

THE BEHAVIOUR OF SCANDIUM IN THE BAYER PROCESS

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Introduction

Scandium (Sc) is enriched in some bauxites of karst type^{1,2} compared to its crustal average concentration (13.6 mg/kg)³. The Bayer process uses bauxite as raw material for alumina production and discards bauxite residue (BR) as a by-product, in which insoluble compounds are roughly doubled compared to their original concentrations. Sc is also enriched into BR and can be extracted from it⁴. Sc has been estimated to comprise over 95% of the commercial value of BR⁵.

Our aim is to clarify the fate of Sc during the entire flowsheet of Bayer process, to understand its distribution behaviour between products and by-products and mineralogical nature before and after the process. The present work will build upon and develop the understanding of Sc distribution previously explained by Derevyankin et al⁶.

Materials and methods

The present study was performed on the example of Aluminium of Greece. Feed bauxites, BR and calcined alumina as well as other minor by-products were analysed for Sc concentrations and combined with mass flow data. Bulk and in-situ analysis using inductively coupled plasma mass spectrometry (ICP-MS), former coupled with laser ablation unit (LA-ICP-MS), X-ray diffraction (XRD) and scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDS) were performed.

Modes of Sc occurrences in bauxite and BR

In Greek bauxites of Parnassos-Ghiona unit horizon B3, Sc was found in the composition of zircons with concentrations up to 1 wt%. Zircon grains exhibit a zonation with higher Sc concentrations that correlate positively to the distribution of calcium and they also contain hafnium and uranium. Similar zircons have been identified in the bauxites of Southern Apennines, Italy⁷. Sc-bearing zircons were also documented to be present in BR.

Iron-rich clusters (>90% FeO) of Parnassos-Ghiona bauxite were shown to be enriched in Sc based on in-situ LA-ICP-MS measurements. Iron appears in trivalent form either as goethite (3 – 4.5%) or haematite (17%) in the studied Greek bauxite samples. Sc concentrations of 146 – 215 mg/kg were identified in iron-rich areas compared to bauxite matrix areas containing 46 – 64 mg/kg Sc. Aluminium oxide rich areas were depleted in Sc (10 – 23 mg/kg). This observation represents the close relation of Sc with iron oxide phases. Sc could either substitute Fe³⁺ in iron oxide phases or be absorbed on the surface of these mineral phases⁸. As iron oxides are insoluble in the Bayer process, a similar form of Sc occurrence is expected in BR.

Previous authors have proposed that in bauxites, Sc should occur in titanium oxide phases^{2,6}. The present study proposes that Sc could be found in perovskite, based on analysis performed on BR and the scale built up on the autoclaves in the Bayer process.

Sc is dispersed between several mineral phases. Mass balance calculations indicate that 43 – 66% of Sc presence in BR can be attributed to appearing in iron oxide phases. The remaining part of Sc is probably found in titanium phases and a minor fraction in zircons.

Sc mass distribution in the Bayer process

In Aluminium of Greece, primary feed bauxite as well as principal source of Sc is Parnassos-Ghiona karst bauxite. Its typical concentration is 70 – 75 mg/kg Sc, while the mean concentration of all feed bauxites is 65 mg/kg Sc (Figure 1). This decrease is due to dilution effect of lateritic bauxite addition to the plant feed with low Sc grade (22 mg/kg). The major proportion of Sc — 80% — is separated from the process in the composition of BR giving rise to a concentration of 131 mg/kg Sc. During precipitation of aluminium hydroxide from pregnant liquor, 16% of Sc is co-precipitated and enters to the composition of precipitate. Therefore, Sc is soluble in the caustic process liquor in minor extent. Mass balance calculations indicate that pregnant liquor should contain at least 1.9 mg/kg Sc to allow Sc to be precipitated with the aluminium hydroxide. The described distribution results in the enrichment of Sc 1.9 times into residues compared to feed bauxite.

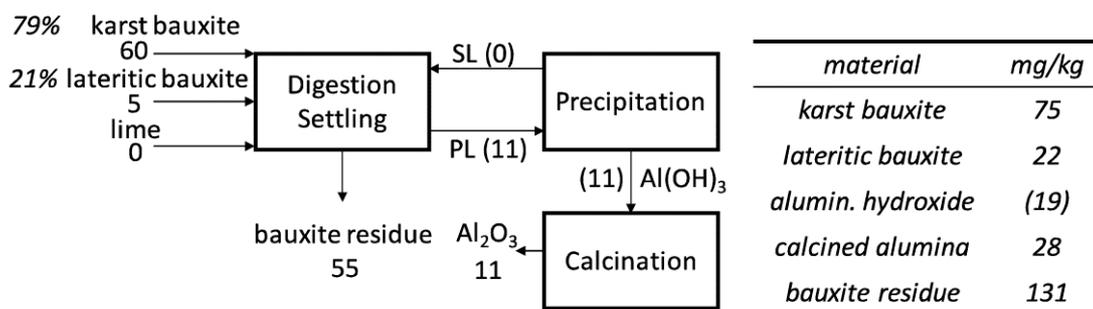


Figure 1: Distribution of Sc on the simplified flowsheet of Bayer process. Concentrations are normalised to the mass of feed bauxite, expressed in mg/kg of feed bauxite. Percentages in italics represent the proportions of lateritic and karst bauxite feed. Figures given in brackets are based on calculations. PL — pregnant liquor; SL — spent liquor.

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POTENTIAL OF SCANDIUM SUPPLY FROM ORES AND INDUSTRIAL PRODUCTS IN THE NEAR FUTURE

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Introduction

Due to lack of affinity to common ore forming anions, scandium was usually obtained during processing of various ores, tailings and residues from previously exploited mines as a by-product. Historically, scandium was first discovered and named in 1879 while extracting ytterbium from the minerals of euxenite and gadolinite originally found in Scandinavia. Then, the applications of scandium were not developed until the 1950s [1]. Scientists in the Soviet Union were the first to recognize the metal's remarkable properties when alloyed with aluminium. It was found that addition of 0.2-0.8% scandium could enhance the mechanical properties of aluminium drastically. Later, scandium's first applications were developed in the Soviet military aircraft and weaponry industry. From 1960 through 1990, the Soviet Union produced the vast majority of the world's scandium concentrates and other scandium compounds, mainly as a by-product from the processing of iron-uranium ores located in Russia, Kazakhstan, Uzbekistan and Ukraine. During this period, small amounts of scandium from fluorite, uranium, tungsten and titanium ore processing were also produced as a by-product in the USA, in Japan and Australia. Chinese scandium supply was mainly provided from mine tailings and existing production streams of niobium, iron, tin, tungsten and REEs. Thus, up to now, iron-uranium, titanium, niobium, tin, tungsten and REE resources have become the main source of scandium as a secondary product [2].

Despite the fact that the first scandium demand started with the requirements for military applications, it was also used in the production of high performance sporting goods such as bicycle frames, ski poles, baseball bats and golf clubs where the performance is much more important than the costs. And now, there is also a huge and urgent demand of scandium for the civil aviation industry. According to the estimates, aircrafts made from welded aluminium scandium alloys would be 15% lighter and 15% cheaper to build compared to present materials. This explains why pioneers like Airbus and Boeing conduct and announce very critical reports regarding the acceptance of scandium use in aircraft body [3].

Due to the strict limitations in emissions and fuel efficiency, the automotive industry is another critical area urgently demanding scandium at an acceptable price. In addition to the demand for the aerospace and the automotive industry, there is an enormous potential for the use of scandium in the marine industry. Moreover, it was reported that the use of Al-Sc alloys in the construction of transmission lines for electricity, will provide several benefits in terms of cost and efficiency. Additionally, because of enhancement in weldability of aluminium alloys after alloying with scandium, it seems that the use of Al-Sc alloys with the latest state-of-the-art additive layer manufacturing technology could bring a breakthrough in the production