A METHOD FOR THE RECOVERY OF ALUMINA AND OTHER VALUABLE CONSTITUENTS FROM CLAY

Thesis

by

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Whenever there is a cheap raw material available in large quantities, and it contains chemicals which are in themselves quite valuable, the natural tendency is to attempt to work out a process for their recovery. Attempts to recover aluminum and other valuable products from clay, feldspar, or similar materials would come in this category of processes.

The products whose recovery has been attempted are aluminum and potassium sulfates and chemically pure silica. The raw materials worked on were usually either feldspar or clay.

There are essentially three factors that determine the economic feasibility of a process. These are the cost and difficulty of obtaining raw materials, the cost of the recovery operations, and the value and market for the products. These factors as they relate to this paper will be taken up in the order given. Feldspar being not easily obtainable all work with which this paper has to deal was done on clay, so clay only will be considered.

The cost and difficulty involved in obtaining clay in practically any amount will be quite low. In this respect it might well be classed with air or water. It may then be said that clay fulfills admirably the first requirement.

The cost of recovery operations being unknown, it is not possible to state the degree to which this condition may be fulfilled.

The third requirement is almost as easily satisfied as the first. The use of aluminum, both in compounds and as a metal, in

almost all the ramifications of modern life shows that there will always be a market for it. As much as it is used now, if the price could be lowered even a relatively small amount, its field of use would be greatly increased because it is unique among the metals in embodying certain desirable characteristics, viz. high tensile strength, low density, high electrical and heat conductivity, and high resistance to atmospheric corrosion. The use of potassium compounds in the industries, especially chemical industries, is too well known to anyone having any knowledge of chemistry to need emphasis. Chemically pure silica is not marketable in quantities at all comparable to aluminum or potassium compounds, but does find several important applications, viz. silica ware, preparation of chemically pure compounds of silicon, etc. That these products are all valuable is shown by approximate market prices for 1925.

$Al_2(SO_4)_3$ per lb.   \$0.02

K_2SO_4 per lb.   .05

SiO_2 per lb.   .15   (c.p. ppt.)

Thus it is seen that the only thing necessary to make the recovery of aluminum, etc. from clay feasible economically is to find a fairly simple process. The attempt to work out such a process is the subject of this paper.

When clay, whose essential constituent is $Al_2O_3.2SiO_2.2H_2O$, is heated to a high temperature with a basic material, it is decomposed and the aluminum is rendered acid-soluble. Other minor complex compounds are also decomposed by the high temperature basic treatment

and the metallic constituents rendered soluble. The basic material
may be either an alkali sulfide or carbonate or other sufficiently
basic compound. The reaction temperature is about 800°C or higher.
The slag obtained from this treatment is treated with an excess of
sulfuric acid, the metals form soluble sulfates and the silica is
precipitated in a very finely divided form. The silica is then
recovered by filtration and the metallic sulfates by evaporation
and fractional crystallization.

The processes for the recovery of valuable products from clay
etc. that have been proposed or attempted are almost innumerable
and so diversified that only a few representative ones will be
reviewed here.

1. L. Grabau treated the clay, which was a variety as free
as possible from iron compounds, with dilute hydrofluoric acid,
and thus obtained a solution of aluminum fluoride. The silica was
volatilized as silicon tetrafluoride.[1]

2. A Sobrero roasted the clay, a variety as free as possible
from iron and calcium compounds; then mixed the powdered mass with
concentrated sulfuric acid, and heated it to about 70°C. Aluminum
sulfate was formed, which was extracted with water and the solu-
tion was then treated with potassium sulfate for preparation of
alum[2].

[1]Mellor, Vol. V, p. 257.
[2]Mellor, Vol. V, p. 258.

3. F. Lauer roasted the aluminiferous material with iron pyrites, which reacted with it forming aluminum sulfate. The mixture thus obtained is leached with water. The aluminum sulfate goes into solution, while the basic iron sulfates are left as slime. The sulfate in solution is converted into potash alum and recovered as such[3].

4. J. Heibling made briquettes from a mixture of the clay with ammonium and potassium sulfates. After calcination at 270° - 280°C, extraction with water gave alum.[4]

5. A. H. Cowles heated briquettes made from clay, sodium chloride, and charcoal in a stream of air and steam. The carbon keeps the mass porous and allows the gases to readily penetrate to the interior of the mass. A sodium aluminosilicate is formed, $2Na_2O.2SiO_2.Al_2O_3$; this is mixed with lime and heated in a rotary kiln: $2Na_2O.2SiO_2.Al_2O_3 + 4CaO = 2Ca_2SiO_4 + 2Na_2O.Al_2O_3$. The sodium aluminate is soluble in water, and the calcium silicate can be used in the manufacture of hydraulic cement[5].

6. P. Miguet heated a mixture of clay, lime, scrap iron, and a reducing agent such as carbon in an electric furnace. Silica calcium aluminate, and ferrosilicon were formed:
$Al_2O_3.2SiO_2.2H_2O + Fe + 4C + CaO = FeSi_2 + 4CO + CaO.Al_2O_3 + 2H_2O$.
The lighter calcium aluminate floats on the regulus, and is tapped

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[3]Mellor, Vol. V, p. 258.
[4]Mellor, Vol. V, p. 258.
[5]Mellor, Vol. V, p. 258.

off, cooled, crushed, and leached with a solution of sodium carbonate, whereby sodium aluminate and calcium carbonate are formed: $CaO.Al_2O_3 + Na_2CO_3 = CaCO_3 + Na_2O.Al_2O_3$. Aluminum hydroxide is obtained from the solution by bubbling carbon dioxide through it. The ferrosilicon is a marketable by-product[6].

7. E. Hart has proposed the following methods of recovery of aluminum, potassium, and silica from feldspar or clay. The raw material is fused with potassium sulfate and carbon. The slag obtained from this treatment, after being finely pulverized, is leached with a sulfuric acid solution. The precipitated silica is recovered by filtration, the aluminum, potassium and any other metallic constituents going into solution as sulfates. On partial evaporation and then cooling alum crystallizes out whereas iron, etc. remain in solution.

The last method, outlined by E. Hart, is essentially the method worked on by the writer.

The raw material worked with was a clay used by the California Portland Cement Company, and trade named "Fleming Clay".

The first step was the analysis of the clay for alumina, potash, and silica. The methods used were:

1. Silica. - A method used by cement companies which is briefly this. A sample of the clay intimately mixed with sodium carbonate is fused in a nickel crucible. The fused mix is then ground and dissolved in hot water. Perchloric acid is added and the

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[6] Mellor, Vol. V, p. 258.

solution is evaporated to fuming. The precipitated silica is filtered out, dehydrated by igniting, and weighed.

2. Alumina. - The solution obtained from the silica filtration was analysed for alumina by the method of precipitating aluminum phosphates as given in Mahin and Carr; Agricultural Analysis. p. 259.

3. Potash. - Potash was determined by the perchlorate method given in Mahin and Carr; Agricultural Analysis, p. 247.

The results of the analysis were:

	Sample I	Sample II
SiO_2	62.4%	62.3%
Al_2O_3	16.5%	15.0%
K_2O	3.6%	3.5%

An average analysis of the clay from the deposit was obtained from the cement company and it ran as follows:

SiO_2	59.08%
Al_2O_3	18.28%
Fe_2O_3	4.70%
CaO	4.04%
MgO	2.11%
SO_3	2.00%
K_2O	2.44%
Na_2O	2.40%
H_2O and CO_2	4.95%

As can be seen there is a fairly large discrepency in the two sets of values. Some of the differences can be explained by the fact that the cement company's values are an average. The large discrepency in the case of alumina was due to the fact that some sulfur came down with the aluminum phosphate precipitate and this necessitated an ignition in Gooch crucibles that had not been previously ignited. The discrepency in the case of silica is probably due to an actual difference in composition of the clay. The determination of potash is a rather complex and uncertain procedure, so the discrepency here can be assumed to be due to errors in technique. Since the analysis of the clay was a minor part of the problem and the time available for work on the problem was limited, it was decided to spend no more time on clay analysis. The values given by the cement company are the values used in calculations throughout this paper.

Fusion Process

The chemical reactions that are thought to take place in the fusion are:

(1) $K_2SO_4 + 4C = K_2S + 4CO$[7]

(2) $Al_2O_3 + K_2S + H_2O = K_2Al_2O_4 + H_2S$

(3) $SiO_2 + K_2S + H_2O = K_2SiO_3 + H_2S$.
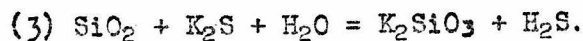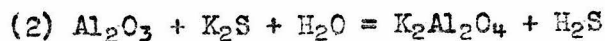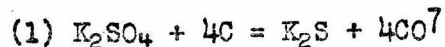
(The Al_2O_3 and SiO_2 are of course largely in the form of the compound $Al_2O_3.2SiO_2.2H_2O$.)

The H_2S produced in equations (2) and (3) is not given off but reacts with the iron or other substances present in the clay, or is

[7]Mellor, Vol. II, p. 622.

burned to water and SO_2.

(4) $Fe_2O_3 + 3H_2S = 2FeS + 3H_2O + S$

(4-a) $S + O_2 = SO_2$

(5) $2H_2S + 3O_2 = 2H_2O + 2SO_2$.
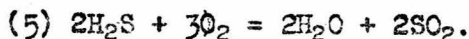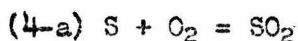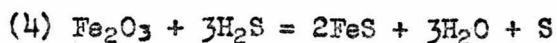
The fusion was carried on in clay crucibles of small size, height 3 inches, inside diameter at top 2.5 inches, fitted with clay covers. The crucible after the charge had been put in was heated in a fire-clay crucible furnace provided with a compressed-air gas burner for the heating element.

The charge, which consisted of clay, potassium sulfate, and carbon, was prepared as follows. The ingredients were ground separately to a fine powder, about ninety percent through eighty mesh. The correct proportions of each (calculations for these proportions follow) were then placed in a mortar and thoroughly ground together so as to provide intimate contact on the reacting surfaces. In spite of the fact that the mass fuses the reaction is essentially a reaction between solids, because even at high temperatures the charge, although fused, is very viscous and hence there can be little mixing. The carbon monoxide and other gases given off during the heating process create a certain amount of stirring action, but its effect is probably small, because of the high viscosity of the fused mix.

Calculations for Charge

Clay - SiO_2 = 59.08% Al_2O_3 = 18.28%.

Molecular weights: SiO_2 = 60.3 Al_2O_3 = 102.2

K_2SO_4 = 174.3

Per unit weight of clay K_2SO_4 required is:

for Al_2O_3 = (.1828)(174.3/102.2) = .312.

for SiO_2 = (.5908)(174.3/60.3) = 1.706.

Total K_2SO_4 per unit clay   = 2.018

Carbon per unit clay = (2.018)(4)(12) /(174.3) = .552.

The size crucible used permitted a charge containing about 24 grams of clay.

Theoretical Charge

Clay   - 24 grams

K_2SO_4 - 48   "

Carbon - 13   "

Calculating K_2SO_4 only for the decomposition of the compound $Al_2O_3.2SiO_2.2H_2O$ and not for the excess SiO_2 in the clay.

Theoretical Charge

Clay   - 24. grams

K_2SO_4 - 18.   "

Carbon - 5.   "

To insure complete decomposition would of course require the theoretical charge first calculated, whereas to merely decompose the alumino-silicate in the clay would require the charge calculated in the second case.

Since the potassium sulfate is the most expensive ingredient in the charge, it is desirable to use a minimum of this material. If the free silica is reacted on by the potassium sulfide produced, in preference to the alumino-silicate, the amount of potassium sulfate required will be that required for complete decomposition, whereas if this is not true the amount will be less. If the reverse is true, i.e. if the alumino-silicate is reacted on preferentially, the amount required for complete recovery of the aluminum will be that calculated in the second case.

Since it was not known which substance would be reacted on first, the rather arbitrary charge given below was used as a starting point.

<div align="center">

Clay   - 24 grams

K_2SO_4 - 27 grams

Carbon - 8 grams

</div>

1st Run

No Data. Crucible split during fusion and charge ran out.

2nd Run

Ingredients: Clay - 24 grams
              K_2SO_4- 27   "
              Carbon - 8   "

Carbon used was a finely powdered charcoal.

Treatment: Heated to a bright red color and held at this temperature for 30 minutes. Slag ground, then leached with excess of dilute H_2SO_4 (4 N.), and filtered.

Data obtained: The SiO_2 precipitated by the acid could not be filtered until it was dehydrated by boiling in acid solution for

some time (approximately twenty minutes in 4 N. acid). The SiO_2 was contaminated by a great many impurities such as carbon, etc.

3rd Run

Ingredients: Same as in 2nd run.

Treatment: Heated to a yellowish red color for 20 minutes. All gas evolution had previously ceased.

Procedure and calculations for the recovery of aluminum in this and subsequent runs was as follows:

After the crucible was removed from the furnace and cooled the slag was as completely removed from the crucible as possible. This was about ninety percent. In each case the amount was somewhat different so it was necessary to estimate the amount unrecovered for each run. The recovered slag was weighed and ground to about eighty mesh. A fraction of it was then weighed out (usually about one-fourth), leached with boiling 4 N. sulfuric acid for thirty minutes, filtered, and diluted in a volumetric flask to 500 cc. Two 50 cc. samples were removed with a pipette, poured into beakers and heated to boiling with about 1 cc. dilute nitric acid, which was added to oxidize the ferrous iron to ferric. It was found that it is very difficult to filter an aluminum iron hydroxide mixture that contains ferrous hydroxide. As soon as the oxidation occurred, this was indicated by the solution becoming yellow, the solution was cooled and dilute NH_4OH was added until all iron and aluminum was precipitated. It was then boiled again for about five minutes or until the odor of ammonia was faint, the precipitate filtered out onto a quantitative

filter, thoroughly washed, ignited, and weighed.

The recovery of iron was assumed in all cases to be the same as that of aluminum, because it is relatively simple to determine the amount of iron plus aluminum present, whereas it is quite difficult to determine aluminum alone.

$$\% \text{ yield} = \frac{(\text{weight ppt.})(\text{weight slag})\overline{(\text{fraction sol. taken for analysis})}}{(\text{fraction slag taken})(\% \text{ slag recovered})(\% \text{ Fe+Al})(\text{weight clay})} \times 100$$

Simplified:

$$\% \text{ yield} = \frac{(\text{weight ppt.})(\text{ratio total slag to am't. used})(\text{ratio total sol. to am't. used in analysis})}{\text{weight Fe + Al in clay}} \times 100$$

Data obtained: For this run percent yield calculated as indicated above was 55 %.

4th Run

Ingredients: Same as in 2nd run.

Treatment: Heated to a yellowish color for 20 minutes.

Data obtained: In an attempt to pour the fused charge out of the crucible it was found that a portion of the charge was very fluid, whereas the other portion was little more than plastic. This indicated the possibility of the formation of two phases at this temperature and considerable qualitative work was done on the two portions of the charge to determine the difference in properties and the distribution of iron and aluminum. Subsequent runs showed, however, that there was not really a two phase system, because a perfectly homogeneous slag could be obtained by a treatment for the same length of time at a higher temperature or a longer treatment at the same temperature. The effect was probably due to the fact that the charge had not had

sufficient time for complete reaction.

No analysis was made to obtain the percent yield of aluminum.

5th Run

Ingredients: 1.5 times those in 2nd run.

Treatment: Heated to bright yellow color for 45 minutes.

Data obtained: The apparent two phases observed in the 4th run were still perceptible in this run, even though the heating period was over twice as long, but the appearance and other characteristics of the two portions were different than those obtained in the 4th run, and the charge was much more nearly homogeneous.

The yield of aluminum and iron was 60%.

6th Run

Ingredients: Clay - 24 grams
 K_2SO_4 - 27   "
 Carbon- 10   "

Carbon used in this and subsequent runs unless otherwise noted was a good grade of soft coal powdered to finer than 80 mesh. 10 grams of coal yields about 8 grams of carbon so the amount of carbon for the charge is essentially unchanged.

Treatment: Heated to a bright red color for 10 minutes.

Data obtained: As in the 4th run the charge consisted very markedly of two portions. The two portions were treated the same as in the 4th run and the results were practically identical to those obtained in the 4th run. It should be noted that in the run the temperature was lower and the time of heating shorter than in the 4th run, which indicates that to obtain a homogeneous slag a higher temperature or longer time of heating is required.

No analysis was made to obtain the percent yield of aluminum.

7th Run

Ingredients: same as in 6th run.

Treatment: Heated for 30 minutes to very bright almost dazzling white color by adding a little powdered coal along with the air blast to the furnace burner.

Data obtained: The slag was perfectly homogeneous indicating, as has already been mentioned under 4th run, that there were not two phases present in equilibrium, but rather an imperfect mixing of the fused mass.

The very high temperature obtained split the crucible and part of the charge was lost so an analysis for recovery of aluminum was not possible.

8th Run

Ingredients: Same as in 6th run, except that a somewhat larger amount of coal was added because it was not so finely powdered as in previous runs.

Treatment: Heated to a good white color, somewhat lower than that obtained in the 7th run, for 90 minutes.

Data obtained: Slag was perfectly homogeneous, very hard, and extremely difficult to remove from the crucible. There was a layer of slag fused to the crucible that could not be very well removed, and as a consequence it was not possible to get an analysis of the recovery of aluminum with any degree of accuracy at all.

To get an idea of the recovery of potassium a determination of soluble salts was made. The entire charge and the portion of the

crucible that the charge had stuck to was leached out with boiling H_2SO_4 (4 N.) solution. All soluble substances, potassium sulfate was the one of primary interest, were thus brought into solution. The solution was diluted to a definite volume in a volumetric flask and a definite portion was removed with a pipette. The iron and aluminum were precipitated out with NH_4OH solution and then removed by filtration. The solution was evaporated to dryness, ignited until all $(NH_4)_2SO_4$ was driven off, and weighed.

% recovery of soluble salts assuming it to be all K_2SO_4

$$= \frac{(\text{weight salt recovered})}{(\text{weight salt in charge})(\text{fraction of sol. taken for analysis})} \times 100$$

For this run the recovery calculated as indicated above was 39.%

9th Run

Ingredients: Clay   -   50 grams
               Na_2SO_4 - 24   "
               Carbon - 12   "

Treatment: Heated to good white color for 30 minutes.

Data obtained: Recovery of aluminum and iron was 77%.

Recovery of soluble salts was 73%

10th Run

Ingredients: Same as in 9th run.

Treatment: Same as in 9th run.

Data obtained: The following runs were made to determine the time required for complete leaching.

Table I

No.	Time of Leaching	Temp. of Leaching	Recovery of Al and Fe
1	60 min.	20°C	41.%
2	Just brought to boil.	--	67.%
3	2 min.	Boiling (100°C)	67.%
4	10 min.	Boiling (100°C)	67.%

In determining (1) after leaching and filtering off the residue, it was necessary to boil the solution and refilter because the silica was not sufficiently dehydrated by the leaching process to be filterable.

11th Run

Ingredients: Same as in 9th run.

Treatment: Heated to reddish yellow color for 45 minutes.

Data obtained: Tests for time required for leaching were made as in 10th run.

Table II

No.	Time of leaching	Temp. of leaching	Recovery of Al and Fe
1	Just brought to boil.	--	Silica not dehydrated so sol. was not analysed.
2	10 min.	Boiling (100°C)	50%
3	30 min.	Boiling (100°C)	51%

12th Run

Ingredients: Clay - 50 grams
Na_2SO_4 - 24 "
Carbon - 18 "

Treatment: Heated to a yellow color for 30 minutes.

Data obtained: Recovery of aluminum and iron was 46%.

Recovery of soluble salts was 35%.

Note. Just prior to this run it was discovered that, if a charge of coal were coked in the crucible before it was used for the heat treatment of the charge, the slag would not stick to the crucible. This made it possible to recover all the slag and eliminated the somewhat uncertain estimation of the amount of slag recovered.

13th Run

Ingredients: Clay - 50 grams
Na$_2$SO$_4$ - 24 "
Carbon - 10 "

Treatment: Heated to reddish yellow for 15 minutes.

Data obtained: The slag from this run was used in attempting to work out the third method for the recovery of aluminum from solution.

Table III

Run	Ingredients Variation from Standard	Temp. of run ± 100°	Length of run	% Al and Fe recovered	Amount Al and Fe recovered	% of soluble salts recovered
3	None	1100°	20 min.	55.	3.03 grams	--
5	"	1300°	45 "	60.	3.31 "	--
8	Powdered coal used instead of charcoal	1500°	90 "	--	--	39.
9	Powdered coal Na_2SO_4 for K_2SO_4 50 grams clay instead of 24	1500°	30 "	77.	8.87 "	73.
10	Same as (9)	1500°	30 "	67.	7.71 "	--
11	Same as (9)	1100°	45 "	51.	5.87 "	--
12	Same as (9) except 18 grams coal instead of 10	1300°	30 "	46.	5.28 "	35

Recovery of Aluminum from the Leaching Solution.

1st Method.

Aluminum sulfate and potassium sulfate can be recovered from a solution quite easily and completely if they are in equi-molal concentrations. Alum ($Al_2(SO_4)_3.K_2SO_4.24H_2O$) is very soluble in hot water (400 parts alum per 100 parts water at 100°C) and only slightly soluble in cold water (5 parts per 100 at 0°C). By concentrating the solution to saturation at 100° and then slowly cooling to 0° or other suitable low temperature it is possible to obtain fine alum crystals and obtain an almost complete recovery. If sodium salts are present in considerable amounts the alum crystals will be contaminated with $NaSO_4.10H_2O$, glaserite ($3K_2SO_4.Na_2SO_4$) and sodium alum[8].

2nd Method. (Unsuccessful)

Since iron is present in the solution in considerable amounts, any method for the recovery of aluminum must provide for the separation of it from the iron. The method attempted was this. The solution is boiled with calcium oxide. Aluminum is amphoteric, whereas iron is not, so in the basic solution the iron would be precipitated as hydroxide and the aluminum would stay in as aluminate. The iron hydroxide is then filtered off, and the solution neutralized until only weakly basic whereupon aluminum hydroxide would be precipitated and could be filtered off.

The method was unsuccessful because the calcium hydroxide solution is not sufficiently basic to form aluminates. Both aluminum and iron are completely precipitated by this hydroxide.

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[8]J. Ind. and Eng. Chem. V.10, p. 348 (1918).

3rd Method.

There was not sufficient time to do any quantitative work on this method but some qualitative tests indicate that it has possibilities.

The slag was leached with a sodium hydroxide solution (about 2 N.)[9]. This dissolved out the aluminum leaving the iron as a sulfide and hydroxide. The residues were filtered off. The hydroxide solution was then diluted to about .2 N and a fair amount of the aluminum was precipitated, and filtered off. It had a very pure appearance. The dilute hydroxide solution could be reused by concentrating it to about 2 N. by evaporation. As soon as the impurities accumulate in such amounts as to interfere the solution could be neutralized with sulfuric acid. This would precipitate the soluble silicates as silica and it could be obtained in a pure form by merely filtering.

In Table III (page 18) the more important data obtained has been tabulated so as to show the relations of certain effects. On the whole the interpretation of these data is rather difficult, but they do indicate a few things.

1. The best yields were obtained in the runs where the temperature was highest.

2. Considerable amounts of potassium were lost during the fusion process, probably both by evaporation and mechanically. The carbon monoxide and other gases formed in the reaction no doubt carry along some of the charge.

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[9] Noyes, "Qual. Chem. Anal.", 8th Edition, p. 95.

3. Also when using sodium considerable amounts were lost, although much less than potassium. Since the amount carried mechanically should be about the same in either case, this would indicate that the sodium is not lost so readily by evaporation.

4. When coal is used as a source of carbon, the loss of charge mechanically is considerable. This is due to the large volume of gas given off when the coal cokes. Since this coking occurs at a temperature below the fusion temperature of the charge, the escaping gases carry off the finely pulverized charge. The exceptionally low yields in run (12) may be explained by this fact, because here an excess of coal was used.

5. The recovery of aluminum in (9) indicates that the optimum amount of clay per unit of sulfate and carbon has not been reached yet. To find the optimum amount further runs should be made using large excesses of clay.

Conclusion

1. Unless the aluminum is recovered as outlined in Method III, (page 20), the recovery of silica is impossible because of the large amount of insoluble impurities in the slag.

2. The use of potassium sulfate as a raw material is uneconomical for these reasons: (a) over half of the sulfate is lost in the fusion process by evaporation and mechanically; (b) the amount of potassium in the clay, and hence the maximum amount that can be recovered, is small; and (c) the sulfate is by far the most costly ingredient.

3. If sodium sulfate is used instead of potassium sulfate as a raw material, the recovery of the potassium in the clay is out of the question.

4. Since potassium cannot be recovered, and it is doubtful if silica can, if the process is to pay, the value of the aluminun salt recovered must pay for the process.

5. Unless some method is discovered radically different from the one worked on by the writer, the value of the aluminum salt recovered will never be able to pay for the process. The high temperatures required for fair yields, the great difficulty involved in the separation of the aluminum from the iron (the only promising method requiring the use of the comparatively expensive reagent, sodium hydroxide), the numerous operations including grinding, leaching, evaporation, etc.: these costs coupled with the fairly low value of the aluminum sulfate, which would probably be the final product, make the process, from an economical standpoint, quite impossible.

The writer wishes at this time to express his indebtedness to Professor William N. Lacey for his guiding suggestions in the performance of the experimental work, and for the helpful advice and criticisms in the preparation of this manuscript.

Thanks are due the California Portland Cement Company, who furnished the sample of Fleming clay used in these experiments.

Summary

The experimental work carried out shows that the recovery of aluminum from Fleming clay is perfectly possible and that by additional experimental work it would be possible to obtain fairly good yields; but that the recovery of silica and potassium would be very difficult if not impossible.

While the aluminum recovery is chemically possible, the cost of reagents and operations makes the process impossible from an economic standpoint.