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Alpha-Alumina Extraction from Al-Ga'ara Bauxite

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Abstract

The bauxite produced from Al-Ga'ara area in Al-Enbar containing 50.4 wt. percentages Al_2O_3 was used for α-alumina production.

For α-alumina production bauxite was mixed with calcium carbonate in a ratio 1:3 and the mixture was burned at temperature range 1150-1350°C, cooled to 500°C; crushed and ground. The powder produced treated then with 6% sodium carbonate solution using different temperature (60-100°C) for fifteen minutes. After filtration, the produced sodium alurninate solution was reacted with 2% of calcium hydroxide at 98°C for thirty minutes. The filtrate was carbonated with purified CO_2 gas at 70°C for different times (30-180min) and different flow rates (20-80 cm^3/min). Alumina was precipitated as hydrate, then washed with water, dried at 110°C, and calcined at 1200°C. The produced α-AL_2O_3 was identified by X-ray diffraction.

Keywords: Alumina extraction, bauxite.

Introduction

In 1886-1887 [1] Bayer developed process for preparation pure alumina from bauxite. The Bayer process involves hydrochemical treatment of bauxite with sodium hydroxide at elevated temperature and pressure. On cooling, the aluminate liquor becomes supersaturated and alumina hydrate precipitates.

Variation of lime (Grzymek's method) [2] and lime-soda sintering processes are used in treatment of high-silica bauxite for alumina production. In these processes a soluble aluminate is formed and silica is insolubilized by its reaction with calcium hydroxide.

Alumina is extracted from calcium aluminate produced from bauxite and limestone by treatment with Na_2CO_3 [2] by Equations 1 and 2.

$$CaO.Al_2O_3 + Na_2CO_3 \rightarrow 2NaAl_2O_2 + CaCO_3 \quad (1)$$

$$12CaO.Al_2O_3 + 12Na_2CO_3 + 5H_2O \rightarrow 14NaAlO_2 + 12CaCO_3 + 10NaOH \quad (2)$$

Desilication of aluminate solution is taken place by treatment with calcium hydroxide by Equation 3:

$$2Na_2SiO_3 + 2NaAlO_2 + Ca(OH)_2 + 2H_2O \rightarrow CaO.Al_2O_3.2SiO_2 + 6NaOH \quad (3)$$

Alumina hydrate is precipitated by treatment with CO_2 [5] according to Equation 4:

$$2NaAlO_2 + CO_2 + 3H_2O \rightarrow Al_2O_3.3H_2O + Na_2CO_3 \quad (4)$$

Conversion of alumina trihydrate to monohydrate occurs below 250°C by Equation 5.

$$Al_2O_3.3H_2O \rightarrow Al_2O_3.H_2O + 2H_2O \quad (5)$$

Alumina monohydrate is converting to γ-alumina in the temperature range of 300 to 900°C by Equation 6.

$$Al_2O_3.H_2O \rightarrow \gamma - Al_2O_3 + H_2O \quad (6)$$

while α-alumina is produced at about 1100 to 1200°C. Sintering and acid-extraction process have been investigated for production of alumina from non-bauxite resources such as kaolin, anorthosite and nepheline ores containing 25 to 30 wt. % Al_2O_3 [3].

Yearly large quantities of alumina are produced for the manufacture of metallic aluminum, abrasive, chemical, refractories and ceramic [4].

Alpha-alumina is one of the most versatile of refractory ceramic oxides and finds used in a wide range of applications [5]. Alumina exists in a number crystalline form. Only one of these forms, α-alumina is thermodynamically stable. When hydrates are heated dehydration occurs and is accompanied structural changes. A series of metastable intermediates are progressively formed, the stable α-Al_2O_3 being the final product of thermal decomposition.

Dehydration and calcination of alumina hydrate also produce change in surface area and density. BET surface area reaches a maximum of about 350 rn^2 g-1 at about 200°C and then decreases [6]. Density increases to near the theoretical value of 3.97 g cm-3 for α-alumina when calcined at 1200°C [7].

On the other hand, α-alumina was found in nature under the name corundum. There are several precious stones are forms of Al_2O_3 containing traces of other metal e.g., chromium (Red Ruby), iron or titanium (Blue sapphire) and (Black Emery) is an impure form [8].

Crystal structure of corundum has very low electrical conductivity, thus alumina is used commonly for high-quality electrical applications where low dielectric loss and high resistivity are needed [9].

Experimental Work

Materials

The bauxite produced by Al-Ga'ara area in Al-Enbar containing 50.4 wt. % Al_2O_3 as shown in Table 1.

Table 1 Chemical analysis of bauxite

Compound	Wt.%
Al_2O_3	50.4
SiO_2	30.04
CaO	0.72
Fe_2O_3	1.17
TiO_2	1.98
Na_2O	0.27
K_2O	0.08
MgO	0.67
L.O.I	14.67

The calcium carbonate produced by Al-Kilo 160 area in Al-Enbar containing 53.85 wt. % CaO was mixed with bauxite. Sodium carbonate (99.98 % purity) supplied from BDH. Calcium hydroxide (98 %) supplied from BDH. Carbon dioxide (99.99 %) was supplied from Baghdad Company.

Alumina Extraction

Bauxite particle and limestone with dimension of less than 90 μm had been mixed in 1:3 ratio, then the mixture was burned in electrical furnace at different temperature ranging from 1150 to 1350°C for six hours. Gradually, the temperature reached to 500°C (cooling stage) the mixture is taken out. Dicalcium silicate (C_2Si), calcium aluminates 12CaO.7Al_2O_3 ($C_{12}A_7$) and CaO.Al_2O_3 (CA) are formed, as shown in Table 2 [10].

Table 2 Chemical composition (wt. %) of Al-Ga'ara bauxite and limestone mixture (mixing ratio 1:3) after calcinations at 1350°C

Compound	Wt. %
$C_{12}A_7$	15.17
CA	3.84
C_2Si	80.29
Total	99.3

After burning, the mixture was crushed to fine powder. Alumina is extracted from the disintegrated powder by extraction with 6% Na_2CO_3 solution at different temperature ranging from 60 to 100°C for 15 minutes.

Sodium carbonate treatment was repeated three times. The calcium aluminates are converted to soluble aluminates according to Equations 1 and 2. The insoluble which contained C_2Si and $CaCO_3$ are removed by vacuum filtration at 60 mmHg.

Desilication of alumina solution is affected by treatment with 2 % calcium hydroxide at 98°C for thirty minutes according to Equation 5. The desilication process was repeated three times. The filtrate (aluminates solution) is then carbonated with CO gas 70°C for different times ranging from 30 to 210 minutes. Alumina hydrate precipitated according to Equation 4.

Alumina is then washed with water for removal of sodium salt, dried at 110°C, then crushed and calcined at 1200°C for 6 hours. The produced α-Alumina was identified by X-ray diffraction.

Results and Discussion

Effect of calcination temperature of bauxite and limestone mixture on the percentage extraction and yield of $Al(OH)_3$

Figures 1 and 2 present the effect of calcinations temperature in the range of 1150-1350°C on the percentage extraction of $Al(OH)_3$ based on Al_2O_3 in the raw material and on bauxite.

Figures and show that the increasing in the calcinations temperature increases the percentage extraction of $Al(OH)_3$, yields based on bauxite and Al_2O_3 in bauxite. The higher percentage extraction and yield obtained at 1350°C. The increasing in calcinations temperature resulted in a good transformation of bauxite-limestone mixtures to dicalcium silicate CS and calcium aluminates CaO.Al_2O_3 (CA) and 12CaO.7Al_2O_3 ($C_{12}A_7$). The calcination temperature 1350°C gave 85.44 wt. % extraction of $Al(OH)_3$ from bauxite. This result is in agreement with Grzymek's work [11].

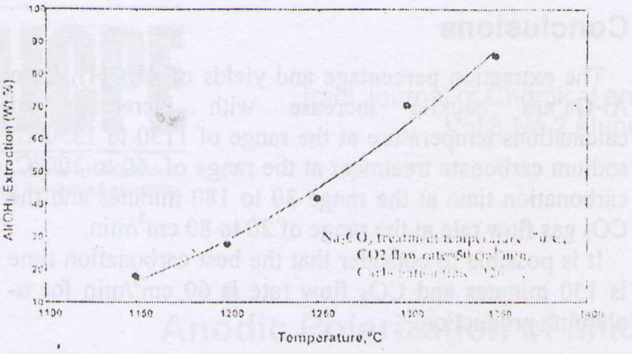

Fig. 1 Effect of calcinations temperature on the $Al(OH)_3$ extraction from bauxite

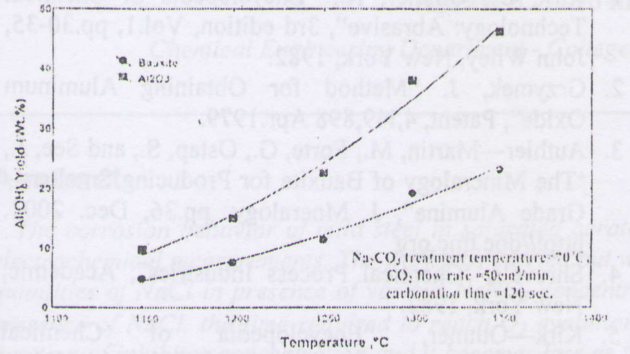

Fig. 2 Effect of calcinations temperature on the $Al(OH)_3$ yield based on bauxite and Al_2O_3 in bauxite

Effect of sodium carbonate treatment on the percentage extraction and yield of $Al(OH)_3$

Figures 3 and 4 show the effect of Na_2CO_3 treatment temperatures ranging from 60 to 100°C on the percentage of $Al(OH)_3$ extraction and the yields of $Al(OH)_3$, based on bauxite and Al_2O_3 in bauxite.

Figures 3 and 4 indicate that the percentage of $Al(OH)_3$ extraction and the yields increase with Na_2CO_3 treatment temperatures increasing.

It is possible to consider that the optimum sodium carbonate treatment temperature is 90°C, because higher temperature gives slight effect on $Al(OH)_3$ extraction, yields of $Al(OH)_3$ based on bauxite and Al_2O_3 in bauxite.

There is a slight difference in the percentage of $Al(OH)_3$ extraction from Ga'ara bauxite compared with the Grzymek work [12]. This may be due to the high SiO_2 (30 wt. %) content of Iraqi bauxite compared with that studied by Grzymek.

Effect of carbonation time and CO_2 flow rate on the percentage extraction and yield of $Al(OH)_3$

Figures 5 and 6 present the effect of carbonation time in the range of 30 to 180 minutes on the percentage of $Al(OH)_3$ extraction and yields of $Al(OH)_3$ based on bauxite and Al_2O_3 in bauxite.

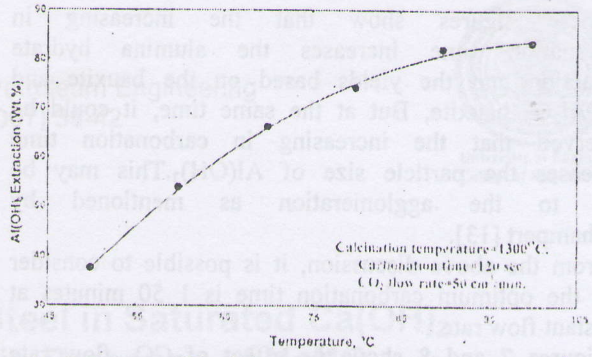

Fig. 3 Effect of Na_2CO_3 treatment temperature on the $Al(OH)_3$ extraction from bauxite

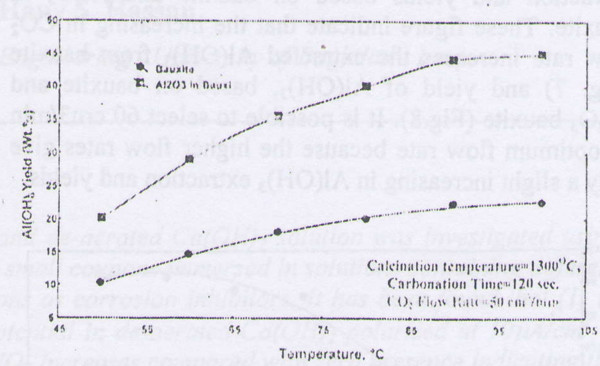

Fig. 4 Effect of Na_2CO_3 treatment temperature on the $Al(OH)_3$ yield based on bauxite and Al_2O_3 in bauxite

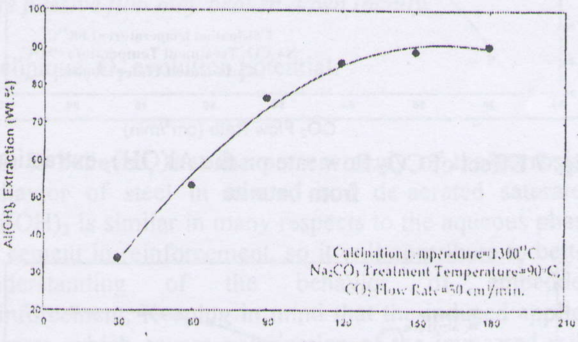

Fig. 5 Effect of calcinations time on the $Al(OH)_3$ extraction from bauxite

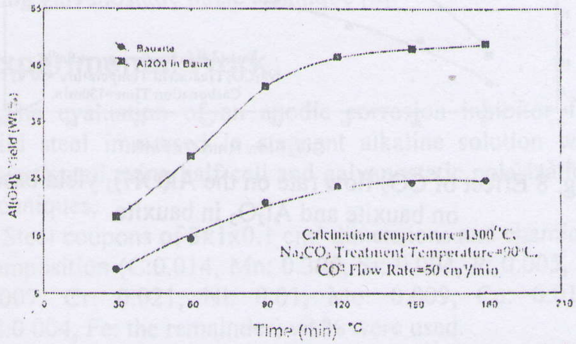

Fig. 6 Effect of calcinations time on the $Al(OH)_3$ yield based on bauxite and Al_2O_3 in bauxite

These figures show that the increasing in carbonation time increases the alumina hydrate extraction and the yields based on the bauxite and the Al_2O_3 bauxite, But at the same time, it could be observed that the increasing in carbonation time increases the particle size of $Al(OH)_3$.This may be due to the agglomeration as mentioned by Tschampert [13].

From the above discussion, it is possible to consider that the optimum carbonation time is 1 50 minutes at constant flow rate.

Figures 7 and 8 show the effect of CO_2 flow rate ranging from 20 to 80 cm^3/min on the percentage of extraction and yields based on bauxite and Al_2O_3 in bauxite. These figure indicate that the increasing in CO_2 flow rate increases the extracted $Al(OH)_3$ from bauxite (Fig. 7) and yield of $Al(OH)_3$, based on bauxite and Al_2O_3 bauxite (Fig.8). It is possible to select 60 crn3/min as optimum flow rate because the higher flow rates give only a slight increasing in $Al(OH)_3$ extraction and yields.

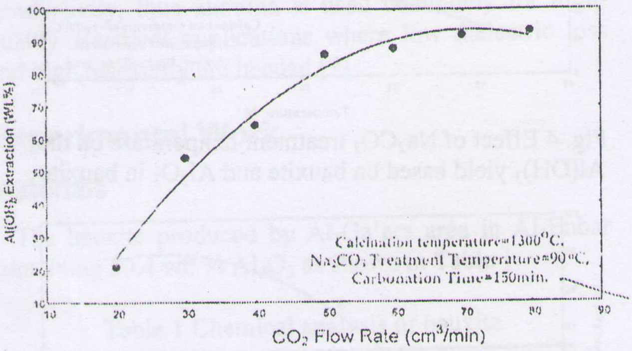

Fig. 7 Effect of CO_2 flow rate on the $Al(OH)_3$ extraction from bauxite

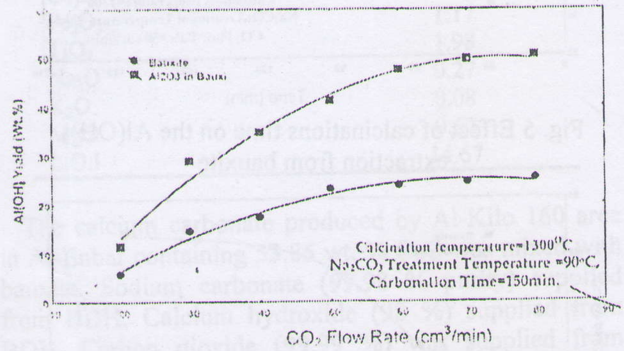

Fig. 8 Effect of CO_2 flow rate on the $Al(OH)_3$ yield based on bauxite and Al_2O_3 in bauxite

Conclusions

The extraction percentage and yields of $Al(OH)_3$ from Al-Ga'ara bauxite increase with increasing of calcinations temperature at the range of 1150 to 1350°C, sodium carbonate treatment at the range of 60 to 100°C, carbonation time at the range 30 to 180 minutes and the CO_2 gas flow rate at the range of 20 to 80 cm^3/min.

It is possible to consider that the best carbonation time is 150 minutes and CO_2 flow rate is 60 cm^3/min for α-alumina production.

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