

Characterization of aluminum hydroxide (Al(OH)₃) for use as a porogenic agent in castable ceramics

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Abstract

Porous structures based on aluminum oxide-hydroxide (Al₂O₃-Al(OH)₃) show high refractoriness. Regarding their use as thermal insulators, the preparation of aqueous castable suspensions requires suitable conditions to produce stable co-dispersions and a deeper knowledge on their porogenic-sintering behaviors. This study reports on the characterization of a commercial grade of Al(OH)₃ and several transition phases of Al₂O₃ (attained through the calcination of Al(OH)₃) aiming at their use as porogenic agents for castable porous ceramics. X-ray diffraction, thermogravimetry, Helium pycnometer method, specific surface area and electron microscopy were used. The dispersion and rheology of Al(OH)₃ and Al₂O₃ were investigated with pH variations and dispersants. Aluminum oxide and hydroxide particles showed high compatibility in aqueous medium and favored the preparation of suspensions. As porogenic agents, the transition phases showed a large quantity of meso-macro pores and a huge variation in the specific surface area, which highlight their potential to produce high refractoriness porous structures.

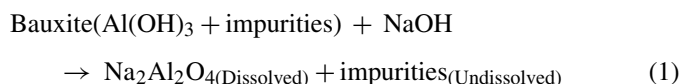
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Keywords: Aluminum hydroxide; Aluminum oxide; Transition phases; Dispersion; Rheology

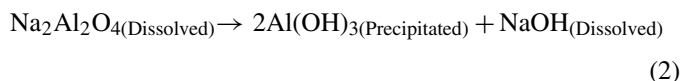
1. Introduction

Aluminum hydroxide (Al(OH)₃) has been used as anti-flame additive for polymers, abrasive medium for soft polishing operations (in toothpaste, for instance), as a precursor for catalysts and in filters for water treatment.^{1–4} Nevertheless, it has been mostly applied in the production of metallic aluminum through the electrolysis of aluminum oxide (Al₂O₃), attained after its calcination.² The most common route to produce Al(OH)₃ is known as Bayer process and bauxite (composed mainly of Al(OH)₃) and impurities such as SiO₂, Fe₂O₃ and TiO₂ is its main raw material.^{1,4} Initially, bauxite is dissolved in a hot (70–90 °C) NaOH solution for the formation of sodium

aluminate, according to the general expression:



After filtration steps for the removal of undissolved impurities, the clarified sodium aluminate solution is cooled down to precipitate Al(OH)₃:



After another filtering and washing steps, the NaOH solution can be recycled and the Al(OH)₃ pulp is spray-dried. Further heating in rotary kilns (1200–1600 °C) produces calcined alumina (α-Al₂O₃).

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Table 1
Characteristics of the as-received raw materials.

Characteristics	Calcined alumina (α -Al ₂ O ₃) ^a	Aluminum hydroxide (Al(OH) ₃) ^b
Composition (wt%)	Al ₂ O ₃ : 99.8; Na ₂ O: 0.08; Fe ₂ O ₃ : 0.02; SiO ₂ : 0.03; CaO: 0.02; MgO: 0.07	Al(OH) ₃ : 99.7; Na ₂ O: 0.2; Fe ₂ O ₃ : 0.07; SiO ₂ : 0.03
Solid density (g cm ⁻³)	3.99 ± 0.07	2.42 ± 0.03
Specific surface area (m ² g ⁻¹)	7.2 ± 1.0	5.8 ± 1.0
Particle size (D ₅₀ /D ₉₀ , μ m)	0.61/1.03	0.89/1.19
Loss of ignition (wt%, 900 °C)	0.81	36.43

^a CT3000SG.

^b Hydral 710: Almatiss, USA.

Due to its technological importance, the Al₂O₃-Al(OH)₃ system has been intensely investigated over the past decades and two fields, in particular, can be highlighted.

- (1) The strong relationship between the Al(OH)₃ calcination conditions and the physic-chemical properties and microstructure of the Al₂O₃ phases produced.^{5–10} The thermal decomposition of Al(OH)₃ is a complex process with an intense crystallographic rearrangement that occurs according to the general expression:



A 34 wt% mass loss can be observed in this stage due to the endothermic release of water vapor, followed by density increase and huge variation in the specific surface area (results above 300 m² g⁻¹ are frequently reported)^{7,11–13}. Several studies on the use of this system as a catalyst support have reported the effects of varying particle size distribution, impurities content, specific surface area, degree of crystallinity, heating rate (assisted or not by vacuum) and maximum temperature achieved.^{10–12} By varying these parameters, significant differences can be observed in the atomic mobility and diffusivity of the precursor particles, which leads to different mass loss intensities and rates, specific surface area levels and phase changes temperature

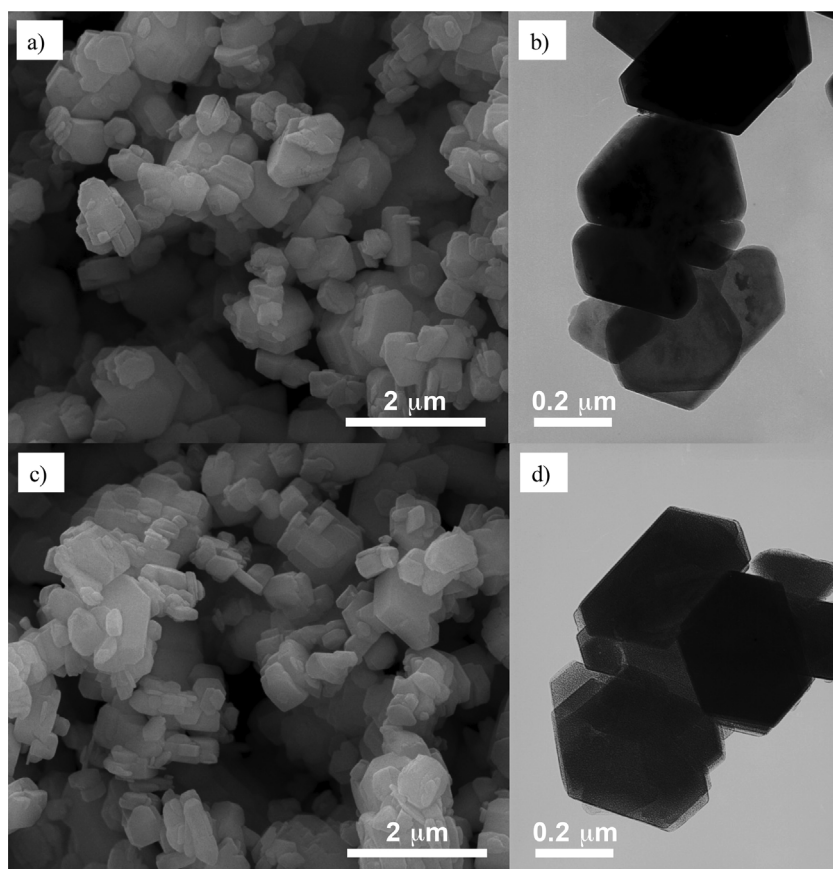


Fig. 1. SEM and TEM for Al(OH)₃ samples (a and b) as-received and (c and d) treated at 300 °C for 5 h.

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