chemical series. Aluminum forms a notable exception. In spite of the high position of this metal in the electrochemical series, its salts invert sugar more rapidly than those of any other metal thus far tested.

3. Chlorides invert sugar more rapidly than sulphates, because the ionizing tendency of chlorine is greater than that of the sulphuric radical.

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[CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF THE CASE SCHOOL OF APPLIED SCIENCE, NO. 32.]

SODIUM ALUMINATE AS A MEANS FOR THE REMOVAL OF LIME AND SUSPENDED MATTER FROM WATER FOR USE IN BOILERS.[1]

BY CHARLES F. MABERY AND EDWIN B. BALTZLEY.

Received October 5, 1898.

THROUGHOUT the section of country including Northern Pennsylvania, Ohio, and farther west, in districts removed from the lake or the large rivers, the only sources of water in seasons of drought are deep wells. Since the water from these wells contains large quantities of lime salts, there are serious difficulties in the way of procuring water suitable for use in steam boilers, especially in locomotive boilers. Even such water as that from Lake Erie or the rivers, deposit scale to such an extent as to occasion extreme inconvenience. In stationary boilers, the deposition of scale may be avoided at least in part by using some of the many so-called scale preventatives, if the boiler is in charge of an intelligent engineer.

The inconvenience of boiler scale, the additional cost in fuel, the injury to the boiler, and the danger are features of this question familiar to all who have charge of boilers. The large masses of scale withdrawn from boilers in which hard or turbid water is used, are not surprising when the great quantities of water evaporated in boilers under high pressures are taken into consideration.

The wide variations in the composition of boiler scale are de-

[1] The work described in this paper formed the subject of a thesis for the degree of Bachelor of Science.

pendent on the differences in the water used. The manner of running the boiler has much to do with the hardness of the scale and the rapidity of its formation. The chief causes of the formation of scale are the calcium carbonate and sulphate and magnesium carbonate contained in solution, and the solid matter held in suspension, both inorganic and organic. All these points must be borne in mind if unpurified water is to be used in a boiler. There has been for some time a feeling on the part of engineers that the only satisfactory method for the prevention of boiler scale is the use of purified water, and many attempts have been made, with more or less success, toward purification of the water before it enters the boiler. The means that have been tried include sedimentation, precipitation by sodium carbonate, sodium hydroxide, slaked lime either alone or in combination. Evidently successful purification depends on removing completely the suspended matter as well as the precipitation of the lime and magnesia. In thinking of what combination should most effectually and economically accomplish these results, in any hard or turbid water, it occurred to one of us (Mabery), that sodium aluminate should fulfill the conditions demanded, and in trying this reagent we find that it meets all requirements.

The general method includes the preparation of sodium aluminate in solution. This may be done in any suitable tank or reservoir, by adding sodium hydroxide in the proper amount to a solution of aluminum sulphate of known strength, and adding to the water a definite amount (the quantity depending on the composition of the water to be purified), agitating thoroughly, and allowing the mixture to stand some time, perhaps twelve to twenty-four hours. The method is based on the following reactions:

For the formation of sodium aluminate:

$$Al_2(SO_4)_3 + 8NaOH = Al_2O_4Na_2 + 3Na_2SO_4 + 4H_2O.$$

In the precipitation:

$$CaH_2(CO_3)_2 + Al_2O_4Na_2 + 2H_2O = CaCO_3 + 2AlO_3H_3 + Na_2CO_3.$$

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4.$$

Similar reactions evidently take place with magnesium carbonate or sulphate. No doubt sodium aluminate can be made much more cheaply by fusing a tolerably pure clay with

soda-ash. Doubtless it may also be obtained cheaply as one of the products in the preparation of soda-ash from cryolite.

Numerous experiments were made with different proportions of sodium aluminate; the best results were obtained by using from one-half the calculated proportions to the calculated proportions of aluminum sulphate, depending on the composition of the water. With proper proportions of aluminate, aluminum hydroxide was completely precipitated on standing. Experiments on different waters with one-fourth the calculated proportion of aluminate showed that this amount was not sufficient to precipitate the lime sufficiently. In applying this method its effect was studied on waters containing different amounts of carbonate and sulphate, as well as on waters with a great variation in turbidity, from the slightly turbid lake water, to specimens thick and muddy. In every instance, after standing from twelve to twenty-four hours, the water became perfectly clear. The extent to which lime and magnesia were removed is shown by results obtained in the following waters:

Very hard water from well in Ohio:

Calcium sulphate	259.0
Calcium carbonate	146.0
Magnesium carbonate	177.3

About eighty-five per cent. of the amount of aluminate required to precipitate all the lime and magnesia was added, air was blown through the solution for a few minutes and the mixture allowed to stand twenty-four hours. Analysis then showed that eighty-eight per cent. of the lime had been removed and 95.6 per cent. of the magnesia. In another determination the theoretical amount of aluminate was added and the solution treated as before. Analysis showed that 98.1 per cent. of the lime had been removed and 97.4 per cent. of the magnesia.

The next water tried was the Massillon city water, containing

Calcium sulphate	99.12
Calcium carbonate	113.2
Magnesium carbonate	131.1

After treatment with the theoretical amount of sodium aluminate the total lime removed was equivalent to 98.8 per cent., and that of magnesia 98.0 per cent.

In another experiment, using one-half the theoretical amount, the lime removed was 83.5 per cent., and that of the magnesia 90.6 per cent.

The next water tried was a very turbid sample from the Cuyahoga river. This water was very muddy and did not settle on long standing. It is used in boilers. A clear sample of this water showed the following composition:

Calcium sulphate	68.0
Calcium carbonate	14.14
Magnesium carbonate	21.3

Treatment with the theoretical amount of aluminate gave unsatisfactory results.

With twice the theoretical amount, the lime remaining was 88.3 per cent., and the magnesia 84.5 per cent. The aluminate is especially serviceable in such waters as this in removing completely the turbidity.

Although the water of Lake Erie does not contain a large proportion of solid matter, it forms scale quite rapidly unless some means are taken to prevent it. Analysis of a sample collected April 28, 1898, gave:

Calcium carbonate	63.53
Calcium sulphate	32.61
Magnesium carbonate	21.53

Analysis, after treatment with theoretical aluminate, gave 97.6 per cent. lime, and 93.2 per cent. magnesia removed, after standing thirty-six hours. With one-half the theoretical amount standing forty-eight hours 98.3 per cent. of the lime was removed and ninety per cent. of the magnesia. With one-fourth the theoretical amount eighty-three per cent. of lime was removed and sixty per cent. of the magnesia.

From a very muddy brook water containing much suspended matter, with

Calcium sulphate	8.1
Calcium carbonate	120.0
Magnesium carbonate	23.0

after standing forty-eight hours, the theoretical amount of aluminate removed ninety-six per cent. of lime and ninety-six per cent. of magnesia. One-half the theoretical amount removed 94.6 per cent. lime and 94.4 per cent. magnesia.

In treating the water from a well in Ashtabula, O., containing

Calcium sulphate	96
Magnesium sulphate	39

the theoretical amount of aluminate removed 98.3 per cent. of the lime and ninety-six per cent. of the magnesia.

A well in Glenville, Ohio., containing

Calcium carbonate	99
Calcium sulphate	36
Magnesium carbonate	23

after treatment with theoretical aluminate showed that 98.1 per cent. of the lime had been removed and ninety-five per cent. of the magnesia.

To test still further the efficiency of the aluminate, experiments were made with sodium hydroxide alone, using various proportions, but the removal of lime was not much more than half the quantity taken out by aluminate, and the magnesia was not affected. An important effect of alumina is to remove suspended matter which it does rapidly and completely.

THE HEAT OF BROMINATION TEST FOR OILS.

BY AUGUSTUS H. GILL AND ISRAEL HATCH, JR.

Received October 5, 1898.

THIS test occupies a middle position between the Maumené and Hübl tests; it suffers from the disadvantages that the required apparatus is not always obtainable, and that the results obtained with different apparatus are not comparable The object of the investigation was to simplify the apparatus and to ascertain if some substance could not be found with which the rise of temperature could be compared, and thus a "specific temperature reaction" obtained similar to the Maumené test.

Apparatus and reagents required twenty five cc. graduated flask; five cc. pipette; burette; thermometer divided into 0.2° calorimeter; measuring apparatus; bromine; carbon tetrachloride.

The calorimeter consists of a flat-bottomed glass tube about three quarters of an inch in internal diameter, and four inches long. This is held by a cork in a beaker two inches in diameter, thus making an air-jacket, and the beaker placed in-