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Technical Note

Investigation of the Recovery of Gold from Cell Phone Scraps by L-Valine Amino Acid

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Abstract: The printed circuit boards of mobile phones contain precious metals such as gold, platinum, and palladium, with 542, 30, and 26 ppm, respectively, and among the available base metals, copper constitutes the highest weight percentage (30.675%). Therefore, the recycling of this waste is very important not only from an environmental point of view but also from an economic point of view. the leaching operation, was performed, on the original sample printed circuit boards of mobile phones and cakes obtained from leaching with sulfuric acid by the amino acid L-valine and the effect of parameters such as L-valine concentration, temperature, pH, time, the oxidizing amount, the pulp density on the gold recovery was investigated and compared. The results showed that the parameters of temperature, leaching time, pH, relative to pulp density, L-valine concentration, and the amount of oxidant are more important in gold recovery, respectively. Recovery of gold leaching with L-valine amino acid under optimal conditions of L-valine concentration of 200 g/t, temperature 80 °C, pulp density 10%, oxidizing amount of 50 ml/l, pH 11.5, and leaching time 32 hours on the original sample and the cake obtained from leaching with sulfuric acid were 62.23% and 87.34%, respectively. In other words, by acid leaching with sulfuric acid before leaching with amino acid L-valine, the recovery of gold leaching by L-valine increases by about 25.11%.

Keywords: Gold leaching, PCB waste, Copper leaching, L-Valine amino acid.

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INTRODUCTION

Technological advances in electrical and electronic equipment and the diversity of people in the use of new equipment have made the issue of electronic-waste (e-waste) a major global problem [1]. The process of recycling e-waste usually includes the stages of separation, shredding, and processing, and in the processing stage, one of the physical or mechanical processes, hydrometallurgy, pyrometallurgy, bio hydrometallurgy is performed [2]. Recent research has shown that the use of amino acids in combination with hydrogen peroxide (as an oxidizer) to leach gold from gold ores and e-waste as an environmentally friendly method reduces the consumption of the leaching agent and increases metal recovery. It is valuable and has no environmental problems related to sodium cyanide (due to toxicity and hydrogen cyanide gas production). The mechanism of gold leaching by the amino acid L-valine using hydrogen peroxide and air oxidizers has been shown in reactions 1 and 2, respectively [3].

$$2Au + 4[NH_2CH(C_3H_7)COOH] + 2OH^- + H_2O_2 \rightarrow 2Au[NH_2CH(C_3H_7)COO]^-_2 + 4H_2O \quad (1)$$

$$2Au + 4[NH_2CH(C_3H_7)COOH] + 1/2O_2 + H_2O \rightarrow 2Au[NH_2CH(C_3H_7)COO]^-_2 + 2OH^- \quad (2)$$

Tanda et al. investigated copper leaching from azurite, chrysocolla, cuprite, and malachite minerals using glycine, and finally, after 24 hours under optimal conditions, pH 11, the glycine to copper ratio was 4% to 1% recovery of copper leaching were obtained from azurite, malachite, cuprite and chrysocolla minerals About 95, 90, 83.8 and 17.4% respectively [4]. Praya et al. investigated the recovery of gold from computer components and a sheet of pure gold using amino acid-alkaline solutions such as glycine and monosodium glutamate. The results of experiments showed that the percentage of gold recovery is affected by the oxidant concentration and pH, which increased to 100% with the presence of Copper ions [5]. Shadi Agha Babaei investigated the effective parameters of copper leaching in printed circuit boards using sulfuric acid and hydrogen peroxide by designing experiments. Finally, under optimal conditions with a stirring speed of 300 rpm, a concentration of 4 M sulfuric acid, an acid-to-oxidizer ratio of 4, a temperature of 50 °C, a time of 4 hours and 35 minutes, and a pulp density of 5%, copper recovery was Obtained by 96% for [6]. Vahid Kiani investigated the effect of amino acids in the cyanation process of the Zarkan Agh Dareh Gold Processing Plant. The results showed that cyanide concentration of 300 g/ton, ambient temperature, pH 10.5, time of 24 hours, pulp density 40%, constant stirring speed and particle size of -53 microns, cyanide leaching recovery for gold, silver, and mercury were obtained at about 90, 55 and 19%, respectively. While the recovery percentage of gold leaching in the conditions of cyanide concentration of 300 g/ton, ambient temperature 75 °C, pH 11.5, leaching time of 24 hours, pulp density 30%, constant stirring speed and particle size of -53 microns for gold, silver, and mercury were obtained by creatine monohydrate, 91, 47.18 and zero percent, respectively, by L-valine, 90.5, 16.56 and zero percent, respectively, and by L-histidine, respectively. 90.5, 15.92, and zero percent [3]. So far, the amino acid leaching process (especially glycine) alone or in combination with cyanide and other leaching agents has been studied mainly for the recovery of metals from ores or gold and silver sheets. The use of amino acids, especially L-valine, in gold leaching from electronic equipment wastes in the world has been less studied as a gold leaching method than other leaching methods. So far no research has been done in this field in Iran and there are still unknowns about the use of these materials in the process of leaching precious metals. The purpose of this study is to investigate the effective parameters in the process of gold leaching from mobile PCB waste by the amino acid L-valine.

MATERIALS AND METHODS

Preparation and analysis of sieve

A combination of printed circuit boards of old and new mobile phones was prepared as a study sample. After sample preparation and separation of ceramic, plastic, and metal parts on the boards, the crushing operation was performed using a hammer mill in two stages and the homogeneous crushed sample was divided into two parts using a riffle. Standard sieves (ASTM) of 1190, 595, 354, 250, 177, 149, and 105 microns were used to study the dimensional distribution of particles. After plotting the sieve analysis diagram, d_{80} of the 684-micron reagent sample was obtained.

Atomic absorption studies and ICP

The results of sample analysis by atomic absorption methods and ICP showed that the printed circuit boards of mobile phones contain a wide range of bases and precious metals. Among the precious metals, gold (542 ppm), platinum (30 ppm), and palladium (26 ppm) are among the precious metals, and among the base metals, copper constitutes 30.675% weight of the total sample. Iron and aluminum are the second and third metals in terms of weight percentage after copper, respectively, and constitute 3.5 and 1.02 wt% of the total sample, respectively.

Materials and equipment

Sulfuric acid (98% purity as copper leaching agent) and L-valine amino acid (99% purity as gold leaching agent), hydrogen peroxide (30% as oxidizer), and sodium hydroxide (with 99% purity percentage as a pH regulator) were bought from the German company Merck. The HPMA700 magnetic stirrer was used to control the temperature and stir the pulp, and the pH paper of the German Merck company was used to measure the pH. The American-made atomic adsorption device (AAFS 240) available in the Central Laboratory of Lorestan University was used to analyze gold and copper soluble and waste samples from leaching.

Leaching tests

Initially, direct leaching tests were performed on 10 g reagent samples. Then acidic leaching of the samples was performed with sulfuric acid and in the next step on the cake obtained from acidic leaching, a leaching operation was performed using the amino acid L-valine and the effect of effective parameters was investigated.

RESULTS AND ANALYSIS OF EXPERIMENTS

Direct leaching tests of PCB waste by L-valine amino acid

Initially, 30 direct leaching tests were performed on 10 g reagent samples using L-valine, and 5 tests were performed to test the effect of L-valine concentration, temperature, pulp density, oxidizing amount, pH, and time, for each one of the above parameters and finally, the recovery of gold leaching under the conditions of L-valine concentration of 200 g/ton, temperature 80 °C, pulp density 10%, oxidizing amount of 50 ml/l, pH 11.5 and time 32 hours was obtained at about 62.23 Percentage.

Leaching tests with sulfuric acid

By 30.675% weight of the studied sample is composed of copper metal. The high leaching rate of base metals compared to precious metals and the high concentration of base metals increase the consumption of amino acids and have a negative effect on the gold leaching process [7]. To remove a significant portion of copper and other base metals, a leaching step with sulfuric acid and hydrogen peroxide under 4 M sulfuric acid concentration, acid to oxidizer ratio 4, temperature 50 °C, time 4.5 hours, pulp density 5% was performed before leaching with L-valine amino acid [6]. Finally, 68.4% of the copper metal in the sample was removed by sulfuric acid as a solution before leaching with amino acid.

L-valine amino acid leaching experiments on sulfuric acid leaching cake

After acid leaching tests with sulfuric acid, leaching tests were performed using L-valine on the cake obtained from acid leaching and the effect of amino acid concentration, oxidant amount, temperature, pH, pulp density, and time on the recovery of case gold was investigated.

Effect of L-valine concentration

5 experiments with different concentrations of 100, 200, 300, 400, and 500 g/ton under constant conditions of other parameters such as temperature (60 °C), time (28 hours), oxidizing amount (20 ml/l), pulp density (15%), pH 11, and stirrer speed (400 rpm) were performed. The results showed that initially with increasing the concentration from 100 g/t to 200 g/t, gold leaching recovery increases from 79.25% to about 81.1%, then increasing the concentration from 200 to 500 g per ton, gold leaching recovery is reduced to 76.79%.

Temperature effect

5 different experiments were performed at temperatures of 40, 50, 60, 70, and 80 °C under constant

conditions of other parameters. The results showed that the recovery percentage of gold leaching at 40 °C is at its lowest level and about 63.42% and at 80 °C is at its highest level of 82.66%. According to the test results, with increasing temperature, the speed of gold leaching increases and this leads to an increase in the rate of gold leaching recovery. With increasing temperature from 40 to 80 °C, the recovery of gold leaching has increased by 19.24%.

Effect of pH

5 experiments were performed with pHs of 10, 10.5, 11, 11.5, and 12 under constant conditions of other parameters. The results showed that with increasing the pH from 10 to 11.5%, gold leaching recovery increases from 68.94% to 84.39% and from this pH upwards, the percentage of gold leaching recovery decreases to 80.21% arrives.

Effect of pulp density

5 different experiments with a pulp density of 10, 15, 20, 25, and 30% were performed under constant conditions of other parameters, respectively. The results show that the recovery of gold leaching decreases from 10 to 30% with increasing pulp density and reaches from 86.11% to 76.77%. This can be due to the reduction of oxygen transfer to the gold surface due to the increase in the pulp density, which leads to a decrease in gold leaching recovery [8].

Effect of leaching time

5 different experiments were performed at 16, 20, 24, 28, and 32 hours under the constant conditions of other parameters, respectively. The results showed that the recovery of gold leaching in 16 hours reaches 73.33% and with increasing leaching time to 32 hours, the recovery of gold leaching increases to 87.34, in fact, with increasing time for 16 hours, recovery of gold leaching increases by about 14%.

CONCLUSION

The printed circuit board contained 542 ppm of gold and the gold leaching operation was performed on 10 g samples with dimensions of 684 microns. Effect of L-valine concentration parameters (100 to 500 g/t), oxidizing value (20 to 140 ml/l), temperature ((40 to 80 °C), pH (10 to 12), the pulp density (10 to 30%) and the time (16 to 32 hours) on the recovery of gold leaching were examined. Studies have shown that in gold recovery, the parameters of temperature, time, and pH, relative to the pulp density, L-valine concentration, and the amount of oxidant are more important, respectively. The recovery percentage of gold leaching by L-valine (on the cake obtained from leaching with sulfuric acid) under the conditions of L-valine concentration of 200 g/ton, Temperature 80 °C, pulp density 10%, oxidizing value 50 ml/l, pH 11.5 and leaching time of 32 hours was about 87.34%. L-Valine was performed and the recovery percentage of gold leaching was about 62.23 %. The results showed that by performing acid leaching before leaching by L-Valine, the recovery percentage of gold leaching was about 25.11% increases.

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