CCCLXXVIII.—*The Action of Alkalis on Clay.*
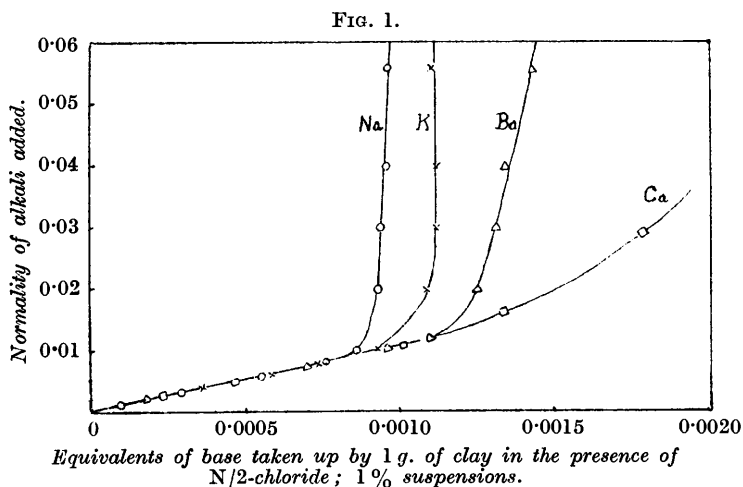
By HENRY BOWEN OAKLEY.

IN the study of the physical and chemical properties of soils, much attention has always been directed towards the clay fraction which, together with humus, is responsible for the colloidal properties of the soil, and is one of the most reactive components chemically.

Although many diverse hypotheses have been put forward to account for the " absorption " of bases by clay, the trend of modern opinion is to regard the action as chemical in nature, being due to the formation of insoluble aluminosilicates, as opposed to the hypothesis of " physical absorption of ions," which is still largely adopted in many branches of colloid chemistry. The view that clay acts as a weak acid towards alkalis is supported by the electrometric titration curves of Bradfield (*J. Amer. Chem. Soc.*, 1923,

45, 2669), and is confirmed by the results presented in this paper. A fairly full bibliography on this subject is given by Bradfield (*J. Amer. Soc. Agronomy*, 1925, **17**, 253).

The clays used in this work were separated by sedimentation in 0·05% sodium carbonate, flocculated by dilute hydrochloric acid ($N/100$), and purified to a high resistance by dialysis (Joseph and Hancock, J., 1924, **125**, 1888).

The Effect of the Concentration of Alkali on the Amount of Base removed from Solution by Clay.—The clay used in these experiments was No. 10195 prepared from a heavy cotton soil : it was practically identical with No. 6640 (Joseph and Hancock, *loc. cit.*). 10 C.c. samples of a 5% suspension were treated with different

FIG. 1.

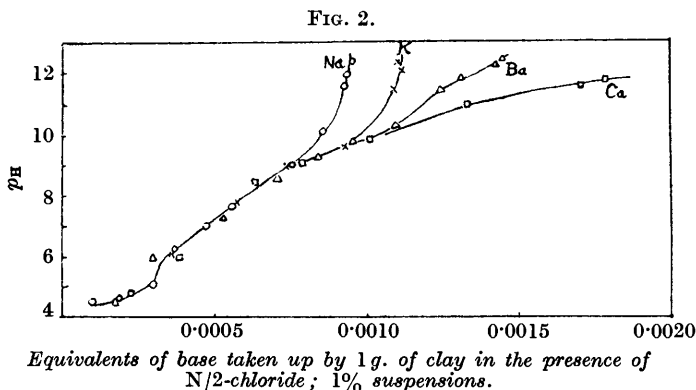*Equivalents of base taken up by 1 g. of clay in the presence of $N/2$-chloride ; 1% suspensions.*

quantities of standard alkali in centrifuge tubes. Water and a standard chloride solution of the appropriate base were added to make the total volume 50 c.c. and $N/2$ with respect to the chloride. This treatment completely flocculated the clay. The tubes were centrifuged, and 25 c.c. of the clear, supernatant liquid were treated with excess of $N/10$-hydrochloric acid and titrated back with $N/10$-sodium hydroxide, as this procedure was found to give the sharpest end-point. Methyl-orange was used as indicator. A further portion was withdrawn for the p_H determination in a Clark cell with a Leeds and Northrup potentiometer. From the change in concentration of the alkali, the amount removed by the clay can be calculated, since any soluble silicates or aluminates which may be formed behave in titration as free alkali.

The results are illustrated in Figs. 1 and 2. The equivalents of base taken up per g. of clay are identical for sodium, potassium,

barium, and calcium up to an initial concentration of alkali of $0.01N$, or an equilibrium p_H of about 9 ; but with a further increase in the concentration of alkali the amounts taken up are in the increasing order sodium, potassium, barium, and calcium.   The amounts of sodium and potassium taken up attain fairly constant values above a p_H of 11, whereas barium and calcium show no such limit.   This order is the same as that found for amorphous silica (Joseph and Oakley, J., 1925, **127**, 2813), and suggests that the quantity of any base retained in the solid phase is partly determined by the solubility or stability of the aluminosilicates and their products of decomposition with increasing concentrations of alkali.

The Total Amounts of Sodium and Calcium Hydroxides neutralised by Clay.—That the quantity of bases removed in the solid phase

FIG. 2.

Equivalents of base taken up by 1 g. *of clay in the presence of* N/2-*chloride;* 1% *suspensions.*

is closely connected with the solubility of the products of combination is illustrated by the following results for calcium and sodium hydroxides, giving the total amount of alkali neutralised in the two cases.   No chloride was added in this experiment, and a lower concentration of clay was used so that the necessarily dilute calcium hydroxide could be present in a greater excess than in the previous experiment.

To determine the total sodium hydroxide neutralised, a series of p_H measurements was made on caustic soda solutions of various strengths; the hydroxyl-ion concentrations were then calculated by subtracting these values of the p_H from the values of Michaelis for log $1/K_w$ at the appropriate temperature (Clark, " The Determination of Hydrogen Ions," p. 29).   These calculated values of the hydroxyl-ion concentrations were then plotted against the concentration of sodium hydroxide.   In a similar manner, the concentration of hydroxyl-ions was calculated from the p_H of the clay suspensions.   The corresponding concentration of sodium

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hydroxide was read from the curve, and this value was subtracted from the original concentration of caustic soda added. The temperatures varied from 30° to 35°, but this was allowed for both in the calculation of the p_H and in the subsequent calculation. The error in the determination of the total hydroxide neutralised may be as much as 10%. An exactly similar method was applied for calcium. The results are in the following table (compare Bradfield, *Soil Sci.*, 1924, **17**, 411).

Total amount of calcium and sodium hydroxide neutralised by clay after standing 1 day. Concentration : 0·52% clay.

Initial conc. of hydroxide.	Equiv. of alkali neutralised per g. of clay.		Final p_H.	
	Sodium.	Calcium.	Sodium.	Calcium.
0·036	0·0018	0·0027	11·92	11·81
0·020	0·0012	0·0021	11·67	11·50
0·008	0·0010	0·0012	11·00	10·75

These results show that, although the total sodium hydroxide neutralised is about twice the amount taken up in the solid phase (compare Fig. 1), thus demonstrating the formation of soluble compounds, yet the amount of calcium hydroxide neutralised is still greater, although no soluble compounds are formed. This is shown by the fact that, for an initial calcium hydroxide concentration of 0·038 and a final p_H of 11·93, the amount of calcium hydroxide neutralised per g. of clay, as calculated from the p_H, was 0·0031, whereas that calculated from titration of the excess of alkali was 0·0032. (The concentration of the clay was 0·26%.)

The compounds formed by silica and calcium hydroxide were also found to be insoluble, but in this case they were equivalent in amount to the total sodium compounds formed under the same conditions (Joseph and Oakley, *loc. cit.*).

The influence of the concentration of the sodium on the amount of base taken up by 1 g. of clay is illustrated by the following figures with various concentrations of chloride :

Conc. of NaOH, 0·04N; conc. of clay, 1%.

Conc. of NaCl	1·0	0·5	0·2	0·1
Na taken up (equiv. × 10⁴) ...	9·68	9·56	9·17	9·15
p_H	12·10	12·16	12·22	12·25

A comparison of the effect of N-solutions of chlorides on the amounts of sodium, potassium, and calcium taken up by 1 g. of clay is given in the following figures (equivs. × 10⁴) :

Chloride.	Concentration of hydroxide.		
	0·08N-NaOH.	0·08N-KOH.	0·03N-Ca(OH)$_2$.
0·0N	8·46	10·4	14·9
1·0N	9·60	12·8	17·8

As had been previously found with silica, the addition of the chloride of the base to an alkaline suspension always increased the amount of base taken up.

The removal of the base from solution by clay is very rapid. This is illustrated by the following figures for 1 g. of clay.

Conc. of NaOH, $0.04N$; conc. of NaCl, $0.5N$; conc. of clay, $\frac{1}{2}\%$.

Time	10 mins.	1 hr.	3 hrs.	1 day
Na taken up	9.7	9.9	9.8	10.3

The Relation between the Soluble and Insoluble Sodium Compounds with Clay.—In order to determine the relation between the soluble and the insoluble sodium compounds formed with increasing concentrations of sodium hydroxide, a series of 0·5-g. samples of clay was treated with different concentrations of standard caustic soda, the volume being always 50 c.c. After standing for 1 hour, 10 c.c. were withdrawn for a p_H determination. The remainder was filtered through a collodion filter and an aliquot portion of the clear filtrate was titrated with standard acid and alkali as before. The difference between the total amount neutralised (calculated from p_H) and the amount taken up (calculated from the titration) gave the equivalents of sodium neutralised in a soluble form. These results are in the following table.

The amounts of sodium neutralised in the solid phase and in solution by 1 g. of clay after 1 hour.   Concentration of clay, 1%.

Initial conc. of NaOH.	p_H at equilibrium.	Equivs. Na in solid phase, $\times 10^4$.	Equivs. Na neutralised in solution, $\times 10^4$.	Ratio, Soluble/Insoluble.
0·07	12·33	9·7	7	0·72
0·04	12·03	9·7	5	0·51
0·02	11·60	9·9	2	0·20
0·01	10·72	8·1	1	0·11
0·006	9·77	5·4	0·6	0·11
0·004	8·62	3·9	0·1	0·02

The amount of soluble sodium compounds formed is small until the p_H exceeds 10·5, or until the concentration of alkali is greater than $0.01N$.*   This is just the concentration at which the amounts of different bases taken up begin to diverge (Fig. 1).   These results leave no doubt, I think, that the later process of the neutralisation of bases by clay at higher concentrations of hydroxide differs from the initial reaction at low concentrations, in that the more concentrated alkali begins to break down the clay substance, forming

* In the case of silica, the amount of sodium in the solid phase is always very small compared with the total silicate formed (J., 1925, **127**, 2816, Table IV).

silicates and aluminates.   In the case of calcium, these are insoluble, and in the case of sodium, they are easily soluble, whilst potassium and barium occupy intermediate positions.   In one special experiment, the amount of lithium taken up by 1 g. of clay in the presence of $0.5N$-lithium chloride was 9.0×10^{-4} equiv. at a p_H of 9.8, and the amount for sodium under similar conditions was 9.5×10^{-4}.

At the lower concentrations of alkali (below $0.01N$), the identity of the amounts of different bases taken up shows that these solubility relationships do not come into play, the compounds formed with any of the bases being equally insoluble.   In this case, there appears to exist a direct reversible equilibrium between these insoluble compounds and the bases in solution, the equilibrium with alkalis having characteristics similar to those of a weak acid in true solution ; this is indicated by the shape of the curves for sodium in Figs. 2 and 4.

From these curves it is seen that the clay acid is half converted into its sodium compound at about p_H 8.   If the laws of dissociation of a weak acid are applicable, this would mean that its dissociation constant is about 10^{-8}.   Bradfield (*J. Physical Chem.*, 1924, **28**, 170), from the variation of the p_H with concentration of a clay suspension, calculated a value of 3×10^{-7}.

Further evidence that clay behaves as an insoluble acid in direct equilibrium with the bases in solution is afforded by the liberation of acid when a neutral salt is added to clay, and by the fact that clay so treated hydrolyses on being washed with water, giving an alkaline solution.   The equivalence of the exchange of bases when clay is washed with the salt of another base also supports the view that the reactions are purely chemical in nature (*Trans. Faraday Soc.*, 1925, **22**, 251).   The speed with which all these reactions take place and the influence of various electrolytes on the electrokinetic potential and stability of clay suspensions (Oakley, *J. Physical Chem.*, 1926, **30**, 902) seem to indicate that the reactions are mainly ionic.   The fact that clay, with its weakly acidic properties, can remove some of the base from the salt of a strong acid, thus setting free this acid, also receives a natural explanation on the above view.

In order to determine the composition of the material dissolved from the clay, 5 g. of clay were shaken with $N/10$-sodium hydroxide in the presence of $N/2$-sodium chloride, the volume being adjusted so that the concentration of the clay was 1%.   This was centrifuged and the clear supernatant liquid analysed for silica, alumina, and ferric oxide.   This treatment was repeated four times for increasing periods of time with fresh additions of sodium hydroxide and chloride.   Two further experiments were made with two separate

portions of the stock clay for periods of 1 hour and 3 days, respectively. The results are in the following table.

Material dissolved from 1 g. of clay by $N/10$-sodium hydroxide in the presence of $N/2$-sodium chloride.   Concentration of clay (No. 14637), 1%.

A.   Successive treatments on the same portion of clay.

Time.	SiO_2.	$Al_2O_3 + Fe_2O_3$.	$SiO_2/(Al_2O_3 + Fe_2O_3)$.
5 mins.	0·0050	0·0046	1·1
1 hour	0·0052	0·0020	2·6
1 day	0·0107	0·0018	6·0
3 days	0·0109	0·0017	6·4

B.   Treatment on two separate portions of clay.

1 hour	0·0065	0·00466	1·41
3 days	0·0115	0·0044	2·62
Untreated clay	0·475	0·328	1·44

On the assumption that the soluble compounds formed are Na_2SiO_3 and $NaAlO_2$, the sodium so combined is $2·8 \times 10^{-4}$ and $4·4 \times 10^{-4}$ equiv., respectively, for the last two experiments (the ferric oxide also was estimated in these cases).   The value obtained from p_H measurements after 3 days' standing was $4·5 \times 10^{-4}$, and the sodium removed in the solid phase was $7·6 \times 10^{-4}$.   The figures in the last column show that the proportion of sesquioxides rapidly falls in successive treatments with caustic soda, there being a higher proportion of sesquioxides in the first extract than in the clay itself.   Another notable result is that the amount of material dissolved increases very slowly on prolonging the time of contact of the alkali with the clay, and this independently of whether the clay has had previous treatments with caustic soda or not.   These results suggest that the material which goes into solution strongly inhibits further solvent action of the alkali.   Since the concentration of the sodium hydroxide is reduced only by about 15% in the case of the initial treatments, and by about 5% in the other cases, the decreased rate of solvent action is unlikely to be due to diminished alkali concentration.

The Effect of Sodium Hydroxide and Sodium Carbonate on the Viscosity of Clay Suspensions.—It was thought that the difference in composition of the material removed by the early treatments compared with that from the later treatments might indicate that this material was identical with the hypothetical " layer of gel " on clay particles, which, according to some writers, gives clay its peculiar plastic and water-holding properties (*Brit. Assoc.*, 3rd Report on Colloid Chemistry, 1920, pp. 113—153).

If this is the case, the viscosity of clay in caustic soda solution of strength sufficient to dissolve this layer should be markedly less

than the value for clay in the presence of alkali too weak to dissolve the layer, since the particle size should be greatly reduced by the former treatment. Complicating factors in the comparison are the state of flocculation, and the state of saturation of the clay with regard to sodium. The times of flow of 10% suspensions of clay in an Ostwald viscometer were determined in a thermostat at 35°. One series of measurements was made on suspensions containing varying amounts of sodium hydroxide, and a similar series was made with sodium carbonate. After these measurements had been completed, sodium chloride was added in amount sufficient to make its concentration $N/2$. The times of flow of the deflocculated suspensions could be accurately repeated, but when the clay was flocculated, the time rapidly decreased with successive readings until an approximately constant value was reached, but this rose

FIG. 3.

Viscosity of 10% clay suspensions.

Time of flow (seconds).
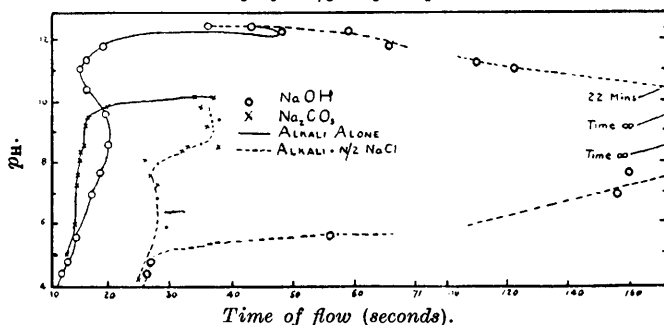
again on standing. The latter measurements are therefore very rough. The suspensions were too thick for the determination of their p_H; they were therefore diluted to one-fifth of their original concentration, and the p_H determinations were made on the diluted samples. If there was no buffer action, this dilution would decrease the p_H value by 0·7 unit, but since both the clay itself and the material dissolved by the alkali exert considerable buffer action, it is safe to conclude that the effect of dilution would not reduce the p_H by more than 0·3. The measurements were made on the suspensions after the addition of the sodium chloride.

The times of flow are plotted against the p_H in Fig. 3. The following data show the concentration of alkali added and the corresponding times of flow before the addition of sodium chloride. The time of flow of water was 10·4 seconds. [It is desirable to point out that the following figures cannot in any way be said to represent *true* viscosity values, for two reasons : (1) The rate of flow of the

uncoagulated suspensions was so high as to cause turbulent flow; and (2) Poiseuille's law is not obeyed by clay suspensions. Nevertheless, the results are of interest in showing that the comparative " thickness " of clay suspensions is affected differently by sodium hydroxide and by sodium carbonate.]

Conc. of NaOH or Na$_2$CO$_3$.	Time with NaOH (secs.).	Time with Na$_2$CO$_3$ (secs.).	Conc. of NaOH or Na$_2$CO$_3$.	Time with NaOH (secs.).	Time with Na$_2$CO$_3$ (secs.).
0·01	12·6	12·3	0·10	16·5	15·6
0·02	13·6	12·7	0·15	15·4	16·1
0·03	15·0	13·6	0·20	16·2	16·2
0·04	17·5	14·7	0·25	19·2	16·5
0·05	19·0	15·0	0·40	48·0	19·5
0·07	20·0	15·0	0·80	43·0	37·0
0·08	18·4	15·3			

The results show that at corresponding p_H values, the viscosity of clay treated with sodium carbonate is never greater than that of the clay treated with sodium hydroxide. The rapid rise in viscosity of the suspensions without sodium chloride at the highest values of the p_H is due to the flocculation of the clay by the alkali. Since the amount of material dissolved by the sodium hydroxide will be far greater than that dissolved by the sodium carbonate (carbonic acid being strong enough to decompose silicates and aluminates), it follows that this dissolved material cannot have existed in the clay in a particularly bulky and gelatinous condition. If this had been the case, its removal would have had a marked effect on the viscosity as compared with the values in the presence of sodium carbonate.

A striking feature of the results is that the curve for sodium hydroxide shows a maximum in viscosity between p_H 8 and 10, and this maximum is enormously enhanced when the clay is flocculated with sodium chloride. There is a complete absence of this effect with sodium carbonate, which suggests that it is connected with the much greater solvent power of the hydroxide. The hypothesis which accounts for the facts is that the sodium hydroxide at certain concentrations, instead of actually dissolving some of the clay, forms a comparatively non-viscous sol with this material. The addition of sodium chloride coagulates this sol, forming a coagulum of a very gelatinous nature. At higher concentrations of sodium hydroxide, this sol dissolves and cannot be coagulated by sodium chloride. This explains (1) why the maximum is only slight with caustic soda alone, but very pronounced in the presence of sodium chloride, (2) why the viscosity of the coagulated clay again falls when excess of caustic soda is added, and (3) why sodium carbonate does not show the effect.

This hypothesis is further supported by the fact that the clay

is more bulky with sodium hydroxide in the same range of p_H values at which the maximum in viscosity is observed, and that the maximum is not shown by sodium carbonate.

The following figures show the volume of 1 g. of clay (*i.e.*, of the clay plus its interstitial water after 10 minutes' centrifuging) after standing 1 day with various concentrations of alkali in the presence of $N/2$-sodium chloride.

Conc.	p_H with NaOH.	Vol., c.c.	p_H with Na$_2$CO$_3$.	Vol., c.c.	Conc.	p_H with NaOH.	Vol., c.c.	p_H with Na$_2$CO$_3$.	Vol., c.c.
0·0	4·0	4·1	—	—	0·1	12·3	5·1	8·3	4·1
0·02	7·6	4·6	—	—	0·2	12·9	4·7	8·8	4·3
0·03	8·0	5·4	—	—	0·3	13·1	4·4	9·0	4·2
0·04	9·5	5·7	—	—	0·5	13·3	4·2	10·2	4·3
0·05	11·1	5·5	8·1	4·0	1·0	13·6	4·1	10·4	4·5
0·07	12·2	5·3	—	—					

The fact that the clay without sodium hydroxide occupies the same volume as the clay in the presence of N-hydroxide affords further evidence that the material dissolved by the alkali is not specifically more bulky than the rest of the clay material.

Finally, the fact that the imbibitional water of the clay was unaltered by the prolonged treatment with sodium hydroxide points to the same conclusion. This water is the volume of water retained by 100 c.c. of the clay less the volume of xylene retained by the same clay after centrifuging for 40 minutes under a force of 1000 times gravity (compare Fisher, *J. Agric. Sci.*, 1924, **14**, 204). It was determined on the original clay (1) after drying with the addition of 9 c.c. of $N/10$-sodium hydroxide per g. of clay, and (2) on the clay left over after the four successive treatments with caustic soda described previously (p. 2825). This was washed until it was deflocculated and then collected on a collodion filter. Separate determinations were made, water and N-sodium chloride being used as the wetting liquids.

Imbibitional water of clay No. 14637.

	Water.	N-NaCl.
(1) 9×10^{-4} equiv. Na/g.	251	103
(2) Prolonged NaOH treatment	248	104

A Comparison of the Properties of a Synthetic Aluminosilicate and of Clays.—Although, in the comparison of different soil clays, some degree of correlation can be traced between base-absorbing capacity and certain colloidal properties such as heat of wetting, imbibitional water, and general clay-like properties, yet it is equally true that a substance having a composition similar to clay, a fair imbibitional water content, and a very large base-absorbing capacity may, nevertheless, show clay-like properties only to a very small

extent. This is well illustrated by the following experiments on a synthetic aluminosilicate. This was prepared (see de Sigmond, *Proc. 4th Inter. Confer. Pedology*, 1924, **2**, 434) by mixing solutions of sodium aluminate and sodium silicate (both $N/10$ with regard to sodium; $Na_2O : SiO_2 = 1 : 2$) in such proportion that the molecular ratio $SiO_2 : Al_2O_3 = 3 : 1$. Under such conditions, as de Sigmond has shown (*loc. cit.*), almost complete precipitation takes place of the compound $3SiO_2, Al_2O_3, Na_2O, 3H_2O$. When the p_H of the mixture was progressively altered by the addition of different

FIG. 4.

Equivalents of sodium taken up, $\times 10^4$.
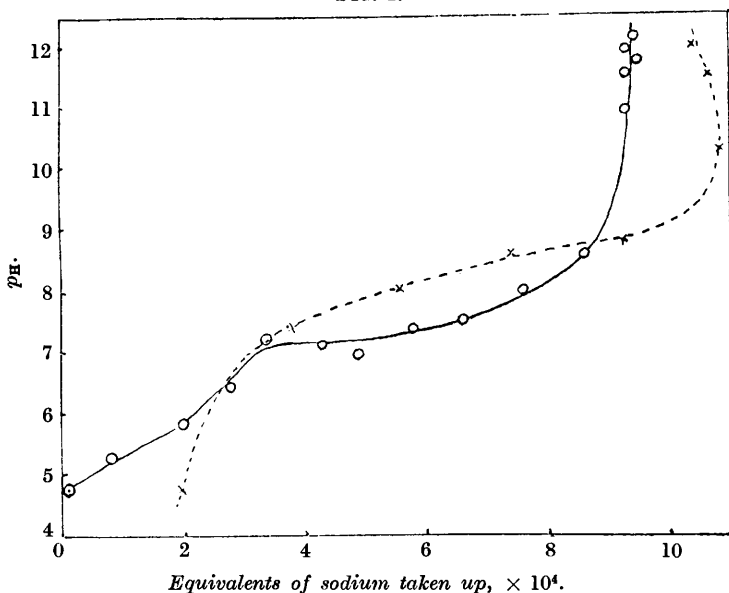
Full curve: $1/2000$ *mol.* ($0 \cdot 17$ *g.*) *of synthetic aluminosilicate in* 50 *c.c.*
Dotted curve: 1 *g. of clay No.* 14637 *;* 1% *suspension.*

amounts of standard hydrochloric acid, the amount of sodium retained by the compound varied with the p_H in a manner rather similar to that in the case of clay (Fig. 4). This very highly gelatinous compound was washed several times by decantation after centrifuging, and evaporated to dryness on a water-bath with frequent stirring to cause the formation of small aggregates. It was then dried at $100°$ and subjected to a process of alternate grinding in a wet condition in an agate mortar and sedimentation. The product was kept for 4 weeks with $N/100$-hydrochloric acid, the acid being renewed at intervals. It was then washed by decantation and centrifuging until it deflocculated and the specific resistance of a 1% suspension was 13,000 ohms. The alternate

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grinding and sedimentation was then repeated, but even after this, most of the material sedimented within 3 hours, so that it was still much coarser than clay, which may be stable for months. This material on standing developed an alkaline reaction (p_H 8). The following table compares the imbibitional water and the behaviour towards sodium and calcium hydroxides of this substance with the same properties of different clays and silica as given by Joseph (*J. Agric. Sci.*, 1927, **17**, 14).

Sample No.	Description.	Na taken up in solid phase: 0·5N-NaCl+ 0·04N-NaOH (1% clay).	Total NaOH neutralised (0·08N-NaOH; 1% clay).	Ca removed in solid phase (0·3% clay).	Imbibitional water.
14637	Gezira.	$10·0 \times 10^{-4}$	12×10^{-4}	30×10^{-4}	143
10118	Kaolin.	0·0	0·0	1	5
13107	Mongalla (red).	3·1	19	22	54
—	Bentonite.	7·6	20	36	362
—	Synthetic alumino-silicate.	24	40	51	74
—	Amorphous silica.	4	About 70	About 70	40
10120	Ball clay.	—	—	—	40

The synthetic product is remarkable for its high sodium-absorbing capacity. All the clays neutralise more calcium than sodium hydroxide. This may be connected with the fact mentioned by Vernadsky (*Rep. Brit. Assoc.*, 1923, 435) that it is a general property of zeolites to form additive compounds with calcium hydroxide. The synthetic material shows a marked contrast with kaolin both in its reactions with bases and in its imbibitional water. It retains 13% of moisture at 150°, in this respect also resembling clays. Kaolin has been prepared synthetically by Schwarz and Walcker (*Z. anorg. Chem.*, 1925, **145**, 304) by precipitating silicic acid with aluminium chloride in an *acid* medium.

Although the first-mentioned synthetic aluminosilicate resembled clay in some important respects, yet its physical properties, as exemplified by its plasticity in the hand, showed that this most characteristic property of clay was only present to a very limited extent—possibly this may be due to the coarseness of its particles. Notwithstanding that bentonite is by far the most highly colloidal clay-like substance known, yet it takes up less sodium than the Gezira clay, whilst silica, which has no clay-like properties, takes up more sodium than the Mongalla clay. The sodium absorption of these substances is therefore not necessarily related to their colloidal properties or to the fineness of division of their particles.

Summary.

1. Clay which has been purified after a mild acid treatment takes up equivalent quantities of bases up to a p_H of about 9.

When the p_H is greater than this, the amounts removed are in the order lithium < sodium < potassium < barium < calcium.   These amounts are increased by the presence of neutral salts of the metals.

2. The amount of sodium hydroxide neutralised in the form of *soluble* compounds is negligible until the p_H is above 9, but increases rapidly when the alkalinity is greater than this.

3. These results, taken in conjunction with evidence from elsewhere, are accounted for on the supposition that clay is an insoluble or a colloidal weak acid in *direct* equilibrium with bases in solution, the salts formed with the various bases being equally insoluble; but unless the alkali is very dilute ($p_H = 9$), the clay begins to break down, giving silicates and aluminates.   With sodium these are easily soluble, and with calcium they are insoluble, whilst barium and potassium occupy intermediate positions.

4. About 1% of the clay was immediately dissolved by $N/10$-sodium hydroxide, but this amount was only slightly increased on prolonged standing.   Renewal of the alkali, however, rapidly caused the dissolution of 1% more.   The ratio of silica to sesquioxides in solution increased from 1 to 6 in four successive treatments.   The imbibitional water of the clay was unaltered by the above treatment.

5. The viscosity and specific volume of coagulated clay show pronounced maxima between p_H 8 and 10 with caustic soda, but not with sodium carbonate at the same p_H values.

6. In base-absorption, water-retention, and imbibitional water a synthetic aluminosilicate showed considerable analogy with clay, although the material was comparatively coarse and was only slightly " clay-like " to the touch.   Large sodium absorption by aluminosilicates does not necessarily indicate highly developed colloidal properties or a particularly fine state of division.   Comparisons are made between three different clays—kaolin, silica, and bentonite.

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