

The Leachability of Calcium Aluminate Phases in Slags for the Extraction of Alumina

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Abstract



Alumina is used primarily as feedstock for aluminum production. It occurs naturally in bauxite and clay and other minerals, and can be concentrated in industrial by-products such as coal gangue, fly ash, blast furnace slag, etc. The hydrometallurgical treatment of bauxite to recover alumina has been widely adopted industrially since the Bayer process was first employed commercially. However, the sustainability of alumina production by this means is less than ideal, due to the high production rate of poorly utilized and highly alkaline by-product that the process yields; bauxite residue or red mud. On the other hand, digestion of alumina-containing slags produced by reduction of bauxite results in no red mud production. In this work, the leachability of binary phases of CaO and Al₂O₃ in slags is studied under given conditions of temperature and time. Advanced characterization techniques are used to study the chemical composition, phases and microstructure of the slags and the digestion products. It is apparent that the leachability of a phase affects that of other phases. A less leachable phase could hinder the leachability of a more leachable phase. The experimental data shows that the leaching rate of slag from highest to the lowest is CaO.Al₂O₃, 3CaO.Al₂O₃, and CaO.2Al₂O₃, respectively.

Keywords: Alumina, calcium oxide, slag, smelting reduction, leachability.

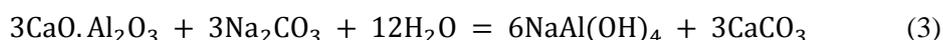
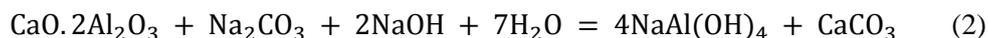
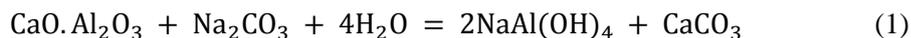
1. Introduction

Alumina (Al₂O₃) is found in different sources in nature, i.e. bauxite, nepheline, clay, and industrial by products such as coal gangue, fly ash, blast furnace slag, etc. However, metallurgical alumina produced from bauxite still dominates the world's alumina production due to the technical and economic feasibility of the Bayer process. A high-grade bauxite, with a mass ratio of Al₂O₃ to SiO₂ greater than 6.25 [1, 2], and/or high Al₂O₃ to Fe₂O₃ ratio [3], can be directly treated without much disruption along the sequential treatment steps of the Bayer process. However, regions that are far from the equatorial zone, who have more karst bauxite than lateritic deposits, generally need more rigorous (and costly) leaching conditions, or use a pyro-hydrometallurgical process to treat the bauxite. This is because in general, the mineralogical composition of laterite is Al(OH)₃ (gibbsite) and AlO(OH) (boehmite), while karst bauxite is AlO(OH) (boehmite) and AlO(OH) (diaspore), the latter being significantly more difficult to process [1].

An alternative method to beneficiate bauxite ore with high iron content is by smelting reduction as our recent studies in *research domain 5-Materials and Society* in SFI-metal production shows its feasibility in avoiding red mud production [4, 5]. It produces pig iron as a by-product, and a calcium aluminate slag as the source of alumina. This approach is the traditional Pedersen process [6]. Although there is no commercial production of alumina by this process, there has been research on hydrometallurgical treatment of calcium-aluminate slags. Lundquist and Leitch [7], Tong and Li [8], and Wang et al. [9] investigated the leachability of three calcium

aluminates ($12\text{CaO} \cdot 7\text{Al}_2\text{O}_3$, $3\text{CaO} \cdot \text{Al}_2\text{O}_3$, $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$). These were produced from the lime-soda sinter process in a different solvent, calcium aluminate produced by smelting reduction of red mud with the addition of TiO_2 , and MgO-containing calcium aluminate phases ($12\text{CaO} \cdot 7\text{Al}_2\text{O}_3$ and $\gamma - 2\text{CaO} \cdot \text{SiO}_2$), and from blast furnace slag with the addition of Na_2O , respectively. Other researchers showed the synergistic effect of $12\text{CaO} \cdot 7\text{Al}_2\text{O}_3$ and $\text{CaO} \cdot \text{Al}_2\text{O}_3$ on alumina leachability [10].

However, the leaching behavior of each calcium aluminate phase in the binary system is not yet clear. The leaching reaction of three calcium aluminate phases in alumina production are described below in Equations (1 – 3).



To gain proper understanding about these slags' digestion, the leachability of CaO- and Al_2O_3 -containing phases in the calcium aluminate slags produced from high purity oxides at elevated temperature is studied in this present work.

2. Experimental Procedure

The experimental procedure consisted mainly of materials preparation and characterization, leaching set up and results analysis. A procedural flow chart is presented in Figure 1.

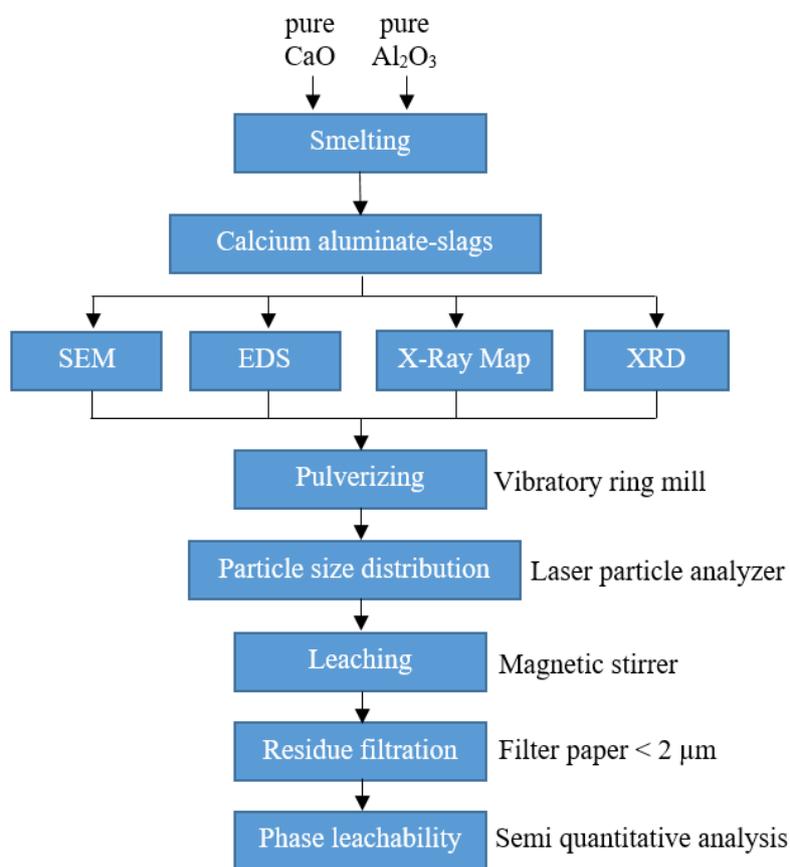


Figure 1. Flow chart of the experimental procedure.

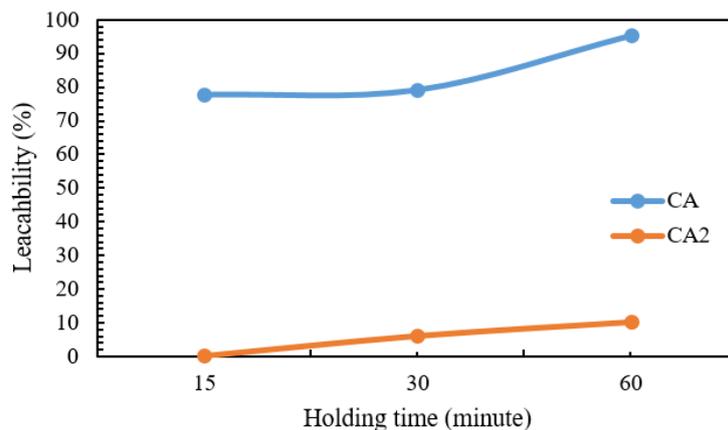


Figure 12. Extent of Leaching of CA and CA₂ phases in Slag I at 45 °C at different holding times.

4. Conclusions

Synthetic high purity calcium aluminate slags were prepared, pulverized, and subsequently leached by solutions containing Na₂CO₃ and NaOH at different temperatures and durations. The main results regarding the leachability of the slags can be summarized as:

1. Increased temperature significantly enhances the leachability. Moreover, the effect of temperature is dependent on the type and amount of phases in the slags.
2. The rate of leaching is fast and significant digestion occurs within relatively short reaction times. However, the extent of leaching in a given duration is dependent on the slag type.
3. In binary calcium aluminate slags, the leachability of one phase affects the leaching behavior of the other ones. The leachability of the CaO.Al₂O₃ phase in Slag I is hindered by the presence of the less leachable CaO.2Al₂O₃ phase.
4. The leachability of studied calcium aluminate phases in binary slags from highest to the lowest is CaO.Al₂O₃, 3CaO.Al₂O₃ and CaO.2Al₂O₃.

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