Technology of Scandium Oxide Production from Bauxite Residue

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Abstract

Bauxites in the North of European Russia (i.e. North Urals bauxites – SUBR, Middle Timan bauxites – STBR, North Onega bauxites – SOBR) are characterized by a high scandium content (up to 350 ppm calculated as Sc_2O_3). Most of scandium is isomorphically embedded into the structure of aluminum-containing minerals (boehmite and diaspore), as well as into zircon $ZrSiO_4$ and apatite. These minerals break down during the pressure digestion of the bauxites, so scandium is re-precipitated in form of oxyhydroxide ScO(OH) and sorbed on the surface of bauxite residue particles. UC RUSAL has develop and pilot tested the extraction of scandium oxide from bauxite residue using a sodium bicarbonate solution that enables to dissolve up to 50 % of scandium into the solution followed by precipitation of the concentrate and purification to obtain 99.0 % Sc_2O_3. The extraction uses actual liquors from alumina production and flue gases. SUBR and STBR bauxites contain a number of REM elements (e.g. zircon, titanium, hafnium, copper, yttrium, thorium, etc.). Chemical behaviour of said REMs during the sodium bicarbonate digestion is similar to the behaviour of scandium. To obtain pure scandium oxide (2N) ($Sc_2O_3 \geq 99.0$ wt.%) without radioactive impurities effective purification of Sc-containing concentrate was developed. The entire process does not use any technologies, which are not applied in alumina production (sorption, extraction, multiple-stage hydrolysis, etc.), therefore, it can be integrated into the Bayer process, as all intermediate products and tailings are recycled into the main process. Moreover, resulting mutual neutralization of some streams allows obtaining a high-grade REM concentrate. Scandium oxide can be produced with minimal operational costs and high total recovery of scandium. The additional advantage of this process lies in reducing the carbon footprint of alumina production due to the use of flue gases containing up to 8 vol.% CO_2, as well as alkali neutralization in the bauxite residue.

Keywords: Scandium oxide, Bauxite residue, Yttrium, Thorium, REM, Neutralization, Carbon footprint.

1. Scandium, Yttrium, REMs, etc. in Bauxites from the North of Russia and their Behaviour in the Bayer Process

RUSAL's Bogoslovsky Alumina Refinery (BAZ refinery) processes ≈ 85:15 mixture of diasporic bauxites from the North Urals deposit (SUBR bauxite) and boehmitic bauxites from the Middle-

Timan deposit (STBR bauxite) at a digestion temperature of 230÷235 °C and residence time of ≈ 2 hours and high caustic soda concentration.
Under such severe digestion conditions almost all bauxite rock-forming minerals decompose (including boehmite, diaspore, kaolinite, chamosite, al-goetite, anatase, rutile, pyrite, calcite, zircon, etc.). The only mineral that is not altered is hematite, which contains approx. 30 % of scandium that could not be extracted by using sodium bicarbonate digestion. Bauxite residue (BR) contains the following phases:

- sodium hydroalumosilicate (DSP) of sulfate-cancrinite type with general formula $Na_6Ca[AlSiO_4]_6(SO_4)\times1.7H_2O$;
- calcium hydrogarnet (HG) represented by formula $Ca_3(Al,Fe)_2[SiO_4]_{1.4}\times(OH)_{9.2}$;
- perovskite with the formula $CaTiO_3$.

Scandium and a number of other impurities demonstrate the following behaviour.

1.1 Scandium

Due to specific conditions of the bauxite formation in the North of the European Russia, scandium is present in boehmite and diaspore, which act as so-called geochemical traps. Over 50 % of scandium is isomorphically bonded in the structure of two polymorphic aluminium oxyhydroxides, i.e. diaspore and boehmite (γ- и α-AlO(OH)) [1].

Some references discuss several polymorphic modifications of scandium oxyhydroxide, including γ-ScO(OH) and α-ScO(OH), which are similar to boehmite and diaspore [2] (see Table 1).

Table 1. Structural characteristics of Sc, Y, Al and Fe hydroxides, oxyhydroxides and oxides.

#	Formula/mineral phase	Crystal system	Unit cell parameters, Å		
			a	b	c
1	$Sc(OH)_3$	hexagonal	5.84	5.84	3.45
2	$Sc(OH)_3$	cubic	7.88	7.88	7.88
3	γ-ScO(OH)	rhombic	4.02	13.04	3.24
4	ScO(OH)	tetragonal	5.23	5.23	5.05
5	α-ScO(OH)	rhombic	4.76	10.30	3.21
6	$Sc_2O_3\cdot0.2H_2O$	cubic	9.82	9.82	9.82
7	$Sc_2O_3\cdot1.3H_2O$	cubic	9.82	9.82	9.82
8	Sc_2O_3	monoclinic	13.36	3.22	8.06
9	Sc_2O_3	hexagonal	3.39	3.39	5.66
10	Sc_2O_3	cubic	9.79	9.79	9.79
11	$Y(OH)_3$	hexagonal	6.26	6.26	3.54
12	YO(OH)	monoclinic	4.28	3.63	6.05
13	α-$Y(OH)_3$	monoclinic	6.25	6.01	15.40
14	Y_2O_3	hexagonal	3.66	3.66	5.92
15	Y_2O_3	monoclinic	14.12	3.52	8.69
16	Y_2O_3	rhombic	5.71	3.20	12.16
17	Y_2O_3	cubic	5.26	5.26	5.26
18	$Al(OH)_3$ (gibbsite)	monoclinic	8.54	5.07	9.72
19	$Al(OH)_3$ (bayerite)	monoclinic	5.06	8.67	4.71
20	γ-AlO(OH) (boehmite)	rhombic	3.09	12.24	2.86
21	α-AlO(OH) (diaspore)	rhombic	4.40	9.39	2.83
22	γ-FeO(OH) (lepidocrocite)	rhombic	3.86	12.50	3.06
23	α-FeO(OH) (goethite)	rhombic	4.61	9.96	3.02
24	γ-Fe_2O_3 (maghemite)	cubic	8.32	8.32	8.32
25	α-Fe_2O_3 (hematite)	rhombic	4.91	4.91	13.26

Due to small production capacities this yttrium concentrate is currently of no commercial value, but upon scaling-up of the production it has the potential of becoming a marketable product.

9. Conclusions

Boehmite and diaspore in the SUBR and STBR bauxites are characterized by a high content of scandium. When these bauxites are processed by the Bayer process scandium is sorbed on the surface of bauxite residue, mainly in form of γ-ScO(OH) and can be easily extracted by a sodium bicarbonate solution. Therefore, this bauxite residue can be considered one of the largest sources of scandium. Additionally, along with scandium a lot of elements with similar chemical properties go into the bauxite residue, i.e. yttrium, hafnium, REMs, etc.

RUSAL Engineering and Technology Center is mastering a technology for extracting scandium oxide from the bauxite residue to produce 2N scandium oxide product at a large-scale pilot facility at Bogoslovsk alumina refinery. Trial batches of scandium oxide have been obtained using the novel technology that are used for production of Al-Sc alloys and Al-Sc master alloys at the facilities of RUSAL Engineering and Technology Center. Scaling-up of the BAZ pilot facility will enable to launch the full-scale production of scandium oxide.

The advantage of the novel technology lies in reducing carbon footprint of the main alumina production process due to the use of kiln flue gases containing up to 8 vol.% CO2, that also results in the BR neutralization.

A reliable and reproducible process have been developed for removing zirconium, titanium, copper, yttrium, thorium and other REMs from scandium by extraction of double salt of scandium sulfate and ammonium sulfate ScNH4(SO4)2. Ammonium purification does not increase or generate any additional tailings. Moreover, neutralization of resulting spent solutions enables to obtain one more product, i.e. 60 % yttrium concentrate containing ~ 15 % of medium REMs.

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