

INTRODUCTION

Chapter 1

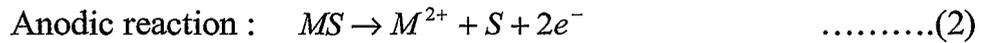
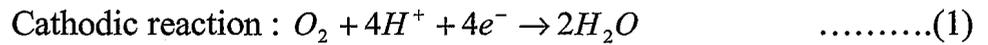
The general practice of the extraction of an economic valuable metal from sulphide ores is by means of conventional pyrometallurgical methods. These methods involve the high cost of energy input needed to attain the high temperatures at which pyrometallurgical processes function. The cost increases further if low-grade sulphide ores are involved due to a larger tonnage throughput required for a specific metal production target as well as the fact that more intensive processing is necessary to produce high metal recoveries from low-grade ores. In addition to the release of sulphur compounds such as SO₂ into the open atmosphere the environmental pollution problem has yet to be satisfactorily tackled.

In contrast, hydrometallurgical techniques are often preferred in the processing of complex sulphide minerals due to advantages such as low cost, better energy efficiency, fewer environmental hazards, by-product recovery and suitability for the treatment of small tonnage deposits (Yelloji Rao & Natarajan, 1988:403).

Hydrometallurgical processes are based on the chemistry of aqueous solutions. Leaching is the primary extractive operation in hydrometallurgical processes and is the process by which a metal of interest is transferred from the naturally occurring minerals into an aqueous solution. In general, with low-grade sulphide ores, a concentrate is produced which is then further treated to extract the valuable base metals. Metal sulphides are practically insoluble in water, even at temperatures as high as 400°C, but in the presence of oxygen, they are solubilised as sulphates. Furthermore, if leaching is undertaken under oxygen pressure, the reactions are exothermic, and cooling rather than heating is required (Woollacott & Eric, 1994:329 and Habashi, 1970:103).

According to Habashi (1970:108) aqueous oxidation of sulphides may be classified into five different mechanisms, depending on the leach conditions: *adsorption complexes mechanism, H₂S as intermediate product, oxide and elemental sulphur as intermediate*

products, oxide and SO₂ as intermediate products and the electrochemical mechanism. The extent of these mechanisms is described in section 2.5.2. In the present research project the electrochemical mechanism is discussed and the reactions can be represented by the following formula:



The liberated metal ion and elemental sulphur formed, undergo further reactions, depending on the conditions present in the experiment. For example, in the presence of oxygen the sulphur undergoes oxidation according to the following reaction:



At a pH less than three and a temperature of 110°C, the main oxidation product of a metal sulphide is elemental sulphur and above this temperature mainly sulphate ions are formed. The metal ion undergoes hydrolysis depending on the pH at which the experiment is done (Habashi, 1970:112).

The prime objective of this investigation was to study and evaluate possible factors influencing the extraction, by means of oxidative pressure-acid leaching also known as the Activox[®] process, of nickel, copper and cobalt from a sulphide concentrate containing pyrrhotite (Fe_{1-x}S), pentlandite (Ni,Fe)₉S₈ and chalcopyrite (CuFeS₂).

The pressure-acid leaching process, studied in the present investigation, can be described in simple terms as a process where the sulphide concentrate is mixed with water and sulphuric acid and then placed under pressure and elevated temperature in an autoclave (pressure vessel). Under specific conditions, in the presence of oxygen, the valuable metals are transferred from the naturally occurring minerals into an aqueous solution.

In previous research (Ximming *et al.*, 1997:143) it was suggested that nickel, copper and cobalt cannot be extracted successfully from a sulphide concentrate at reasonable

temperatures and retention times by means of oxidative pressure-acid leaching, unless the mineral is pre-treated in some fashion to increase its reactivity, or temperatures exceed 200°C. The application of attrition grinding, as a pre-treatment method, is investigated in the present research project to verify these suggestions.

Hypotheses

The formulation of the following hypotheses emanates from relevant literature:

1. The main oxidising products in a leaching process of sulphides will be elemental sulphur and metal sulphates when leaching has been carried out under 120°C in an acidic medium.
2. Attrition grinding, as a pre-treatment process, will offer significant advantage for the processing of complex sulphides.
3. If a leaching process is diffusion-controlled, then it will be greatly influenced by the speed of agitation. On the other hand, if it is chemically-controlled then it will not be influenced by agitation, provided that sufficient agitation occurs to prevent the solids from settling.
4. The leaching rate increases with increasing temperature. However, this increase is much less remarkable for a diffusion-controlled process than for a chemically-controlled process.
5. The rate of leaching increases with increasing leach agent concentration.
6. The rate of leaching increases with decreasing pulp density.
7. An increase in oxygen partial pressure enhances the leaching kinetics.
8. Oxidative pressure-acid leaching of chalcopyrite, (CuFeS₂), at low temperature (110°C) is slow and ineffective, whilst pentlandite (Ni,Fe)₉S₈ oxidises completely at near ambient temperatures and pressures.