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# Conversion of Aluminum Phosphate to Sodium Phosphate

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**Abstract:** The phosphorus recovered from sewage sludge by acidic treatment is mainly composed of aluminum phosphate. To make a wide utilization of recovered phosphorus, removal of the aluminum component is considered a very important matter. In order to find a method to convert aluminum phosphate to sodium phosphate, a basic investigation was carried out. A reagent of aluminum phosphate was dissolved by aqueous solution of sodium hydroxide, and mixed with sodium silicate to make a alunino-silicate gel. Sodium phosphate was recovered from residue water in the gel.

**Key words:** Aluminum phosphate, sodium phosphate, gelation, sodium silicate.

## 1. Introduction

Sewage sludge contains significant amounts of phosphorus, and in order to recover the phosphorus, some studies have been carried out [1-6]. The phosphorus which is recovered by acidic treatment contains a lot of aluminum [7]. To make a wide utilization of recovered phosphorus, the removal of the aluminum component is considered a very important matter, and some methods were investigated [8].

The aluminum component in the recovered phosphorus is considered to exist mainly as a form of aluminum phosphate. Aluminum ion reacts with alkali metal silicate to form a silicate gel, which is widely known as zeolite synthesis. Aluminum phosphate is dissolved by the addition of aqueous solution of alkali metal hydroxide, and is also expected to react with alkali metal silicate to make an alkali metal silicate gel. Using this reaction, alkali metal phosphate is considered to be recovered as reaction (1) [9].

$$\begin{aligned} &M_2SiO_3 + mAlPO_4 + nMOH \\ &\rightarrow M_2O \cdot xAl_2O_3 \cdot ySiO_2 \cdot zH_2O + M_3PO_4 \end{aligned} \quad (1)$$

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where M is alkali metal, m, n, x, y and z are indefinite numbers.

In order to confirm this method, we investigated the reaction using a reagent of sodium hydroxide, aluminum phosphate and sodium silicate.

## 2. Method

### *2.1 Preparation*

In this experiment, sodium hydroxide: Kanto chemical Co., INC (assay minimum 97%), aluminum phosphate: Kanto chemical Co., INC (assay minimum 95 % as $AlPO_4$), sodium silicate: Kanto chemical Co., INC (assay minimum $SiO_2$: 37%, $Na_2O$: 18%) was used.

Aqueous solutions of these reagents were prepared as mentioned below:

Aq. aluminum phosphate solution: 50 g of aluminum phosphate was resolved by addition of 50 g of sodium hydroxide in 1,000 mL of water.

Aq. sodium silicate solution: 100 g of sodium silicate was in 100 mL of water (total volume 155 mL).

### *2.2 Experimental Procedure*

The experiment was carried out as shown in Fig. 1.

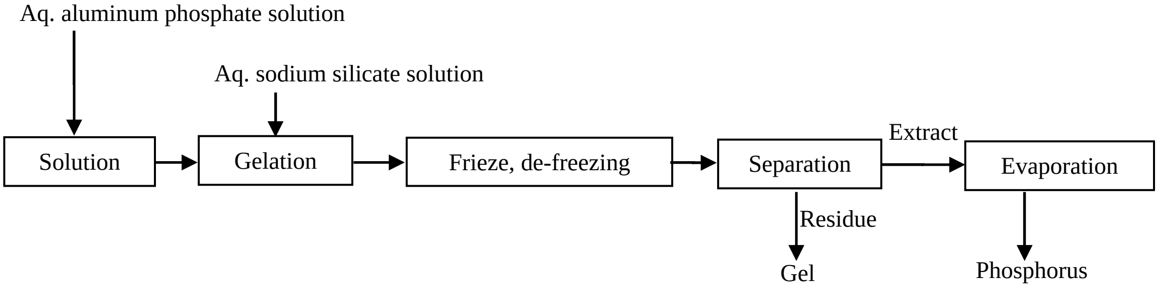


**Fig. 1 Experimental procedure.**

Aq. sodium silicate solution was added to the aq. solution of aluminum phosphate at room temperature and the mixture formed a transparent gel. In order to estimate the amount of the gel, dehydration is needed. To make rapid dehydration, a freezing and de-freezing method applied to the dehydration of sludge [10], was carried out. The formed gel was cooled in an ice box (under -10 ºC) for one day, later, the frozen gel was retained at a room temperature (about 25 ºC) to make de-freezing. The dehydration was brought about through de-freezing, and the dehydrated gel was separated by filtration, and the residue was dried at 105 ºC for analysis. The phosphorus component was recovered from the extract through evaporation.

*2.3 Addition Rate*

In order to find a proper addition rate, 5 mL to 20 mL of aq. sodium silicate solution was added to 100 mL of aq. aluminum phosphate solution at room temperature (about 25 ºC), and the mixture formed a gel in a few minutes. The formed gel was cooled in an ice box for 24 hours, and the frozen gel was retained in a room for de-freezing. Dehydration took place through de-freezing, and the dehydrated gel was separated using filter paper (ADVANTEC, No2, Toyo Roshi Co LTD), and residue (gel) was dried at 105 ºC for analysis.

*2.4 Recovery of Phosphorus*

A 200 mL of aq. aluminum phosphate solution was mixed with a 30 mL of aq. sodium silicate solution at room temperature, and a gel was formed in a condition of pH 11.5. The formed gel was cooled in an ice box, and dehydration was carried out as mentioned before. The dehydrated gel was dried and the phosphorus containing extract was evaporated for analysis, and gel (17 g) and phosphorus, (23 g) were recovered.

## 3. Result and Discussion

*3.1 Addition Rate*

The relation of the amount of the formed gel and the addition rate of the sodium silicate is shown in Fig. 2. The amount of the formed gel, increased by addition of sodium silicate, and when the addition rate reached 10g, amount of the gel tends to plateau. This addition rate is considered to correspond to a molecular ratio $Al_2O_3 : SiO_2 = 0.35 : 1$.

*3.2 Properties of Recovered Materials*

The recovered gel is a white powder, particle size: under 0.05 mm as shown in Fig. 3, bulk density: 0.2~0.3 g/cm$^3$. The chemical component of the recovered gel and phosphorus was analyzed by X-ray

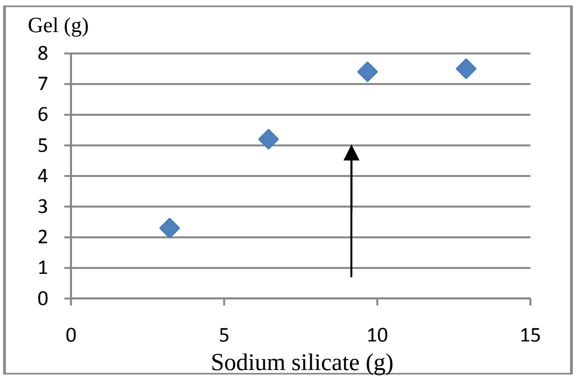


**Fig. 2 Relation of sodium silicate and formed gel.**

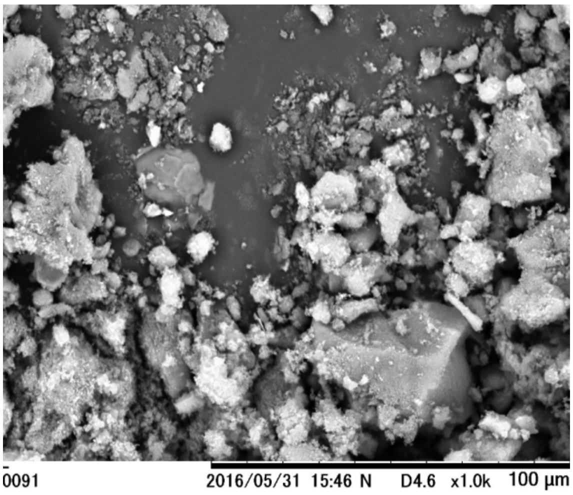


**Fig. 3 Photo of the gel.**

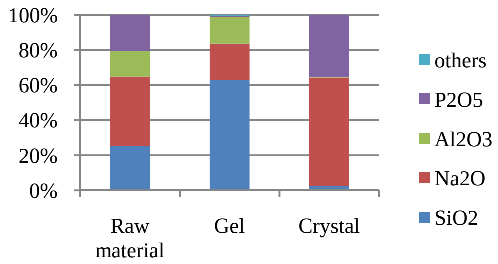


**Fig. 4 Chemical composition of recovered materials.**

analyzer, (XRF, Rigaku Corporation SPECTRO XEPOS) and the result is shown in Fig. 4. The chemical composition of the raw material was calculated by mass balance of the reagent used in this experiment. The recovered gel was composed of $Na_2O$、$SiO_2$、$Al_2O_3$, and it was considered to be a compound of alumino- silicate. The elemental ratio of the gel was calculated from the analyzed data and the approximate molecular ratio was considered as (2).

$$Na_2O{\cdot}xAl_2O_3{\cdot}ySiO_2; \quad x/y = 1/3 \qquad (2)$$

The ratio of x : y corresponds to the chemical composition of a zeolite [11]. However, XRD of the gel shows the pattern of an amorphous compound (Fig. 5), and further investigation is needed to identify some properties and physical structure.

The amount of $P_2O_5$ component in the gel is small, and almost of all the phosphorus was separated from the gel as an extract. The recovered phosphorus was composed of $P_2O_5$ and $Na_2O$, and is considered to be a form of $Na_2HPO_4{\cdot}7H_2O$ by the XRD analysis (Fig. 6) and recovered condition (pH11-pH12) [12].

A small amount of $SiO_2$ component was found in the recovered phosphorus, which is considered non-reacted sodium silicate which remained in the recovered phosphorus.

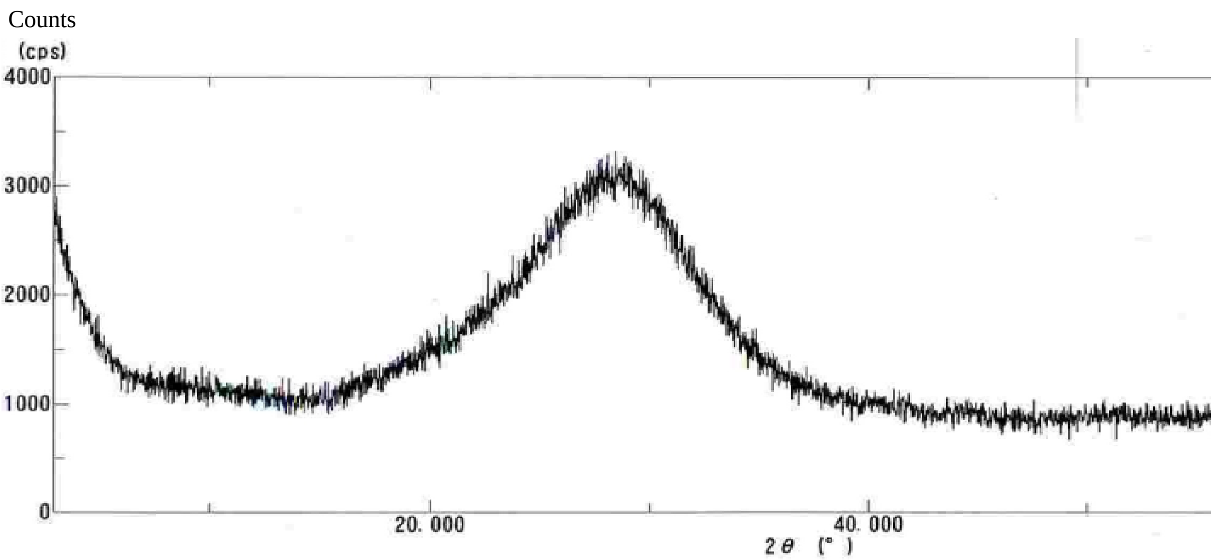


**Fig. 5 XRD spectrum of the gel.**

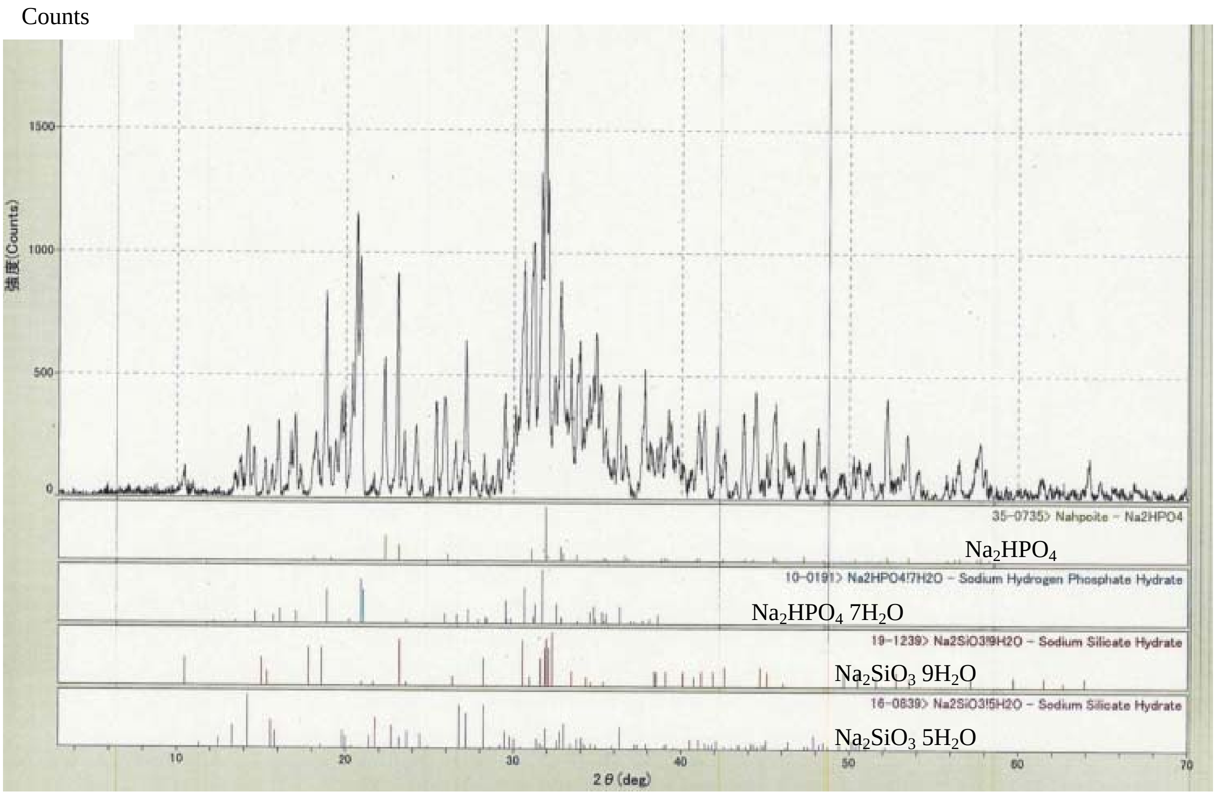


**Fig. 6 XRD spectrum of the recovered crystal.**

## 4. Conclusions

In order to find a wide utilization of aluminum phosphate which is recovered from sewage sludge, a conversion method of aluminum phosphate to sodium phosphate was investigated using a reagent of aluminum phosphate. Aluminum phosphate which was dissolved by sodium hydroxide reacted with sodium silicate, and formed a silicate gel. Aluminum phosphate was converted to sodium phosphate through the formation of alumino-silicate gel. The result indicates a possibility to make a recovery method of sodium phosphate from sewage sludge. However, further study is needed to investigate the conversion of sodium phosphate from aluminum phosphate which is recovered from sewage sludge.

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