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EXTRACTION AND QUANTIFICATION OF SILICON FROM SILICA SAND OBTAINED FROM ZAUMA RIVER, ZAMFARA STATE, NIGERIA

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Abstract

This is a research on the extraction and quantification of Silicon from Silica Sand obtained from Zauma River in Zamfara state. The Silica Sand sample was removed from the water in Zauma River which was allowed to dry and heated in a heating mantle. Silicon and Silica was extracted from the sample. Quantitative analysis of the sample was then done under the following parameters; determination of loss on ignition, determination of CaO, determination of MgO, determination of Fe_2O_3, and determination of Al_2O_3.The results reveals that, the sample contains numerous cations in form of oxides and SiO_2 and Si having the highest percentages of 81.5% and 77% respectively. Based on the findings some recommendations were given.

Keywords: Silica and Silicon, Quantitative analysis, determination, Oxides, Elements

Introduction

Silica Sand is a brownish glassy with high reflection like broken glasses. It usually contains Silicon (Si) as the major element as its constituents and other cations (Ratson 2007).

Silicon, symbol Si, semimetallic element that is the second most common element on the earth crust, other than Oxygen. The element is a metalloid with a divided metallic luster and it is quite brittle. It crystallizes in the in the diamond lattice, has a specific gravity of 2.42 at $20^{o}C$ .Silicon occurs in many forms of the dioxide and as almost countless variations of the natural silicates (Norbert etal, 2010).

Alamos National laboratory, (2000). In abundance Silicon exceeds by far every other element except Oxygen. It constitutes 27.72% of the solid crust of the earth, where as Oxygen constitutes 46.6%.This tremendous abundance of Silicon makes it of popular interest as a chemical raw material and the versatility of its chemical behaviors has encouraged more and more uses to be developed through intensive research.

Silicon is reported to form compound with 64 of the 96 stable elements and it probably forms silicides with 18 other elements. Beside the metal silicides, used in large quantities in metallurgy, silicon forms useful and important compounds with Hydrogen, Carbon, the halogen elements, Nitrogen, Oxygen and Sulphur (Hills, 1967). Silicon is found in nature in several forms, including, flint, quartz, and opal. Infact, 35 crystalline forms have been identified (Iller, 2007)

The hydrides of silicon are named silane. The compound SiH_4 being called monosilane,Si_2H_6 disilane, Si_3H_8 trisilans, and so on (Hills, 1967).

The hydrides of Silicon were first investigated thoroughly by Alfred stock who prepared them by the reaction of Magnesium silicide (from the reaction of silica with excess Magnesium at minimum with dilute aqeous Hydrochloric or Phosphoric acid.

The reduction of silica with excess carbon under appropriate conditions give silicon carbide (Sic), which crystallizes in a number of forms, but is best known in cubic diamond form with spacing 0.435nm (compound with 0.356 for diamond).

In the pure form form silicon carbide is green (α – hexagonal) or yellow (β – cubic), but the commercial product is black and has a bluish or greenish. The carbide is not easily oxidized by air except above 1000^{oc} (1830^{of}) and retains its physical strength up to this temperature (Hills, 1967).

$Si0_2 + 2C \rightarrow SiC + CO_2$

Iller (2007) Silicon dioxide (SiO_2) is perhaps the best known as one of its crystalline modification known as Quartz, colorless crystals of which are also rhinestones and a glen falls diamonds purple or lavenders colored quartz and the yellow type citrime. Twenty two different phases of silica have been identified. At 573oc ($1063^{o}f$), the ordinary or α – Quartz changed over reversibility to β – Quartz which has a lower density and 867^{oc}.($1593^{o}f$), β –

Quartz changes to a different crystals modification, β – tridymite at still higher – temperature 1470^{o}c (2678^{o}f), β- tridymite becomes a third modification called β – cristobalite (Popular science, 2007).

Hills (1967) Silicon dioxide (SiO) is a brownish powder that can be obtained by heating a structure of finely divided silica and elemental Silicon in the absence of air above O^{o}c. It is much more volatile than the dioxide and is used to form a durable Coating on lens and mirrors and in electron microscopy for shadowing. The monoxide oxidizes rapidly to dioxide which does not interfere with its uses as a lens coating.

$Si + O_2 \rightarrow SiO_2$

Silicon is a very useful element that is vital to many human industries. Silicon is used frequently in manufacturing computer chips, transistors and integrated circuits (Ratson, 2007).

Silicon is also useful in (Metallurgical grade Silicon) is in aluminium – silicon alloys to produce cast parts mainly for automotive industries (Popular science, 2005).

Quartz crystals (Silicon dioxide) are used for keeping time in watches as its oscillations are extremely stable (popular science).

Royal society, (2007) the organic compounds of silicon that contain both directly attached organic groups and silicon chloride or silicon hydrogen bonds are of greater interest than the tetraaryl silanes, because they lend themselves so well to further reactions and hence may serve as chemical intermediates for a wide variety of organ silicon products.

Amjad (1998) the white silica sand around Riyadh city kingdom of Saudi Arabia with grain size distribution and proportion heavy metals in metals in the sand samples of size 300, 294,and 200 respectively contain cations like Si^{4+}, Ca^{2+}, Mg^{2+}, K^+, Na^+, Ba^{2+}, Ba^{2+} etc and express as oxides such as SiO_2, Al_2O_3, CaO, TiO_2, MgO, K_2O, MnO and P_2O_5.

Encarta (2010) Silica sand contain cations like Mg^{2+}, Na^+, Ca^{2+}, Al^{3+}, Fe^{3+} and Ba^{2+}, which are in oxide forms. And glass is first produced in Egypt by melting silica sand at very high temperature.

Garret (2007) Si can be extracted when SiO_2 is reduced to obtained pure silicon. The reducing agent is coke. Finely powdered is mixed with coke and heated in a electric furnance.The reaction is shown below.

$SiO_2 + 2C \rightarrow Si + 2CO$

Magnesium powder is used instead of coke as a reducing agent. The reaction is

$SiO_2 + 2Mg \rightarrow Si + 2Mg$

Silicon is processed when crushed , the silicon cracked so that the weaker impurity rich regions were on the outside of the resulting grains of silicon's a result, the impurity rich silicon was the first to be dissolve when treated with acid leaving behind a more pure product (popular science,2005).

America foundry men's society (1991) foundry sand sample found in Illinois united states of America indicated that, the sand contains many cations as it constituents, which are in oxide form. The table 1 below shows all the cations and the percentage composition.

Table 1: Foundry sand sample from Illinois

Constituents	Values (%)
SiO_2	87.91
Al_2O_3	4.70
Fe_2O_3	0.94
CaO	0.14
MgO	0.30
Na_2O	0.19
K_2O	0.25
TiO_2	0.15
Mn_2O_3	0.02
L OI	5.15

The aim of this research is to extract and quantify the amount of pure silicon from silica sand obtained from Zauma River in Zamfara state.

Materials And Methods

Sample collection and treatment

The brown glassy sand with very high reflection like broken glasses, was collected from ,Zauma river in Zamfara state, 3km away from Bukuyum local government. The sample was removed from the water, allowed to dry and visible impurities removed and the sample was heated in an oven and placed in a plastic bag and sealed.

Extraction Of Silicon And Silica From Silica Sand

Royal society of chemistry, (2007) the magnesium powder and the silica sand were dried in an oven for 2- hours at about 100^{o}c and were stored in desiccators until ready for use. The test tube was also dried. 2g of silica sand and 1g of magnesium powder were weighed and mixed thoroughly. The mixture was spread along the bottom of the test-tube that was clamped almost horizontally. One end of the mixture was heated with a roaring Bunsen flame. After a few seconds the mixture glowed, this glow was chased along the tube with flame until all the mixture had reached when the reaction was completed. The mixture was allowed to cool (for about 5 minutes) and with the aid of a spatula, the product poured to about of 2mHCl to dissolve away unreactedmagnesium oxide. The solid contained silicon.

Magnesium oxide (the main product), magnesium silicide formed from the reaction of excess magnesium with silicon, unreacted with small yellow flames. These are caused by silanes that were formed from the reaction of magnesium silicide with silanes inflame spontaneously in air. After a few minutes the pops ceased and grey silicon powder possibly with a little unreacted sand were left on the beaker, the acid was poured off, the solid was washed few times with the silicon was filtered off which is slightly metallic silver grey colour.The product was allowed to dry in a desiccators' and the silicon and unreacted sand separated physically and weighed.

The percentage of silicon in the silica sand was calculated using the formula.

$$\% \text{ silicon} = \frac{\text{Weight of silicon}}{\text{Weight of silica sand}} \text{ x } 100$$

The silicon product was placed in a platinum crucible weighed and put in a furnace at 1100oc for 30 minutes after which it was removed allowed to cool in a discicator and weighed again. The percentage silica was calculated using the following formula;

$$\% \text{ SiO}_2 = \frac{\text{Final wt. pt – crucible – initial wt. of pt – crucible}}{\text{Weight of silica sand}} \text{ X } 100$$

Determination of loss on ignition(L.O. I)

Royal chemical society (2007) 2.0g of sample was placed in a separate pure – weighed platinum crucible. The crucible and the content were then ignited in the furnace maintained at 1100^{o}c for 30 minutes after which it was removed and placed in a descicator to allow it to cool. After cooling the crucible and its content were weighed and percentage loss on ignition was calculated using the formula below.

$$\% \text{ L.O .I} = \frac{\text{Weight before ignition} - \text{weight after ignition}}{\text{Weight before ignition}} \text{ X } 100$$

Determination of calcium oxide (CaO)

50cm^3 of the sample solution was pipetted in to separate 400cm^3 conical flask.150cm^3 of distilled water was added to dilute to 200cm^3.The conical flask was then placed on the magnetic stirrer and few drops of KOH solution were added with calcon indicator which changed the colour to purple. The solution was then titrated against EDTA solution with an automatic burette until the colour changed to blue. The percentage calcium oxide was calculated using this formula (Royal chemical society, 2007).

% CaO = Titre value X factor for CaO

The equation for the reaction is; $Ca2^+ + H_2Y_2 = Ca^{2+} + 2H^+$

Determination of magnesium oxide (MgO)

50cm^3 of the filtrate was pipetted in to 400cm^3 conical flask and diluted to 200cm3 with distilled water .The beaker was placed on electric magnet stirrer and stirring commenced .Few drops of conc. ammonia solution was added to adjust the PH level to between 5- 6 followed by addition of 10cm^3 of triethanolamine with 10cm^3 ammonia solution . Addition of mix indicator changed the colour to blue. The solution was titrated against EDTA until the solution became colorless.

% MgO = Titre value X factor for MgO

The equation for the reaction is

$Mg^{2+} + H_2Y^2 = MgY^2- + 2H^+$

Determination of Iron III oxide (Fe_2O_3)

100cm^3 of the filtrate was pipetted into 500cm^3 of volumetric flask; the beaker was then placed on an electric magnetic stirrer 3 drops of Bromophenol indicator was added until colour changed to yellow .Addition of few drops concentrated ammonia solution changed the solution to blue. When 20cm^3 of 0.05m hydrochloric acid solution was added colour changes back to yellow 15cm^3 of buffer solution with few drops of salicylic acid changed the colour to violet. The solution was then titrated against EDTA solution until it changes to yellow.

% Fe_2O_3 = Titre value X factor for fe_2O_3

The equation for the reaction is given below

$Fe^{3+} + H_2Y^2 = FeY + 2H^+$

Determination of Alumina (Al_2O_3)

From the end point of the Iron (III) oxide determination, the titration was continued by adding few drops of ammonium acetate in to the solution until the colour changed to blue, then few drops of acetic acid were added to change the colour to yellow .Addition of few drops of complexing indicator and pan indicator changed the colour to pink. The solution was titrated against EDTA until the colour became yellow.

% Al_2O_3 = Titre value X factor for Al_2O_3

The equation for the reaction is

$Al^{3+} + H_2Y^{2+} = AlY + 2H^+$ (Royal chemical society, 2007)

Determination of Potassium oxide and oxide by flame photometry

The flame photometer was set – up and the instrument read out was calculated using standard solution. The meter reading was set up at zero while aspirating distilled water or blank solution then meter reading was set at 100% while aspiration, the top concentration of the intermediate standard solution. Then the sample solution was aspirated and reading of the percentage was recorded. There for the concentration of element in the sample solution was read and contents of potassium and sodium in the silica sand was calculated by the formula;

% Na_2O = Concentration X dilution factor X conversion factor

% K_2O = Concentration X dilution factor X conversion factor (ppm)

Table 1: Foundry sand sample from Illinois

Constituents	**Values (%)**
SiO_2	87.91
Al_2O_3	4.70
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CaO	0.14
MgO	0.30
Na_2O	0.19
K_2O	0.25
TiO_2	0.15
Mn_2O_3	0.02
L OI	5.15

Results And Discussion

Results

Table: 2: Results of quantitative analysis of silica sand

S/N	**Parameters determined**	**percentages in each sample %)**
1	Loss of ignition (L.O.I)	18.5
2	SiO	81.5
3	Si	77
4	Al_2O_3	0.64
5	Fe_2O_3	0.76
6	CaO	0.14
7	MgO	0.99
8	Na_2O	0.54
9	K_2O	0.23

Source; Survey, 2012

Discussion

Results (table; 2) of the quantitative analysis of the silica sand shows that, these elements expressed as oxides are in the following percentages; Sio_2 (81.5 %), Al_2O_3 (0.64%), Fe_2O_3 (0.76%), CaO (0.14 %), MgO (0.99), Na_20 (0.64), and (0.23%). The loss on ignition (L.O.I) is 18.5% while the silicon content is 77%. These results shows that, the silica sand deposit found in Zauma, Zamfara state, Nigeria is very comparable to the foundry sand found in Illinois, United state of America as shown on (table; 1)of the study reported by the American foundry men's society (1991).

It can be seen from table 1 and 2 that, the SiO_2 contents of the Illinois sand and Zauma sand are 87.91% and 85.5% respectively, which do not vary very much. Even the Fe_2O_3, Na_2O, K_2O are very close. Only the Al_2O_3 content and the L.O.I vary very much. It can therefore said that the Zauma silica sand deposit is of good quality and it can therefore be used for making various types of glasses which is in line with Encarta (2010) silica sand contain many cations like Mg^{2+}, Na^{+}, Ca^{2+}, Al^{3+}, Fe^{3+} etc which are in oxide form. and glass is first produced in Egypt by making silica sand at high temperature.

Silicon extracted from silica sand was determined to be 77%.This means that, the Zauma sand can serve as good source of silicon for the computer industry.

Conclusion And Recommendation

Conclusion

From the results obtained, it can be concluded that, silica sand found in Zauma area, Zamfara state, can be used for the extraction of silicon, because of the percentage (77%) of silicon. It can also be concluded that, it is good quality silica sand because of its high percentage of silica which is 81.5%.

Recommendation

A part from crude oil, silicon is the second source of industrial economy used in making computer processors, direct conversion of solar energy in to electricity, calibration in x-ray diffraction, alloying constituent and manufacturing organosilicon etc.Therefore government should encourage, assist and invest in the companies that will extract silicon from silica sand in Nigeria because of the large abundant of it we have in different parts of the country.

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