



Use of amino acids for gold dissolution

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ARTICLE INFO

Keywords:

Gold leaching
Cyanide alternatives
Organic solvent

ABSTRACT

As oxidants under alkaline conditions. To analyze the kinetics of leaching, tests were performed using electrical contacts pins and sheets of pure gold to avoid the effects of pore diffusion. The efficiency of each oxidant was evaluated, for concentrations of 0.004, 0.01 and 0.03 M, at pH values of 9.4 and 11. At the end of each test, the solid residue was analyzed to determine the total grade and percentage of metal extraction. The experimental results indicated that the percentage of gold extraction was affected by the oxidant concentration and the pH. Furthermore, it improves with the presence of Cu^{2+} ions, increasing by 100% for glycine and approximately 6 fold for glutamate as compared to glycine solutions. In assessing the percentage of gold extraction in the different conditions at 25 and 40 °C, it was observed that the kinetics of extraction is sensitive to temperature change, which suggests that the leach is chemically controlled.

1. Introduction

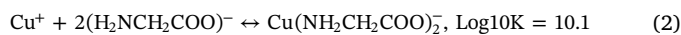
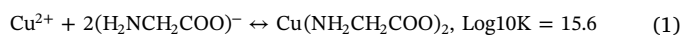
The extraction of gold from its minerals is achieved through hydrometallurgical processes, where the traditional process of cyanidation has dominated. Since the beginning of the 20th Century, the acceptance of cyanidation by gold producers is a tribute to its effectiveness (Avraamides, 1982). As a process, it has resisted economic difficulties imposed by the fall in the price of gold, and the introduction of Carbon in pulp (CIP), has tended to make it even more attractive as a leaching system.

The main disadvantage of cyanidation is its toxicity. The environmental problems associated with the leakage of cyanide into ground-water systems and the health risks inherent in the use of this on any scale are a strong drawback (Avraamides, 1982). Furthermore, its instability, its high affinity with other elements, the decrease easily extracted gold and the presence of refractory minerals that are not susceptible to cyanide, sometimes cause relatively high operating costs. (Poisot, 2010).

For that reason, there is a clear need to implement clean technologies for the extraction of silver and gold, that increase productivity by avoiding the generation of waste contaminants (The corral, 2003). The scientific community has proposed alternative hydrometallurgical processes for the dissolution of these precious metals using thiosulphate, thiourea, chlorine, thiocyanate, among others. An alternative route could employ other organic ligands, that can compete with the cyanidation in cost, performance and effectiveness (Guzmán, 2013; Galindo, 2013).

In this study, a method was evaluated for the recovery of gold from computer contact pins and a sheet of pure gold, using alkaline solutions of amino acids such as glycine and monosodium glutamate. The selection of these reagents was based on a review of scientific literature (Aylmore, 2005; Eksteen and Oraby, 2015a,b,c), where the former conducted a review of different methods of gold leaching as an alternative to cyanidation, mentioning the dissolution with amino acids and using as potassium permanganate oxidizing agent. Meanwhile Eksteen and Oraby performed the leaching of metallic gold using amino acids such as glycine, alanine and histidine at low concentrations, in alkaline solutions with hydrogen peroxide (H_2O_2), evaluating the influence of reagent concentration, temperature and presence of sulphide minerals in the rate of leaching.

This methodology could represent an alternative to cyanide for gold recovery and could diminish the environmental impacts generated by the inadequate handling of the compounds used for gold beneficiation. Oraby and Eksteen (2014) also evaluated the extraction of copper and gold from a copper concentrate employing glycine; their results show a copper extraction of nearly 96%. However, a very low content of gold was found in solution, using hydrogen peroxide at pH values between 8 and 11. The reactions below indicate a strong affinity of copper with glycine, both in the cuprous as well as cupric oxidation states:



Therefore, further study is warranted to evaluate the ability of

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amino acids in general, not only to enhance, but to completely replace cyanide as a ligand for gold extraction. In the present work, two amino acids, glycine and glutamate, were employed.

2. Materials and methods

All leaching experiments were carried out using pins from computers and thin gold sheets, to avoid the effects of pore diffusion, common in mineral, and to evaluate gold dissolution with these selected amino acids. The pins are electrical contacts, composed of gold-plated metal alloys. Therefore, these pins, due to its characteristics and its relatively low cost, became the ideal material to assess the conditions in which gold dissolves in aqueous solutions of these organic ligands (amino acids). The results obtained with the pins were compared with two tests performed on samples cut from a pure gold sheet (99.95%, Sigma-Aldrich). The organic ligands (glycine and glutamate) and oxidizing agents (hydrogen peroxide (30% w/v) and potassium permanganate) employed in this work were of analytical grade. For pH adjustment, NaOH was used.

The pins were characterized by scanning electron microscopy SEM-EDX (ZEISS EVO MA10), in order to estimate the chemical elements present and their distribution. A sample of these was digested in a mixture of nitric acid and hydrochloric acid, later the elemental composition of this solution was determined by using atomic absorption spectrophotometry (Varian SpectraAA 220fs).

The pins were subjected to a pre-treatment, which consisted in the placement of 5 g of pins into 200 ml of 1.8 M H_2SO_4 and 7.8 M H_2O_2 aqueous solution for 3 h, mixing at 300 rpm, to eliminate the presence of other metals that might affect the gold leaching process. The filtered residue contained mainly gold.

Leaching experiments of the residue were performed in aqueous solutions of 0.5 M glycine or glutamate, with potassium permanganate or hydrogen peroxide as oxidizing agents (Eksteen and Oraby, 2015a,b,c). Liquid samples of 0.5 ml were drawn at 1, 2, 4, 6, 23 and 24 h. Each of the samples was filtered and analyzed to determine the gold content in solution by the atomic absorption spectrophotometer.

In Table 1 is shown the conditions of the leach test, where the pH value of 9.4 was selected based on the thermodynamic analysis (see below), while the pH 11 and the initial concentration of oxidizing agent to the 0.03 M was based on previous work (Eksteen and Oraby, 2015a,b,c) (Aylmore, 2005). Once the leach time was completed, the solution was filter and the leach residue was digested using a mixture nitric and sulfuric acids, which was analyzed by atomic absorption spectrophotometry, to determine the final gold content and to carry out the mass balance.

3. Thermodynamic analysis

The thermodynamic analysis was performed with the Hydra – Medusa software suite, where the effect of the concentration of oxidizing agent and pH, to determine the potentially adequate conditions and interpretations of the kinetics for gold leaching. The stability constant for the complex gold-glycine complex was given by Aylmore (2005) and the reagent concentrations to be evaluated by Eksteen and

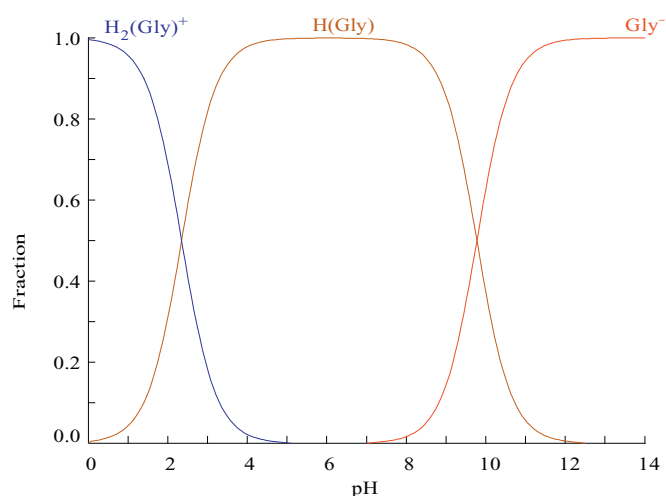


Fig. 1. Species distribution diagram as a function of pH for glycine at 25 °C, $[\text{Gly}] = 0.5 \text{ M}$.

Oraby (2015a,b,c). No value was found for the gold-glutamate complex; given its chemical similarity to glycine (glutamate has an additional carboxylic group), similar behavior can be assumed.

In Fig. 1 is presented the species distribution diagram for 0.5 M glycine as a function of pH. At alkaline pH, the dissociation of the glycine increases, thus achieving the highest concentration of glycinate available to form complexes with gold or any other metal.

Aylmore (2005) reported a \log_{10} (stability constant) of 18 for the gold (I) - glycine complex. In Fig. 2 is shown the diagram of thermodynamic stability Eh-pH for the gold-glycine at room temperature in 0.5 M of glycine. As may be noted, the elemental gold is the species stable at all values of pH and potential under 0.5 V; for higher values, there is a zone of stability for the formation of the complex gold-glycine, although the lowest oxidation potential is reached at pH 9.4. Meanwhile, Fig. 3 shows the diagram of thermodynamic stability Eh-pH for the gold-glycine at temperature of 40 °C in 0.5 M of glycine. As may be noted, the elemental gold is the species stable at all values of pH and potential under 0.5 V; for higher values, there is a zone of stability for the formation of the complex gold-glycine, although the lowest oxidation potential is reached at pH 9.4. However, at higher values of potential of 0.5 V and pH 11, the predominant species is $\text{Au}(\text{OH})_2^-$, which

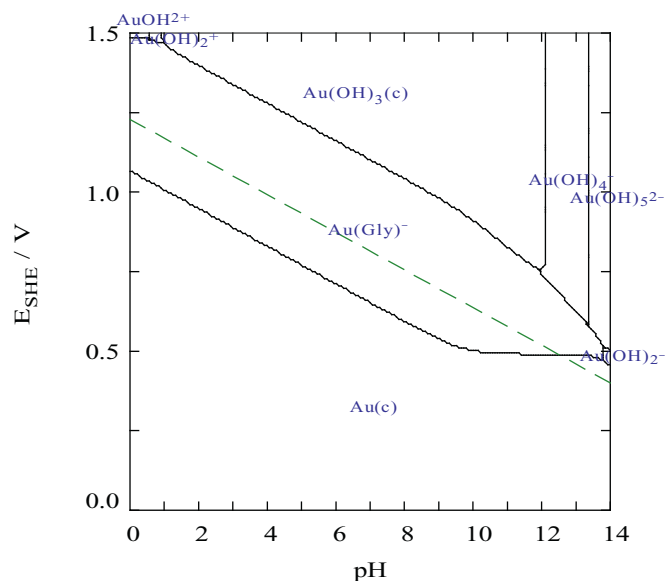


Fig. 2. Eh-pH diagram for the Au-glycine system at 25 °C, $[\text{Au}] = 10^{-5} \text{ M}$, $[\text{Gly}] = 0.5 \text{ M}$.

Table 1

Conditions of the computer pin leaching experiments.

Reagents	Oxidizing agents (concentration)	pH
Glutamate	KMnO_4 (0.03 M)	9.4
Glutamate	H_2O_2 (0.03 M)	9.4
Glutamate	KMnO_4 (0.01 M)	11
Glutamate	KMnO_4 (0.04 M)	11
Glycine	H_2O_2 (0.03 M)	9.4
Glycine	KMnO_4 (0.01 M)	11
Glycine	KMnO_4 (0.04 M)	11

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