Influence of the content of caluminate on their physicochemical properties

I T Zhadovskiï¹, I V Berlinskiï¹, V V Vasiliev¹, A V Stogov¹

¹ Saint-Petersburg Mining University, 2, 21st line, St. Petersburg, 19916, Russia

E-mail: sergaur@mail.ru

Abstract. The research of the properties of the complex aluminate solutions obtained through Bayer process or sintering process, will enable to determine the optimal parameters for the process, to increase the efficiency of the production and will be instrumental in high quality alumina production. The key stages of the alumina production through Bayer process which define its efficiency are digestion and decomposition processes. The main properties of the obtained products and amount of losses of the commercial components are established on these stages.

1. Introduction

Physicochemical methods of analysis are widely adopted for analysis of hydrometallurgical solutions, which contain different speciations of light, rare and heavy non-ferrous metals. However, in case of aluminate solutions, classic methods of analysis are very limited in its application or cannot be used. These restrictions occur due to the complexity of the system and its unique behaviour under different conditions. To develop modern methods of analysis and quality control it is necessary to continue to research the nature, properties and composition of alkaline solutions of these metals.

It is critical to review physicochemical properties of aqueous sodium aluminate solutions such as surface tension, density, metastable zone of aluminate solutions. It is well-known that properties of any aqueous system are determined by its surface tension and viscosity, these properties are commonly used in different fields such as thermal physics, molecular physics, biophysics, etc. The values of the surface tension and viscosity coefficients are decreasing with the increase of the temperature, i.e. the change in temperature is followed by the same change in these parameters, therefore, it is necessary to determine the relationship between these properties.

The behaviour of the viscosity of the sodium aluminate solution in defined temperature zone and set Na₂O concentrations in the Na₂O – Al₂O₃ – H₂O system was considered by N. M. Baron and R. P. Matveev [1-3]. These researches were performed in the clear solutions with no additional impact of the impurities.

Experience of alumina production proved that real composition of an aluminate solution differed significantly from perfect Na₂O – Al₂O₃ – H₂O system. Industrial aluminate solutions contain different organic and mineral impurities. The main source of these impurities is the raw material – bauxite.

Theoretical analysis is presented in the paper written by I. I. Makarov and E. I. Hrinin. As a result of this analysis, the relationship between surface tension coefficient of the solution and its viscosity is established [4-5]. The authors used solutions, which contain ethanol, to validate their research,
therefore, it is critical to validate these calculations for the aluminate solutions. In the works [6-7], the properties and methods of using products obtained from Bayer solutions in Na₂O - Al₂O₃ - H₂O systems as sorption materials for composition correction were investigated. In the works [8–12], the author considers the possibility of identifying compounds in technological processes. Bayer also takes into account the properties of systemic formation and various substances: phenolates, polyalcohols and additional carboxylates.

2. Materials and methods
Thermostat was used to maintain the constant value of the temperature. Surface tension was measured using semi-automatic du Nouy tensiometer (ring) Lauda TD1C. Density was measured using pycnometer in the volume of 50 ml. Dynamic viscosity was measured using viscometer VPZH-4, automatic viscometer Herzog HVM 472 and action camera Sony HDR as-20 capable of slow motion shot to accurately determine the time, moreover, professional non-linear editing program Adobe Premiere Pro was used.

Standard strong test solution of caustic was used in this research. Strong caustic solutions of the invariant point were prepared on the first stage of the experiment. The content of NaOH expressed as Na₂O₆ was around 300 g/l and α = 1,45 – 1,60. This solution is very close to the equilibrium composition solutions, stable and can be stored for a long period of time. The initial solutions were diluted with the calculated amount of water to prepare diluted solutions with the required composition; where applicable, alumina to caustic ratio can be changed by changing the amount of caustic. Sodium hydroxide (NaOH) AR and industrial aluminum hydroxide for alumina G-00 production were used as the original reagents.

The required volume of the initial strong solution, which contains equivalent amounts of Na₂O₆ and Al₂O₃, was calculated to prepare the diluted solutions. The measured volume of the solution was diluted using distilled water with constant stirring and adjusted to the required value. The sample of the prepared solution is collected to analyze the content of Na₂O₆ and Al₂O₃ in the diluted solution. This analysis was carried out in compliance with industry standard procedure for the analysis of aluminate solutions.

3. Experiment
The research was carried out using test solutions of sodium aluminate. Four main impurities of the alumina system were taken into consideration: sodium chloride, carbonate, sulphate and oxalate. The main physical properties of the aluminate solutions were reviewed in this research: dynamic viscosity, density and surface tension. The experiments to determine the impact of the impurities were carried out under the following conditions: the temperature was set on 60 °C and 80 °C, the impurities were added to the aluminate solutions (with the content of Al₂O₃ of 120 g/l and αₖ = 1,6) in the amount corresponding to its content in industrial aluminate solutions. The analysis of the solutions was done using thermostatic temperature control. Results of the experiments are on Fig. 1-12.

4. Conclusion
1. The dependencies of main physicochemical parameters, such as viscosity, density, surface tension and ionic strength, on the content of the solution were determined. Some of these dependencies are non-linear functions; therefore, these parameters have a complex impact on the main parameters of the alumina production. Carbonate, sulphate and oxalate ions increase viscosity and density of the solution, which influence the stability of the aluminate solution.
2. The duration of the induction period of the Na₂O – Al₂O₃ – SiO₂ – H₂O system in the preferential thermodynamic state depends on the relationship between the surface tension coefficient and the crystal-forming coefficient of the medium.
Figure 1. Dependence of the surface tension on the concentration of sodium chloride, carbonate and sulphate in the aluminate solution under 60 °C.

Figure 2. Dependence of the density on the concentration of sodium chloride, carbonate and sulphate in the aluminate solution under 60 °C.

Figure 3. Dependence of the dynamic viscosity on the concentration of sodium chloride, carbonate and sulphate in the aluminate solution under 60 °C.

Figure 4. Dependence of the surface tension on the concentration of sodium chloride, carbonate and sulphate in the aluminate solution under 80 °C.

Figure 5. Dependence of the density on the concentration of sodium chloride, carbonate and sulphate in the aluminate solution under 80 °C.

Figure 6. Dependence of the dynamic viscosity on the concentration of sodium chloride, carbonate and sulphate in the aluminate solution under 80 °C.
Figure 7. Dependence of the surface tension on the concentration of sodium oxalate in the aluminate solution under 60 °C.

Figure 8. Dependence of the density on the concentration of sodium oxalate in the aluminate solution under 60 °C.

Figure 9. Dependence of the dynamic viscosity on the concentration of sodium oxalate in the aluminate solution under 60 °C.

Figure 10. Dependence of the surface tension on the concentration of sodium oxalate in the aluminate solution under 80 °C.

Figure 11. Dependence of the density on the concentration of sodium oxalate in the aluminate solution under 80 °C.

Figure 12. Dependence of the dynamic viscosity on the concentration of sodium oxalate in the aluminate solution under 80 °C.

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