



# Combined mechanochemical and thiosulphate leaching of silver from a complex sulphide concentrate

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## Abstract

The intensification of the thiosulphate leaching of silver from a silver-bearing complex sulphide concentrate (Casapalca deposit) using mechanochemical alkaline leaching as the pretreatment step was investigated. The leaching of “as-received” concentrate with the thiosulphate solution afforded only 6% recovery of Ag into leach. The mechanochemical pretreatment resulted 85% amorphization of tetrahedrite as a silver-bearing mineral in the concentrate as well as an increase in specific surface area from the original value of  $0.26 \text{ m}^2 \text{ g}^{-1}$  to a maximum value of  $15.7 \text{ m}^2 \text{ g}^{-1}$ . The pretreatment was performed in a stirred ball mill using variable milling times and sample weights. The physico-chemical changes in the concentrate as a consequence of mechanochemical pretreatment had a pronounced influence on the subsequent silver extraction. The optimum results from mechanochemical pretreatment and subsequent leaching of the concentrate with ammonium thiosulphate were achieved by using a milling time of 60 min and a weight of sample of 60 g. In this case, 99% recovery of Ag was achieved after only 3 min of leaching. © 2005 Elsevier B.V. All rights reserved.

*Keywords:* complex sulphide concentrate; silver; mechanochemical pretreatment; thiosulphate

## 1. Introduction

Hydrometallurgical processes are especially suitable for the treatment of silver-bearing sulphidic materials. A great number of silver-bearing minerals exist in nature. Gasparri (1984) states over 200 minerals bearing silver in major, minor and variable amounts. However, of these, only 10–12 minerals are of practical importance. One of these minerals is

tetrahedrite, which belongs among silver sulphides with bad leachability.

Modern hydrometallurgy of silver is based on the application of cyanide leaching. The cyanide process is a highly toxic technology. Silver is sometimes finely disseminated in sulphidic minerals and cannot come in contact with cyanide solution. Classical cyanide leaching of the sulphides results in 5–10% Ag extraction (Lodejščík and Ignateva, 1973).

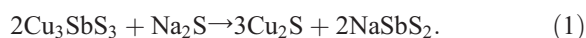
Chemical, biological and physical pretreatments have been applied to sulphide ores and concentrates with the aim of changing the chemical composition

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and/or the particle sizes of the silver-bearing sulphides, thus facilitating the subsequent leaching in order to increase the recovery of noble metals (La Brooy et al., 1994; Ficeriová et al., 2002).

Intensive milling as a pretreatment of sulphide minerals has been applied in recent years (Baláž, 2000). Mechanical activation induces significant changes to both the surface and bulk structure of minerals. It increases the fraction of fine particles and the specific surface area, and decreases the crystallinity of these mineral components of a concentrate. The relatively new process of mechanochemical pretreatment is now being successfully applied in plant operations. Among modes of mechanochemical pretreatment, mechanochemical leaching seems to be very promising. Mechanochemical leaching integrates milling and leaching operations into a single step. In addition to an improvement in milling performance (the leaching agent also acts as a milling additive) there are operational benefits relating to the economy of the overall process.

Alkaline leaching using  $\text{Na}_2\text{S}$  and  $\text{NaOH}$  has been shown to be effective for the decomposition of silver-bearing antimony and arsenic sulphosalts (Baláž, 2000). The chemistry of the reaction between tetrahedrite and  $\text{Na}_2\text{S}$  can be described (Anderson and Nordwick, 1996) in simplified form by equation



Ammonium thiosulphate has been used by the authors in the presence of an oxidizer as an alternative solvent for treating tetrahedrites as well as silver-bearing concentrates. Thiosulphate has the ability to bind silver in a form of stable soluble complex. Moreover, ammonium thiosulphate is relatively non-toxic; it has been used for many decades as a fertilizer and, consequently, from an environmental standpoint, has a definite advantage over cyanide (Hiskey and Atluri, 1988). Comparing reagent unit costs, ammonium thiosulphate is far cheaper than sodium cyanide (US\$ 0.13/kg vs US\$ 1.80/kg). Consequently, with similar or even slightly higher lixiviant consumption, the application of thiosulphate for silver recovery can be economical and compete effectively with cyanidation (Molleman and Dreisinger, 2002).

This paper investigates the combined process of mechanochemical and chemical leaching of silver from a complex sulphide concentrate with tetrahedrite

as the main silver-bearing component in the concentrate. This process comprises mechanochemical leaching in alkaline sodium sulphide medium to decompose the sulphide followed by leaching in ammonium thiosulphate to extract the silver.

## 2. Experimental

### 2.1. Materials

A silver-bearing complex sulphide concentrate from Casapalca, Peru was used to test the effect of mechanochemical leaching and subsequent thiosulphate leaching of silver. The chemical composition of the “as-received” concentrate is given in Table 1.

### 2.2. Physicochemical characterization

The specific surface area ( $S_A$ ) was determined by the BET technique using low temperature nitrogen adsorption in a Gemini 2360 sorption apparatus (Micromeritics, USA).

X-ray diffractometry was accomplished by using a DRON 2.0 diffractometer with a GUR-5 goniometer (Techsnabexport, Russia) equipped with an  $\text{FeK}_\alpha$  source operating at 25 kV and 10 mA. Data were collected every 2 s and the detector was moved at a rate of  $2^\circ \text{ min}^{-1}$ . The effect of mechanochemical and mechanical treatment was evaluated by an increase in the X-ray amorphous portion of the sulphide minerals compared with the reference sample (“as-received”) which is assumed to correspond to 100% crystallinity,  $X$ . It holds that:

$$X = \frac{U_0}{I_0} \cdot \frac{I_X}{U_X} \cdot 100 [\%]. \quad (2)$$

where  $U_0$  and  $U_X$  denote the backgrounds of “as-received” (reference) sample and activated sample, while  $I_0$  and  $I_X$  are integral intensities of diffraction

Table 1  
Chemical composition of the “as-received” Casapalca concentrate

Components [%]										
Ag	Au	Cu	Pb	Zn	Fe	Sb	As	S	Na	$\text{SiO}_2$
15 500	0.9	19.49	16.52	8.8	3.35	8.25	3.23	29	0.02	0.73
[ppm] [ppm]										

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