Coordination Compounds of Aluminium with Lactic Acid

By A. B. SEN and SUBODH N. KAPOOR

With 2 Figures

Summary

Conductometric and electrometric studies of the mixed solutions of aluminium sulphate and sodium lactate reveal the existence of two compound at (1 : 2) and (1 : 3) molecular ratios. (1 : 3) compound was isolated in a pure state. The composition was established by estimating aluminium and lactic acid present in the compound.

No work seems to have been carried out on complexes of aluminium with lactic acid, although a number of compounds of aluminium with other hydroxy acids have been isolated and characterized such as mandelate[1]), citrate[2])[3]), malate[4]), salicylate[5])[6]). 2-hydroxy naphthoic acid also forms a complex salt with aluminium[7]). Tartrates[8])[9])[10]) of aluminium are known for a very long time and their optical properties have been studied in detail. J. L. DELSAL[11]) studied the aluminium complexes of tartaric and malic acids with the help of Polarimetric and Electrometric methods.

Physicochemical properties such as conductivity and pH have been used by us to study the complexes of aluminium with lactic acid, which show the evidence of the formation of two complexes at the molar ratios of (1 : 2) and (1 : 3).

[1]) SRIVASTAVA and MANOHAR, J. I. C. Soc. No. 5, 299 (1960).

[2]) G. SPACU and E. POPPER, Kolloid-Z. 103, 19 (1943).

[3]) N. BOBTILSKY and J. M. E. GOLDSCHMIDT, Bull. Research Council, Israel, 7 A, 12 (1958).

[4]) J. L. DELSAL, Compt. rend. 202, 1589 (1936).

[5]) GIUSEPPE ILLARI, Ann. Chim. (Rome) 42, 32 (1952).

[6]) L. K. BURROWS and I. W. WARK, J. Chem. Soc. London 222 (1928).

[7]) B. A. CRACIUN and O. SOANITESCU, ,,Al I₂ Cuza‟, Iasi, sect. I. (N. S.) 227 (1956).

[8]) G. SPACU and E. POPPER, Kolloid Z. 103, 19 (1943).

[9]) I. CADARIU and L. ONICIU, 5, No. 3, 95 (1954).

[10]) S. P. GOVEL and B. L. VAISHYA, J. I. C. Soc. 12, 193 (1935).

[11]) J. L. DEISAL, J. Chim. Phys. 35, 350 (1936).

Experimental

Materials

Aluminium sulphate [$Al_2(SO_4)_3 \cdot XH_2O$ where x is approximately 18] (AR/BDH) and Lactic acid (A. R.) were used for the preparation of solutions. Sodium lactate solution was prepared by neutralizing lactic acid with caustic soda and then making upto the desired concentration.

An approximate 0.1 M solution of aluminium sulphate (A. R./B. D. H.) was prepared and the aluminium content was estimated gravimetrically by the "Oxinate method"[12]. This stock solution was used for the preparation of the solutions of desired concentration. For all the studies monovariant method of Nayar and Panded was adopted.

Conductometric Titrations

0.04 M aluminium sulphate and 0.04 M sodium lactate solutions were prepared from the original stock solutions described above. Three sets of mixtures of aluminium sulphate and sodium lactate in the stoichiometric rations of (1 : 1), (1 : 2) and (1 : 3) were prepared. The titrations were performed on an electrical magic eye apparatus (Type GM/4249/Philips).

To a constant volume of the mixtures of aluminium sulphate and sodium lactate in the ratios of (1 : 1), (1 : 2) and (1 : 3) varying quantities of 0.4 M NaOH of known strength were added from a micropipette. The sulution was stirred and kept for sufficient time in the thermostat to attain equilibrium. All measurements were made at 35°C $\pm$ 0,1. The observations are plotted in the Fig. 1.

pH-Titrations

pH-measurements were carried out by using a Leeds and Northraph pH-meter (No. 7663-AI Assembly). The instrument was standardized with a 0.05 M solution of potassium hydrogen phthalate (pH 4.005 at 25°).

0.05 M aluminium sulphate and 0.05 M sodium lactate solutions were prepared from the original stock solutions and three sets of mixtures containing the two salt solution in stoichiometric ratios of (1 : 1), (1 : 2) and (1 : 3) were prepared.

For performing pH- titrations 30 ml of the mixed solution was taken and titration was performed by adding 0.5 M NaOH solution from a micropipette time to time and recording the pH on the scale of the instrument. For comparison (1 : 0) solution of aluminium sulphate and sodium lactate was also titrated with the alkali under the same conditions. The observations are plotted in Fig. 2.

Isolation of Compound: $AlH_3(C_3H_4O_3)_2 \cdot 5H_2O$

Aluminium was precipitated as $Al(OH)_3$ from aluminium sulphate solution by adding dilute ammonia and the precipitate was washed well till free from sulphate ions. The precipitate of $Al(OH)_3$ was suspended in water and small quantity of lactic acid was added to it. This was kept on water bath and lactic acid was added from time to time until all precipitate nearly dissolved. The solution thus obtained after filtration was concentrated and finally cooled when well defined white crystals of a compound separated. The compound was filtered, washed and recrystallized from water when shining white crystals were obtained.

The compound was analysed to derive its probable formula.

---

[12]) A. I. Vogel, "A Text Book of Quantitative Inorganic Analysis", page 372, edition 1951.

Analysis

The aluminium content of the compound was estimated gravimetrically by "Oxinate method"[12]). The lactic acid content of the compound was determined by the method of EARNEST and HORVATH[13]).

% Aluminium found = 7.010

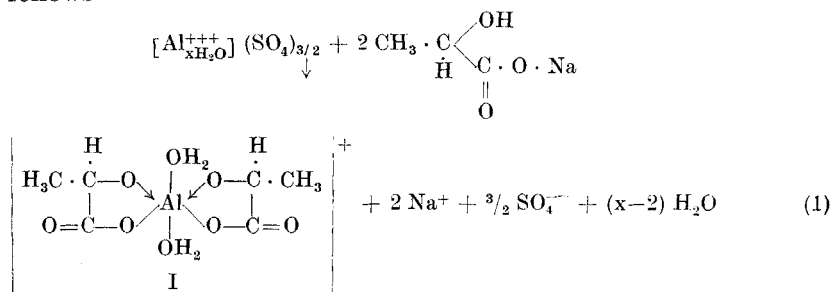% Lactic acid found = 70.25

Calculated from the formulae:
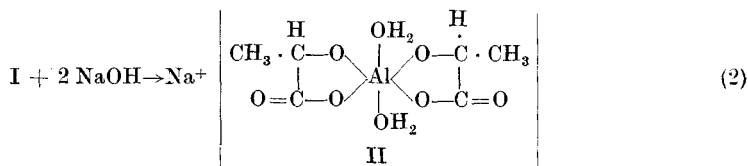
% of Aluminium = 7.023

% of Lactic acid = 70.30.

Discussion

Figure 1 represents the changes taking place in conductance of the solutions when equivalent alkali is added.

The addition of a solution of equivalent alkali to a (1 : 2) mixture of aluminium sulphate and sodium lactate lowers the conductance of the latter. The continuous addition of alkali results in a progressive decrease in conductance which reaches a minimum when two equivalents of alkali have been added. With further addition of alkali the conductance incresaes (Curve B). The decrease in conductance is due to the removal of H^+ ions and as soon as all the H^+ ions have been removed the conductance increases due to the excess of NaOH. The reaction during the titration may be assumed to take place as follows

$$[Al^{+++}_{xH_2O}] (SO_4)_{3/2} + 2\ CH_3 \cdot C\underset{\dot{H}}{\overset{OH}{\diagdown}}\!\!\diagup C \cdot O \cdot Na$$
$$\overset{\parallel}{O}$$

$$
\begin{array}{c}
\left[\begin{array}{c}
\overset{H}{\overset{\cdot}{H_3C \cdot C}}\!\!-\!\!O\diagdown\ \overset{OH_2}{\underset{|}{|}}\diagup O\!\!-\!\!\overset{H}{\overset{\cdot}{C}} \cdot CH_3 \\
\underset{|}{O}\!\!=\!\!\underset{|}{C}\!\!-\!\!O\diagup\ \overset{}{\underset{OH_2}{Al}}\diagdown O\!\!-\!\!C\!\!=\!\!O
\end{array} \right]^{+} + 2\ Na^+ + {}^{3}/_{2}\ SO_4^{--} + (x-2)\ H_2O
\end{array}
\tag{1}
$$

I

I then reacts NaOH forming compound II as below:

$$
I + 2\ NaOH \rightarrow Na^+
\begin{array}{|c|}
\overset{H}{\overset{\cdot}{CH_3 \cdot C}}\!\!-\!\!O\diagdown\ \overset{OH_2}{\underset{|}{|}}\diagup O\!\!-\!\!\overset{H}{\overset{\cdot}{C}} \cdot CH_3 \\
\underset{|}{O}\!\!=\!\!\underset{|}{C}\!\!-\!\!O\diagup\ \overset{}{\underset{OH_2}{Al}}\diagdown O\!\!-\!\!C\!\!=\!\!O
\end{array}
\tag{2}
$$

II

---

[13]) EARNST and HORVATH, Biochem. Z. 224, 133 (1930).

In the same way examination of curve C shows a minimum value of conductance where there equivalents of alkali have been added which indicates the formation of (1 : 3) compound in solution. The increase in conductance after the break is due to the excess of NaOH in solution. The reaction taking place during the titration may be assumed to be as follows:

$$[Al^{+++}_{xH_2O}](SO_4)_{3/2} + 3\ CH_3 \cdot C{\overset{\displaystyle OH}{\underset{\displaystyle COONa}{\Big\langle}}}_{H}$$

$$+\ 3\ Na^+ + \sqrt[3]{_2}\ SO_4^- + x\ H_2O \qquad (3)$$

III

This compound III further reacts with NaOH giving product IV as shown below:

$$III + 3\ NaOH + x\ H_2O \rightarrow Na_3 \qquad \qquad + (x + 3)\ H_2O \qquad (4)$$

IV

This compound III has been isolated in solid state. The compound is soluble in water and gives an acidic solution. When a solution containing known quantity in water is titrated against alkalies electrometrically break occurs when three moles of alkali have been consumed.

Figure 2 represents the pH-titration values of mixtures. The pH of (1 : 2) mixture of aluminium sulphate and sodium lactate increases with the addition of equivalent alkali in curve B. This rise in pH is probably due to the formation of (1 : 2) chelate in solution. When nearly two equivalents of alkali have been added, pH rises more rapidly showing an inflection in curve. The addition of alkali results in the liberation of H+ ions and take part in neutralization reaction the pH rises and ultimately a break in the curve occurs.

An examination of curve C in fugure 2 which is for (1 : 3) mixture, shows an inflection at three equivalents of alkali indicating the formation of (1 : 3) compound.

Examination of curve A in figure 1 and 2 shows that addition of equivalent akali did not produce any abnormal change which would show the formation of (1 : 1) chelate in solution.
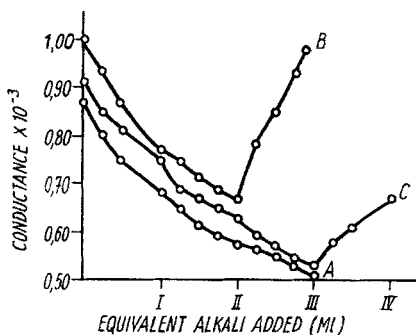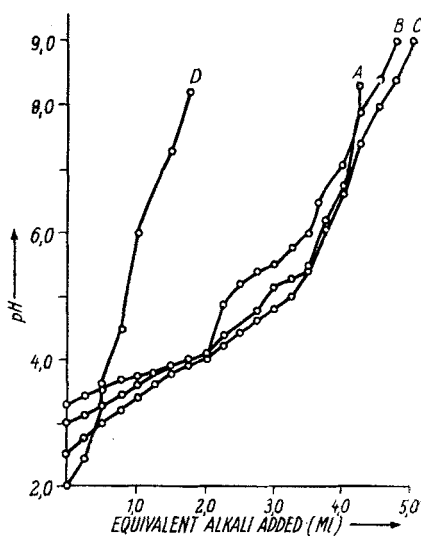

Fig. 1. Conductometric Titrations

Fig. 2. pH-Titrations

Lucknow (India), Chemical Department, University of Lucknow