

## Determination of Bauxite's phases by the bomb digest method at Kamsar laboratory ISO 9002 (Guinea)

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**Abstract:** This paper presents the results of the experimental work done to find out the extraction percentage of alumina content in ore samples of bauxite from three mines of Guinea. So the knowledge of the chemical composition of a matter or a product directs us on its origins, its possible use and especially towards the technology which it will be necessary to apply for its transformation. This chemical composition is given at the laboratory which, to have reliable results uses adequate methods of analysis for each type of element to be proportioned in the matter. Thus for the analysis of bauxite exploited by the company of bauxites to Guinea (C.B.G.) and which currently comes from the plates of Sangaredi, Bidikoum and Silidara, the chemistry laboratory of Kamsar uses mainly two categories of methods which are instrumental and wet chemical method (volumetric). This study has relied on the chemical method due that it primarily rests on the quality of the matter to analyze and the concentration of the chemical elements which make it up. To this end, the Guinean bauxite exploited by the C.B.G having a high percentage in  $\text{Al}_2\text{O}_3$  and a content of  $\text{SiO}_2$  not exceeding 7%, for the determination of the various phases from this one, the section bomb digest of the laboratory at Kamsar uses a wet alkaline attack. Under high pressure and at variable temperatures according to the mineralogical phase to determine, this digestion is schematized as:  $\text{Al}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaAlO}_2 + \text{H}_2\text{O}$ . Soluble aluminate. [Journal of American Science 2010;6(6):139-145]. (ISSN: 1545-1003).

**Key words:** Bauxite's phases, Gibbsite, Boehmite, Guinea and Bomb digests

### I. Introduction

Initially the bauxite term was introduced in 1821 by the French man Berthier to indicate a red ground deposit level on the ground, close to the village of the Baux - de - Province (valley of Rhone) in the Southern France (Sedat et al. 2006; J.Canérot et al 1999) The term bauxite is used to describe weathering products rich in alumina but low in alkali, alkaline earth and silica. It is composed principally of one or more hydrated aluminum minerals: gibbsite ( $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ ), boehmite ( $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ ) and diaspore ( $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ ) with impurities of silica, iron oxide, titanium oxide and other elements in minor or trace amounts (Y. Idris et al.2004 .Shaffer, 1975). Valeton (1972) defined bauxite ore as bauxite that is economically mineable at present or in the foreseeable future, containing not less than 45–50%  $\text{Al}_2\text{O}_3$ , and not more than 20%  $\text{Fe}_2\text{O}_3$  and 3–5% combined silica.

In terms of the geological field exploration for bauxite, the quantities and topological distribution of the main components and that of the contaminants

are of great importance to be reckoned with in the search for new resources. Early international practices of bauxite analyses are usually done to determine loss of ignition, and alumina, silica, iron oxide and titanium contents. But recently, the range of bauxite components considered has been extended to the contaminants, substantially influencing bauxite processing (Authier-Martin et al., 2001; UNIDO, 1985). An idea of the contents of these contaminants is therefore very important as it is taken into account when determining the individual value and price of a given ore.

The world's prospective bauxite resources are located mainly in the developing countries, where one half of the world production comes from (Dash et al., 2007; Lotze, 1978). In Africa, the largest deposits are found in Guinea, which account for Africa's 83.7% proven and probable resources of high-grade bauxite (Y. Idris et al.2004 ) with Cameroon coming second in terms of proven reserve (Clarke, 1987). Other African bauxite producers are Ghana, Mozambique, Sierra Leone and Zimbabwe. The bauxite is a no definite geological formation, it is a

mixture of oxides whose aluminum oxide is far more dominating, then comes the iron oxide which gives the reddish color to bauxite, the silica oxide and some compounds from metals such as: vanadium, titanium, lead, calcium, Zinc. Sometimes sulphur, copper, Nickel ,according by M.Karadag et al 2009.

The composition of bauxites generally varies in the following percentages (Santos et al 2004):

Al<sub>2</sub>O<sub>3</sub> 40-60%;H<sub>2</sub>O 12-30%;Fe<sub>2</sub>O<sub>3</sub> 5-30%;  
SiO<sub>2</sub> 1-20%

The bauxites quality initially depends on their content of Al<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub>. The more the bauxites contain Al<sub>2</sub>O<sub>3</sub> and less SiO<sub>2</sub>, the higher their economic and industrial values are significant (Tardy et al. 1991).

In Kamsar, it is the trihydrate which is most widespread whose characteristics make this bauxite most economically exploited. It is most soluble in alkalis and dissolves between 90 at 100 C. It comes in

## II - Properties of alumina hydrates

The properties of alumina hydrate (A. Asghar Calagari, 2007) as following  
**Table 1.**The Properties of alumina hydrates

N°	Designation	Gibbsite or Hydrargillite	Boehmite	Diaspore
1	Content alumina	65.4	85	85
2	System Crystallin	Monoclinic	Orthorhombic	Orthorhombic
3	Mohs hardness	2.5-3.5	3.5-4.0	6.5-7.0
4	Fast temperature of dehydration	150°C	350°C	450°C
5	Product of dehydration	X-Al <sub>2</sub> O <sub>3</sub>	Y-Al <sub>2</sub> O <sub>3</sub>	Z – Al <sub>2</sub> O <sub>3</sub>
6	Density	2.42	3.01	3.44
7	Solubility in Na <sub>2</sub> O 100g/l à 125°C, Al <sub>2</sub> O <sub>3</sub> g/l	128	54	Unsoluble

## III - Method and Materials

### III.1- Materials and solutions needed

This study has used the following materials.

**Table 2.** materials and specifications

N°	Materials	Specifications
1	Thermometer	control the temperature
2	Whattman 40	filter the solution
3	Bombs	in which is the bauxite-soda mixture

general from the deterioration of the sediments (schist, aleurolothes, argillites) and basic magmatic rocks (dolerites, gabbro-dolerites, kongga-diabase) (Luke J. Kirwan 2009).

The bauxite of Guinea exploited by the CBG is in the open air very rich in alumina and a content of SiO<sub>2</sub> lower than 7 % ( Santos M.C, 2003). For bauxites rich in Al<sub>2</sub> O<sub>3</sub> and low SiO<sub>2</sub>, the wet alkaline process is best according by N. Zwingmann et al 2009 .The purpose of this study therefore is to ascertain the quality and the nature of bauxite often the customers' request. Compared to the other methods of decomposition and setting in solution such as the triacid method (HCl, HNO<sub>3</sub> and H<sub>2</sub>SO<sub>4</sub>), this method uses little reagent, less expensive, less toxic, gives reliable and precise results (S.A. Hussain et al. 2000).One of the sections in the kamsar's laboratory use this method which calls section Bomb digest.

4	Furnaces of 143C and 235C	allow heating the bomb containing the mixed solution (bauxite-soda)
5	Copper disc	for the bomb
6	Drying oven 105C	dry bauxite
7	Torque wrench	tighten the lid of the bomb firmly
8	Burette and stand	for the titration
9	Bomb pilot	for the control
10	Sound stop watch	for the time
11	Grip	leave the bombs in the furnaces
12	Bain-marie	cool the bombs
13	Policeman	: in which we put water to clean the bombs
14	Magnetic stirrer	make homogeneous the solution
15	Cone cup 500ml	in which the mixture occurs

### Solutions Needed

1. NaOH standard solution ( $C_{\text{NaOH}}=0.500$  mol/L)
2. HCl standard solution ( $C_{\text{HCl}}=0.500$  mol/L)
3. NaOH.SiO<sub>2</sub>, 102 g/l
4. Starch and paper pulps
5. Gluconate of sodium ( $\text{NaC}_6\text{H}_{11}\text{O}_7$ )
6. NaCl 5 g/l
7. NaOH 102g/l
8. Phenolphthalein indicator
9. Buffer solution pH 8.0
10. HCl1:1 solution
11. KF solution

### III.2- Methods used

The quantity (1,3±0,0001g and 0,65±0,0001g) of bauxite are heated, under pressure, in a solution of sodium hydroxide (102g/l) respectively at 143°C, 235°C (fig.1); the insoluble matters are separated by filtration. An alumina present in the filtrate is given by titrating the equivalent of the ions hydroxides ( $\text{OH}^-$ ) released by fluorine in a chelating solution containing sodium gluconate (Loh et al., 2005).

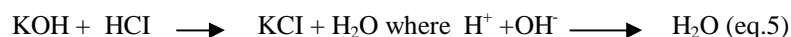
The Chemical Processes involving the dissolution of  $\text{Al}_2\text{O}_3$  by soda is done according to the reaction below:  
 $\text{Al}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaAlO}_2 + \text{H}_2\text{O}$  (eq.1)

A part of  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  combined in kaolinite reacts on soda according to the equation (eq.2)



The starch and paper pulp make it possible to agglomerate the fine suspended particles in the bomb and to release the base with the policeman from it. The sodium gluconate ( $\text{NaC}_6\text{H}_{11}\text{O}_7$  or  $\text{CH}_2\text{OH}-(\text{CHOH})_4\text{C}^{\ominus}\text{ONa}$ ) in solution 25% combines with sodium aluminates to form a complex easily hydrolysable as shown in equation 3.  
 $\text{NaAlO}_2 + \text{CH}_2\text{OH}-(\text{CHOH})_4\text{C}^{\ominus}\text{ONa} + 2\text{H}_2\text{O} \longrightarrow \text{Al}(\text{OH})_3 + \text{CH}_2\text{OH}-(\text{CHOH})_4\text{C}^{\ominus}\text{ONa} \pm \text{NaOH}$  (3)

The KF solution moves sodium gluconate to fix aluminum in the form of cryolite (Santos et al 2004a) (eq.4).  
 $\text{Al}(\text{OH})_3 + \text{CH}_2\text{OH}-(\text{CHOH})_4\text{C}^{\ominus}\text{ONa} + 6\text{KF} \longrightarrow \text{AlF}_6\text{K}_3 + \text{CH}_2\text{OH}-(\text{CHOH})_4\text{C}^{\ominus}\text{ONa} + 3\text{KOH}$  and the potash releases which one titrates by HCl 0.5 normal by using at the same time the pHmeter and the indicator according to the equation 5.

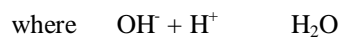
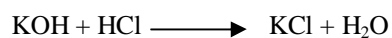
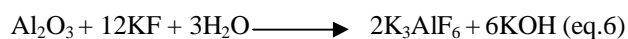




**Figure 1.** The furnaces of 143°C and 235 °C

### III.2.1- Determination of alumina by the equations of the reactions

Adding equations 1,3 and 4 by multiplying the two last by 2 to obtain the general equation of proportioning



Equation (5) is a reaction of neutralization and at equivalence we have: quantity of ions  $\text{OH}^-$  released by the solution of KOH is equal to that of the ions  $\text{H}^+$  brought by the solution of HCl 0.5 N.

$$n_{\text{OH}^-} = n_{\text{H}^+} \quad N_{\text{OH}^-} \times V_{\text{OH}^-} = N_{\text{H}^+} \times V_{\text{H}^+} = \text{meg}$$

According to the formula mass  $m = \text{Eq} \cdot \text{meg}$      $\text{meg} = m / \text{Eq} = N_{\text{OH}^-} \times V_{\text{OH}^-} = N_{\text{H}^+} \times V_{\text{H}^+}$

And the equation of reaction, we obtain

$$N_{\text{OH}^-} \times V_{\text{OH}^-} = N_{\text{H}^+} \times V_{\text{H}^+} = m_{\text{KOH}} / \text{Eq}_{\text{KOH}} \quad m_{\text{KOH}} = N_{\text{H}^+} \times V_{\text{H}^+} \times \text{Eq}_{\text{KOH}}$$

From equation (6)

$$102\text{g Al}_2\text{O}_3 \quad 6 \times 56\text{g KOH}$$

$$m_{\text{Al}_2\text{O}_3} = m_{\text{KOH}} \times m_{\text{Al}_2\text{O}_3} = 102g \cdot m_{\text{KOH}} / 6 \times 56g = 102xN_{\text{H}^+} + V_{\text{H}^+} \times \text{Eq}_{\text{KOH}} / 6 \times 56g$$

$$\text{Eq}_{\text{KOH}} = 56/1 = 56; N_{\text{H}^+} = 0.5N$$

$$m_{\text{Al}_2\text{O}_3} = 102g \times 56 \times N_{\text{H}^+} \times V_{\text{H}^+} / 6 \times 56g = 102 \times 0.5 / 6 \times V_{\text{H}^+}$$

$$m_{\text{Al}_2\text{O}_3} = 8.5 \cdot V_{\text{H}^+} + \text{en mg.}$$

In practice, we checked if all the quantity of KOH is proportioned by adding 5ml HCl 0.5 N in excess which we titrated by soda having same normality.

Not proportioned KOH is equal to  $5 - V_{\text{NaOH}}$  where  $m_{\text{Al}_2\text{O}_3} = 8.5 \times 10^{-3}(V_{\text{H}^+} + 5 - V_{\text{NaOH}})$  in gram but  $V_{\text{NaOH}} + 5 = V_{\text{THCl}}$  therefore  $m_{\text{Al}_2\text{O}_3} = 8.5 \times 10^{-3}(V_{\text{THCl}} - V_{\text{NaOH}})$ .

Knowing the mass of  $\text{Al}_2\text{O}_3$ , we determined its percentage according to the relation

$$\frac{\text{PE}}{m_{\text{Al}_2\text{O}_3}} = \frac{100}{y}; y = (m_{\text{Al}_2\text{O}_3} / \text{PE}) \times 100$$

$$y = \% \text{Al}_2\text{O}_3 = (8.5 \times 10^{-3}(V_{\text{THCl}} - V_{\text{NaOH}}) / \text{PE}) \times 100$$

In the furnace of  $143^\circ\text{C}$   $\text{PE} = 1.3 \pm 0.0001$

$$\% \text{Al}_2\text{O}_3 = 0.85 (V_{\text{THCl}} - V_{\text{NaOH}}) / 1.3. \quad \% \text{Al}_2\text{O}_3 = 0.65(V_{\text{THCl}} - V_{\text{NaOH}})$$

In the furnace of  $235^\circ\text{C}$   $\text{PE} = 0.65 \pm 0.0001$

$$\% \text{Al}_2\text{O}_3 = 0.85 (V_{\text{THCl}} - V_{\text{NaOH}}) / 0.65. \quad \% \text{Al}_2\text{O}_3 = 1.3(V_{\text{THCl}} - V_{\text{NaOH}})$$

### III.2.2- Mass percentage of $\text{Al}_2\text{O}_3$

**Formula:**  $\% \text{Al}_2\text{O}_3$  (gibbsite) =  $(axV \pm b / 1.30) \times x100$

$\% \text{Al}_2\text{O}_3$  (gibbsite and boehmite) =  $(axV \pm b / 0.65) \times x100$

**Factor of the day:**  $y = 0.00891x - 0.0114$

### IV- Results and Discussions.

The concentration of  $\text{Al}_2\text{O}_3$  ( $143^\circ\text{C}$ ) and  $\text{Al}_2\text{O}_3$  ( $235^\circ\text{C}$ ) in the samples as presented respectively in Table 3 ranges from 44.43% to 44.49% ; Table 4 ranges from 50.33% to 50.34% . For the standard bauxite sample N°021002040s the analyzed concentration of  $\text{Al}_2\text{O}_3$  ( $143^\circ\text{C}$ ) as presented

below in Table 3 is 44.83% as compared to the certified value of 44.77%; in Table 4 is 51.84% as compared also to the certified value 51.84 This shows that the error in terms of accuracy of the measurement is less than 1%. Also the error in terms of precision of the measurements defined as one standard deviation of the percentage of the mean is less than 2% for all the samples.

**Table 3:** Quantity of gibbsite contained in each  $1,3 \pm 0,0001\text{g}$  of bauxite samples at  $143^\circ\text{C}$

N° Bomb	N° of Laboratory	Mass samples	Calculation	%Mass
06	021002035	1.3000	$65.70 + 5 = 70.70 - 4.50 = 66.20$	44.49
12	021002036	1.3000	$65.80 + 5 = 70.80 - 4.50 = 66.30$	44.56
13	021002037	1.3000	$65.60 + 5 = 70.60 - 4.50 = 66.10$	44.43
14	021002038	1.3000	$65.70 + 5 = 70.70 - 4.50 = 66.20$	44.49
15	021002040s	1.3000	$66.10 + 5 = 71.10 - 4.50 = 66.60$	44.77
16	021002040s	1.3000	$66.20 + 5 = 71.10 - 4.50 = 66.70$	44.83

**Table 4:** Quantity of gibbsite and boehmite contained in each 0,65±0,0001g of bauxite samples at 235°C

N° Bomb	N° of Laboratory	Mass samples	Calculation	%Mass
17	021002035	0.6500	$37.60 + 5 = 42.60 - 4.60 = 38.0$	50.34
18	021002036	0.6500	$37.40 + 5 = 42.40 - 4.60 = 37.80$	50.34
19	021002037	0.6500	$37.60 + 5 = 42.60 - 4.60 = 38.00$	50.33
20	021002038	0.6500	$37.60 + 5 = 42.60 - 4.60 = 38.00$	50.34
24	021002040s	0.6500	$38.60 + 5 = 43.60 - 4.50 = 39.10$	51.84
25	021002040s	0.6500	$38.60 + 5 = 43.60 - 4.50 = 39.10$	51.84

From table (3) and (4), the experiment showed that trihydrate (gibbsite) is more soluble than monohydrate (boehmite). It dissolves at lower temperatures but in the solution, it is transformed into monohydrate at high temperature

The results show that solubility increases with the soda concentration used and the temperature. This is why in the bomb digest, trihydrate is attacked at 143°C and at the temperature of 235°C we have the two (2) phases which are attacked (H. Chuanbin et al

#### V- Conclusion

This study briefly focused on the section bomb digest of chemistry laboratory, to define the types of bauxite and especially the contents of  $Al_2O_3$  soluble. The determination of the bauxite mineralogical phases by the Bomb digest method makes it possible to know well the nature of bauxite and especially its content of soluble  $Al_2O_3$ , i.e. the decompositions at the temperature: 143°C pour le trihydrate (gibbsite) and 235°C for total alumina

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2008) .The advantage of these proportioning results from the request of the customers for whom the choice of quality depends on the nature of bauxite, otherwise if the bauxite is a monohydrate or a tri hydrate.

By P. Smith 2009, the bauxites with weak content of  $SiO_2$  are the best on the market; because in the current industry of  $Al_2O_3$ , the most delicate operation is the separation of impurities containing silica.

(trihydrate and monohydrate).The chemical composition in  $Al_2O_3$  soluble is significant, but it is also necessary to lay a particular stress on the method of proportioning for the bomb digest which for the moment is used. The method of the calibration curve can show the impossibility of measurement in consequence of awkward substances, if a line is not obtained, in this case it is recommended to use the chemical reactions for the calculation of the percentage of  $Al_2O_3$ .

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