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Activation of Hydrometallurgical Treatment of PbS in Nitric Solutions

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Abstract

The results of experimental work on lead extraction with nitric solutions of $Fe(NO_3)_3$ from PbS lead concentrate after its mechanical activation are reported.

INTRODUCTION

The extraction of nonferrous metals from mineral raw material by means of leaching to a greater extent proceeds in the diffusion regime. The processes under development in hydrometallurgy of lead are not an exception. An increase in the rate of PbS dissolution is possible both due to the changes in the salt composition of the aqueous phase and due to activation of the solid component. new processes involved in lead production [1] were proposed mainly for the extraction of Pb–Zn from the intermediate product of pyrometallurgy, while the autoclave processes are still under investigation. The processes in nitric solutions have been tested for the treatment of PbS from the sulphide concentrates [2–5]. We investigated the extraction of lead from PbS lead concentrate in the system $Fe(NO_3)_3 - HNO_3 - H_2O$ in the low-temperature mode.

EXPERIMENTAL

Lead sulphide (mineral) was isolated from the sulphide lead concentrate of one of the deposits in Siberia; the concentrate was obtained under industrial conditions using the lead-zinc ores from the Krasnoyarsk Territory; it contained 57.9 % Pb (PbS), 2.6 % Zn (ZnS), 10 % Fe (~20 % $FeCO_3$). The $Fe(NO_3)_3$ $9H_2O$ salt of the «ch.» grade (pure) and nitric acid «kh. ch.» (chemically pure) were used as reagents.

The treatment was carried out in a thermostated reactor (cell) with different working solution volume (50–500 ml) and with the possibility to sample the pulp for analysis. Lead sulphide was admitted in the cell after the necessary solution temperature was achieved. The suspension was mixed with a magnetic or mechanical mixer. The dissolution of PbS was monitored according to the data of analysis of pulp samples. The solutions were analyzed for Pb, Fe by means of atomic absorption and chelatometry. Insoluble residues (i. r.) were analyzed using chemical and X-ray methods for the content of PbS, $PbSO_4$, S^0 phases [7, 8]. The DRON-3 instrument (CuK_α radiation with monochromatization of the diffracted beam) was used. According to the data of analyses of solutions, Pb and Fe fractions extracted were calculated; the degree of PbS treatment was determined taking into account the data obtained by chemical and X-ray examination of the i. r. with an estimation of the formation of new compounds in the solid phase ($PbSO_4$, S^0).

RESULTS AND DISCUSSION

The use of HNO_3 for the extraction of lead from PbS is efficient only when leaching is carried out at the temperature not lower than 50 °C and initial concentration more than 2.5–3 mol/l (Fig. 1). The decomposition of galena at a level of 84–92 % is achieved under these conditions (curve *4*); the time of experiment is 55–60 min.

The dissolution process is substantially changed in a salt system $Fe(NO_3)_3 - HNO_3 - H_2O$ (see Fig. 1, curves *5*, *6*). One can see that in this case we need not heat the system or create high HNO_3 concentration (5–10 g/l). The decomposition of the mineral by more than 91 % was achieved within 25–30 min (see Fig. 1, curve *6*). Theoretical foundations of MeS oxidation in aqueous salt solutions were described in [5].

The state of PbS surface in the mineral differs from that in the lead concentrate. During dressing lead-zinc ores, the PbS mineral gets partly oxidized with the formation of $PbSO_4$ on the surface; in addition, adsorption of floatation agents is possible. The indicated factors bring complications into the dissolution of PbS due to its inaccessibility for the solvent ions.

Mechanical activation (MA) is one of the methods to prepare mineral raw material for leaching. By means of MA, lead concentrate can be made homogeneous in particle size by excluding conglomerates formed during dressing; the particles can also be purified from floatation agents. The results of leaching galena after MA in $FeCl_3$ solution are discussed in [6]. The process was carried out at a temperature above 50 °C. In our experiment, MA of lead concentrate was carried out in a ball activator for 1, 5 and 15 min.

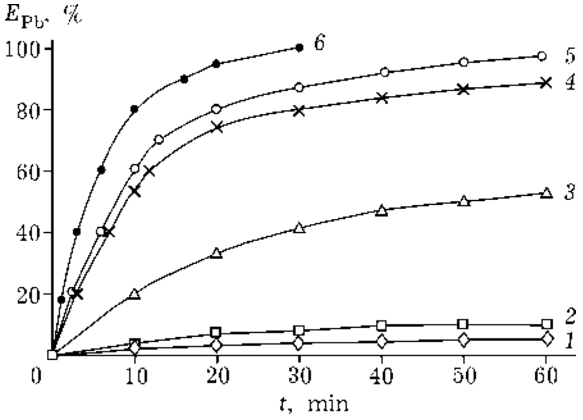

Fig. 1. Kinetics of lead extraction from galena in the solutions of nitric acid. HNO_3 concentration, mol/l: 0.5 (*1*), 1.0 (*2*), 2.0 (*3*), 5.0 (*4*), 1.0 + 0.1 M Fe^{3+} (*5*), 0.1 M + 0.3 M Fe^{3+} (*6*); *T*, °C: 51–52 (*1–5*), 20 (*6*).

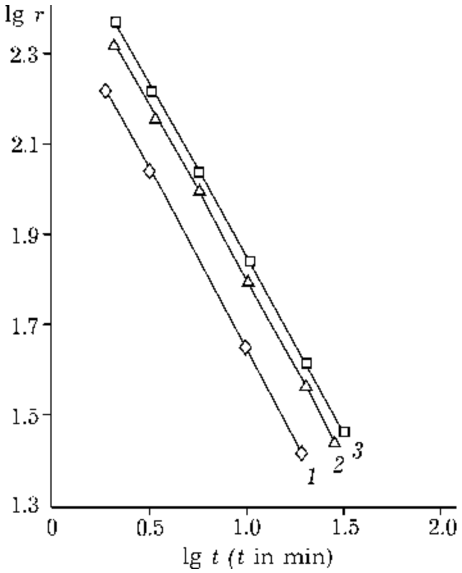

Fig. 2. Changes in Pb leaching rate before (*1*) and after MA of the concentrate for 5 (*2*) and 15 min (*3*) in 0.5 M $Fe(NO_3)_3 + H_2O$ solution.

It was established that the specific surface of particles of the concentrate increases, but aggregation of the particles occurs during MA for 5 and 15 min:

Activation time, min	Specific surface, m^2/g
0	1.64
1	4.79
5	2.54
15	2.95

Changes in the particle size, in the structure of the mineral, and possible opening of the sulphide surface together accelerate leaching lead from the concentrate treated by MA (Fig. 2).

The analysis of the behaviour of straight lines depicting lg *r* leaching rate of lead from the concentrate before and after MA proves that the process follows the same reaction in both cases:

$$PbS + 2Fe(NO_3)_3 + H_2O = Pb(NO_3)_2 + 2Fe(NO_3)_2 + S^0 + H_2O \quad (1)$$

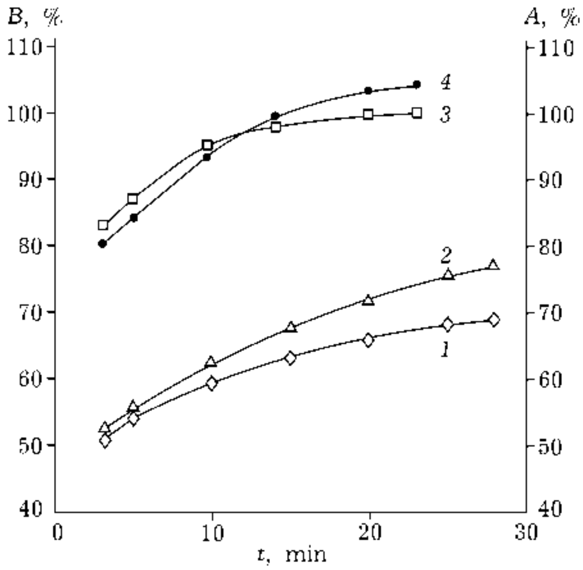

Fig. 3. Lead fraction (*A*) extracted from the PbS lead concentrate (*1, 3*) and the consumption of Fe^{3+} (*B*) with respect to the TNA (*2, 4*): *1, 2* – before MA, *3, 4* – after MA for 5 min.

X-ray investigations of the insoluble residues after leaching and the quantitative data on lead extraction (Fig. 3) indicate that the consumption of Fe^{3+} ions (theoretically necessary amount (TNA) calculated according to the reaction stoichiometry) (see Fig. 3, curves *2, 3*) is higher than lead extraction (curves *1, 4*). For the concentrate after MA, the consumption of Fe^{3+} only insignificantly differs from the TNA. Lead fraction extracted from PbS concentrate after MA exceeds 99.5–99.7 %; SiO_2, S^0, $PbSO_4$, $FeCO_3$ remain in the insoluble residues after leaching the mechanically activated concentrate.

CONCLUSIONS

1. It is demonstrated that the nitric treatment of the initial lead sulphide is achieved in the HNO_3 solution with concentration more than 1.5 mol/l and temperature 80–85 °C.

2. The application of the aqueous salt system $Fe(NO_3)_3$ – HNO_3 – H_2O allows one to carry out the treatment in the low-temperature mode (15–25 °C) with the amount of Fe^{3+} ions theoretically necessary for the oxidation of PbS (according to reaction (1)).

3. Mechanical activation of the initial sulphide product increases the rate of lead leaching and its fraction extracted into solution.

4. It is necessary to use $Fe(NO_3)_3$ salt and to carry out mechanical activation of the concentrate in order to intensify hydrometallurgical treatment of PbS in nitric solutions.

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