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Phase Transformation of Minerals in Bauxite

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Abstract

Bauxite comprises five major elements viz. Al_2O_3, SiO_2, Fe_2O_3, TiO_2, and LOI. Major aluminium bearing mineral phase present in the bauxite are gibbsite, boehmite and diaspore however Iron minerals are mainly in the form of alumo-goethite, hematite and some accessory minerals like magnetite, Illmenite etc. The alumo goethite and hematite are structurally and characteristically different from each other. In general, Indian bauxite contains alumo-goethite is a dominant mineral as compared to hematite. In the beneficiation of bauxite process, an iron mineral plays an important role in magnetic separation study. Hematite being a paramagnetic mineral gets easily separated via magnetic separation process while alumo-goethite is feebly magnetic in nature and requires high intensity.

For the phase transformation study of Indian bauxites, samples from various geological origin such as Eastern Ghat, Gujarat and Jharkhand deposits have been selected. X-Ray diffraction and other studies have been carried out on original bauxite and thermally treated (200-600^{0}C) bauxite samples. The study shows that the thermally treated various bauxite samples indicate transformation of iron minerals mainly alumo-goethite into hematite and gibbsite into boehmite with amorphous phase of both the minerals. In this paper an attempt has been made to study the factors affecting conversion of alumo-goethite to hematite and related minerals present in bauxite and also magnetic behavior of thermally treated bauxite.

INTRODUCTION

India is endowed with vast resources of bauxite, out of which about 70% resources of bauxite are concentrated in Eastern Ghat region and it is highly suitable fo· alumina production. Bauxite also contains various impurities, which restrict their use in refractory, abrasive and chemical industries. The gibbsitic bauxite is preferred for alumina production, however for non-metallurgical applications required specific grade of bauxite.

In the present study X-ray diffraction technique has been used for qualitative identification and quantitative estimation of the various crystalline phases present in bauxite and thermally treated bauxite samples. Qualitative identification is carried out by comparing the x-ray diffraction pattern (known as diffractogram) of the unknown sample with the internationally recognized International Centre for Diffraction Data (ICDD) reference database which contains the reference patterns for more than 75,000 phases. Using XRD technique, it is possible to detect the phases present in a given sample and their concentration levels.

In this paper an attempt has been made to study the effect of temperature on phase transformation/ conversion of various minerals present in bauxite and also the effect of magnetic properties on thermally treated bauxite samples.

METHODS AND MATERIALS

Bauxite samples from various Indian bauxite deposits like Eastern Ghat -Panchpatmali, Jharkhand and Gujarat have been chosen for the present studies. The representative sample was drawn by conning

and quartering procedure and ground to –50 mesh size and same sample was taken for the further experimental study.

100 gm (–50 mesh) of bauxite sample was taken in china clay crucible and kept in muffle furnace for 60 minutes at 200, 300, 350, 400, 450 and 600 °C for thermal treatment. Further thermal treatment on two bauxite samples has been carried out in Lenton furnace at 400°C with heating and cooling rate of 10 °C and 20°C per minute and residence time for 60 minutes. The purpose of these experiments is to study the effect of temperature in mineralogical transformations in bauxite after rapid heating and slow heating. The above samples have been analyzed using, X' Pert Pro MPD X-ray diffractometer and the quantitative mineralogical composition was determined using XDB software.

The chemical and mineralogical composition of the original and thermally treated bauxite samples is presented in **Table 1 and 2** respectively.

RESULTS AND DISCUSSION

Above experiments leads to following observations.

The chemical analysis shows that as the temperature increases, alumina, iron, titania, and silica contents increases and at same time LOI content decreases gradually (**Table 1**).

The phase analysis results obtained by X-ray diffraction technique shows that as the temperature increased the iron content as well as alumina content in alumo goethite and gibbsite was decreased (**Table 2**). In case of gibbsitic bauxite of Orissa, It is observed that as the temperature increases higher the rate of transformation of goethite to hematite and same time the conversion of gibbsite phase to boehmite at temperature 350-450°C. The alumno goethite to hematite was weak reaction starting about 200°C which gets stronger at 450°C. It is observed that at 450°C significant transformation of gibbsite phase to boehmite and alumno goethite to hematite and unaccounted alumina and iron phase (**Table 2**) which may be in the form of amorphous/ poor crystalline form.

The thermal treatment study on mixed gibbsitic boehmitic Jharkhand bauxite has been carried out at 400° C. The conversion of alumo goethite to hematite and small amount of lepidocrocite and at the same time gibbsite to boehmite phase has been formed with unaccounted alumina and iron which may be in the form of amorphous/ poor crystalline form (**Table 2**).

Table 1: Chemical Composition of Original and Treated Bauxite

S N	Bauxite	Temp (°C)	Al_2O_3 %	SiO_2 %	Fe_2O_3 %	TiO_2 %	LOI %	CaO %
1.	Orissa Bauxite	0.00(original)	54.00	0.63	12.58	2.12	29.95	-
2.		200	54.18	0.68	12.58	2.16	29.68	-
3.		300	58.55	0.79	13.95	1.97	23.81	-
4.		350	62.32	0.81	14.73	2.79	18.52	-
5.		400	68.85	0.90	15.57	2.81	11.32	-
6.		400 (10°/ min.)	70.80	0.96	16.56	2.79	8.19	-
7.		400 (20°/ min.)	71.36	0.96	16.73	2.79	7.78	-
8.		450	71.85	0.99	16.85	2.79	7.08	-
9.	Jharkhand Bauxite	0.00 (original)	44.07	3.60	22.78	8.74	20.55	-
10.		400	52.18	4.05	26.17	9.70	7.66	-
11.	Gujarat Bauxite	0.00 (original)	47.00	1.84	21.25	3.38	25.64	0.54
12.		400	56.00	3.35	26.11	4.30	9.10	0.16

Table 2: Mineralogical Composition of Original and Treated Bauxite Samples by XRD

Sample No	Temp (^{0}C)	Fe_2O_3 in Al-goethite	Al_2O_3 in Al-goethite	Al_2O_3 as Gibbsite	Al_2O_3 as Boehmite	Al_2O_3 as Diaspore	Fe_2O_3 as Hematite	Fe_2O_3 as Magnetite	Fe_2O_3 as Lepidocro	Fe_2O_3% (chemical)	Diff. In analysis	Al_2O_3% (chemical)	Diff. In analysis
Orissa Bauxite (Original)	0.00	10.84	1.22	52.29	0.00	-	2.00	-	-	12.58	-	54.00	-
B-3	300	10.04	1.31	34.64	19.55	-	3.00	-	-	13.95	0.91	58.55	2.64
B-4	350	6.42	0.72	25.49	22.10	-	4.00	-	-	14.73	4.31	62.32	13.42
B-2	400	0.80	0.09	9.15	33.99	-	8.00	-	-	15.57	6.77	68.85	24.83
B-6	400 (10^0/ min.)	0.80	0.09	0.00	29.75	-	9.00	-	-	16.56	6.93	70.80	41.07
B-5	400 (20^0/ min.)	0.40	0.05	0.00	34.84	-	7.50	-	-	16.73	8.66	71.36	35.28
B-7	450	0.40	0.05	0.00	28.47	-	9.00	-	-	16.85	7.45	71.85	41.47
Gujarat Bauxite (Original)	0.00	12.25	1.38	43.30	0.42	-	9.00	-	-	21.25	-	47.00	-
C-2	400	1.60	0.18	-	2.55	1.70	15.00	-	0.90	26.11	7.92	56.00	50.38
Jharkhand Bauxite (Original)	0.00	11.64	1.31	32.35	5.52	0.85	10.00	1.03	-	22.78	-	44.07	-
C-1	400	1.61	0.18	-	22.10	1.70	21.00	-	1.80	26.17	1.77	52.18	26.62

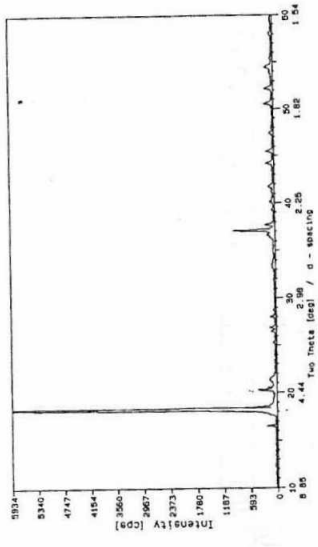

Fig. 1

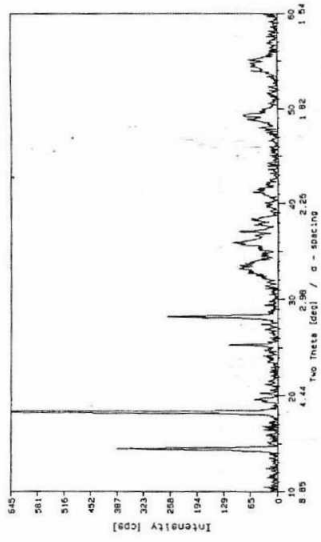

Fig. 2

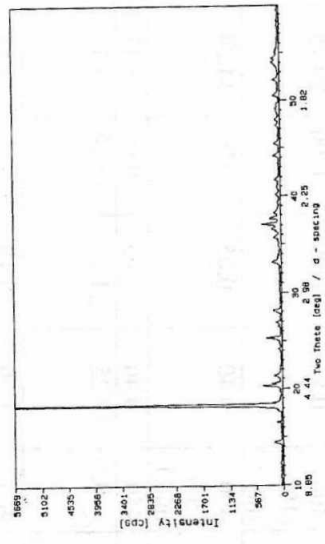

Fig. 3

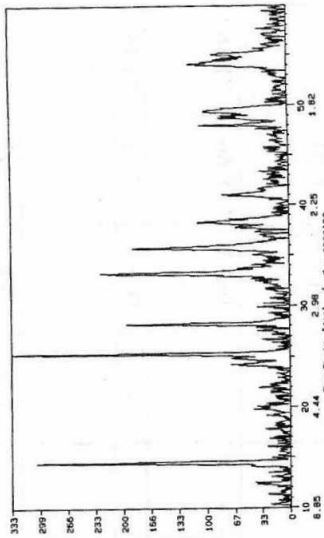

Fig. 4

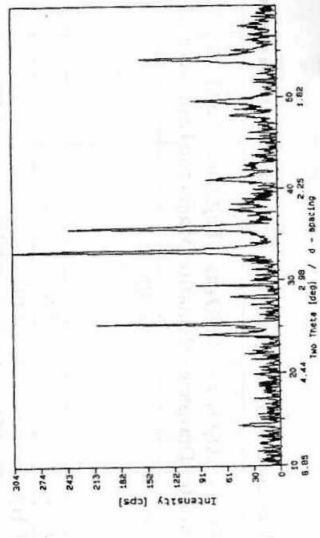

Fig. 5

In case of Gujarat bauxite, it is observed that at 400^0 C phase conversion of alumogoethite to hematite with small amount of lepidocrocite occurred with unaccounted iron. The important observation is that there is no significant phase transformation of gibbsite to boehmite/ diaspore as compared in Orissa and Jharkhand bauxite. Almost all gibbsite was converted into unaccounted alumina may be in the form of amorphous/ poor crystalline and are more as compared to Jharkhand bauxite and Orissa bauxite (**Table 2**). The X-ray diffraction results indicate the formation of lepidocrocite phase in Jharkhand and Gujarat bauxite at 400^0C, however it is not observed in Orissa bauxite at any temperature. As per literature, the ferrihydrate and lepidocrocite phases are formed at 200-300°C.

The thermal studies on Orissa bauxite in slow heating and cooling conditions at 400°C shows encouraging results at 10^0/min as compared to 20^0/min. At 10^0/min maximum goethite transformed to hematite phase and also conversion of gibbsite to boehmite phase (with unaccounted alumina and hematite may be in amorphous nature). However at 20^0/min shows that higher phase transformation of gibbsite to boehmite with unaccounted alumina material and lower transformation rate of hematite as compared to 10^0/min. It indicates as higher heating rate and cooling resulted in conversion of gibbsite to boehmite and unaccounted amorphous phases of alumina and iron.

The phase transformation study has also been carried out at higher temperature i.e. 600^0 C on Orissa, Gujarat and Jharkhand bauxite. The chemical analysis result shows the enrichment of Al_2O_3, Fe_2O_3, SiO_2 and TiO_2 content in treated bauxite with respect to original bauxite. The mineralogical phase of X-ray diffraction studies indicate that maximum transformation of alumo goethite to hematite however it does not show any well defined peaks of the alumina bearing mineral phases due to poor crystalline/ amorphous material.

The diffractogram of treated Orissa bauxite at 200^0C doesn't show any major phase transformation of the minerals. However at 300 and 400^0C shows that conversion of alumo goethite to hematite and gibbsite to boehmite and other minerals (**Fig. 2**). It indicates that the mineralogical changes and phase transformation in bauxite starts from 250^0C and above. The X-ray diffractogram of original bauxite sample is presented in **Fig.1**

The X-ray diffractogram of Jharkhand bauxite at 400^0C shows maximum conversion of alumo goethite to hematite with Lepidocrocite phase (**Fig. 4**) and the diffractogram of original bauxite is given in **Fig. 3**. The diffractogram of thermally treated (at 400^0C) bauxite of Gujarat is presented in **Fig. 5**

Beneficiation Study

Physical (magnetic) separation study on thermally treated bauxite of Orissa using Wet High Intensity Magnetic Separator (WHIMS) has been carried out at 7000 gauss magnetic intensity. It is observed that there is a significant reduction of iron and enrichment of alumina in beneficiated bauxite.

CONCLUSIONS

- The transformation of iron and alumina minerals depends on mineralogy of the bauxite and crystallanity.
- At higher temperature all goethite and gibbsite are converted into hematite and boehmite phases respectively along with amorphous material of both the minerals.
- The rate of transformation of minerals in various bauxite is different even at same temperature
- The rate of heating and cooling is an important factor for the conversion of minerals in bauxite.
- High alumina and low iron bauxite can be produced from beneficiation of thermally treated bauxite.
- More detailed work is required on various bauxite at different time, temperatures and grain size to study the factors affecting conversion of alumo goethite to hematite and also studies of the magnetic properties of thermally treated bauxite.

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