	⬚	▩	■
Talloil	Fatty acid	1	□	□	□
Oleic	"	1	□	□	□

Date..April, 1965.....

EFFECT OF MODIFIERS



Date ....April, 1965.......

RESPONSE TO COLLECTORS

KEY: Excellent Flotation ■ Fair Flotation ⬚

Good Flotation ▩ Poor Flotation □

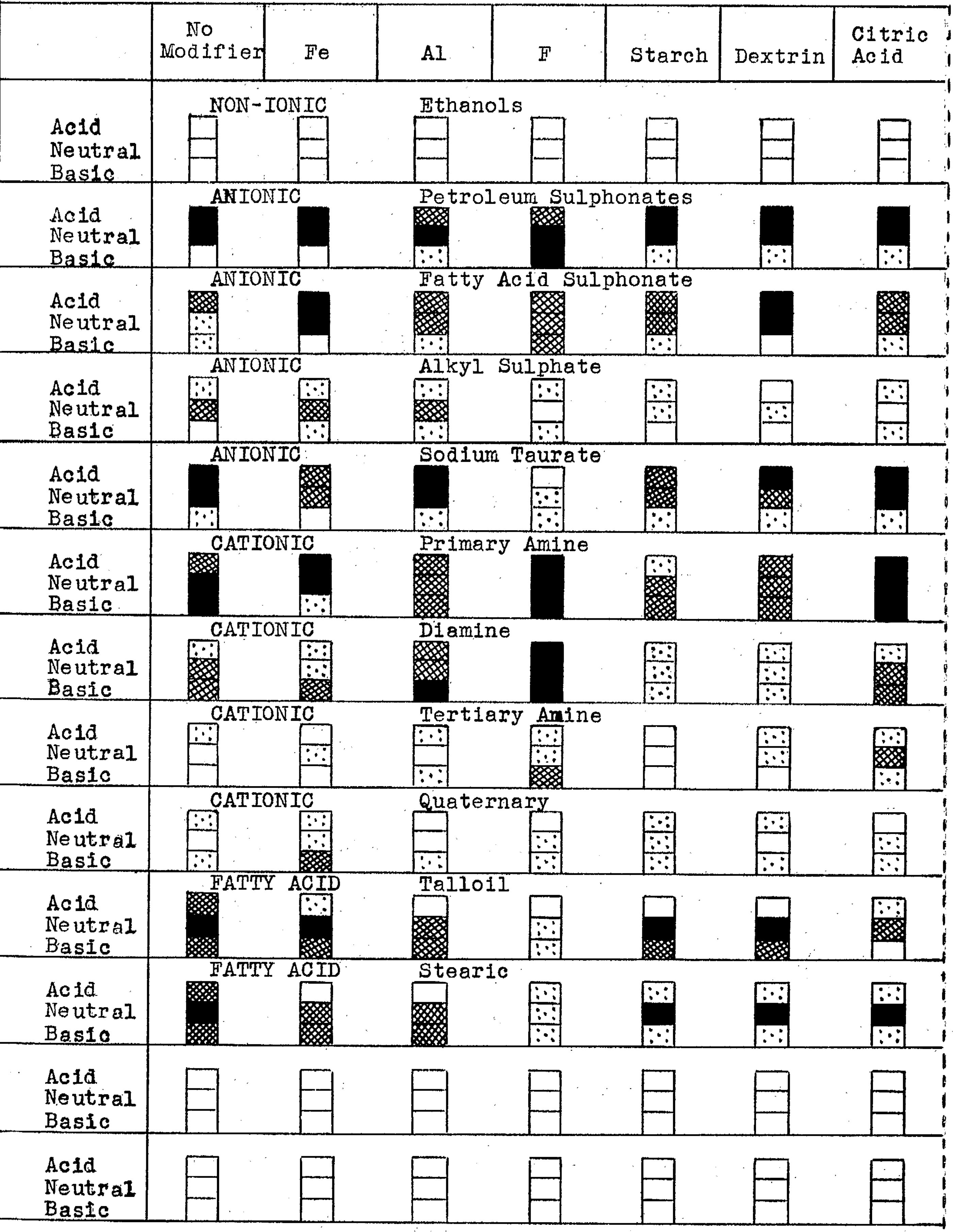
Class	No. Tested	Acid	Neutral	Basic
Non-ionic	2	□	⬚	□
Anionic	6	▩	▩	□
Cationic	7	⬚	⬚	⬚▩
Fatty acid	2	▩	■	▩

TYPE	Class	No. Tested	Acid	Neutral	Basic
Ethanol	Non-ionic	2	□	⬚	□
Petroleum sulphonate	Anionic	3	■	■	□
Fatty acid sulphonate	"	1	▩	⬚	⬚
Alkyl sulphate	"	1	⬚	▩	□
Sodium taurate	"	1	■	■	⬚
Primary amine	Cationic	1	▩	■	■
Diamine	"	1	⬚	▩	▩
Tertiary amine	"	1	⬚	□	□
Quaternary	"	4	⬚	□	⬚
Talloil	Fatty acid	1	▩	■	▩
Oleic	"	1	▩	■	▩

Date.....April, 1965.........

TOPAZ

EFFECT OF MODIFIERS



Date ..April, 1965........

DISCUSSION

A detailed discussion of the results would be both unnecessary and tedious - they are designed to be used. Examples of the various effects show up clearly and may be readily picked out. A few cases are given below to illustrate:

1) Non-collection: Barite with anionics and non-ionics; calcite with quaternaries.

2) Effect of pH: Barite with petroleum sulphonates; quartz with cationics.

3) Activation: Beryl with primary amine and starch, dextrin, or citric acid; topaz with diamine and fluorine.

4) Depression: Topaz with fatty acids and fluorine; fluorite with fatty acids and metal ions.

The Industrial Minerals Milling Section has found this type of graphic presentation of results effective and easy to use. It is hoped that other workers will find it similarly useful.

CONCLUSIONS

Basic flotation systems have been outlined for eleven common non-metallic minerals and the effect of certain modifiers indicated. The graphic method of presentation of results allows relatively easy selection of systems for the possible isolation of individual minerals from groups composed of the minerals covered.

ACKNOWLEDGEMENT

A substantial contribution to the project was made by J.H. Colborne of the Industrial Minerals Milling Section. All of the individual experiments (some 3500) and the observations were made by Mr. Colborne. The success of the project is in large measure due to his careful and thorough workmanship.

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