Recovery of Gold from Pregnant Thiourea Leaching Solution by Synergistic Extraction

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Abstract. Aim of this research is to investigate the ability of synergist system of D2EHPA-isodecanol to recover gold from thiourea leaching solution. Synergistic extraction was introduced to replace single extraction due to enhance the extraction efficiency of heavy metal such as gold, silver copper and etc. In order to improve extraction efficiency, di-(2ethylhexyl) phosphoric acid (D2EHPA) was mixed with isodecanol to provide synergistic effect together with leaching solution which thiourea. From the synergist extraction system. The optimum pH is at 2.5 which in acidic range producing the highest yield of %E of 94.6%. It was found that synergistic D2EHPA-isodecanol extraction is successful as it yield %E of 99.4% if the ratio aqueous: organic is set to 1:2.

1. Introduction

Gold is one of the precious metal on earth and has a wide range of application in electronics, telecommunication, and other electronics industry [1]. Because unused electronic object will later end up in landfills and become e-waste. Liquid-liquid extraction or solvent extraction is one of the oldest and most widely used technique in the preparation of samples for qualitative and quantitative analysis [2]. It involves the distribution of sample components between two immiscible liquid phases [3]. After the leaching process, gold and thiourea become a gold-thiourea complex ions in acidic solution exist as cationic species, cation-exchange reagent, such as D2EHPA are generally used as extractant. In this work the solvent extraction of gold from acidic thiourea solution with synergistic of D2EHPA-isodecanol was investigated in order determine the extraction efficiency with pH and ratio as the parameter.

2. Material, Equipment and Methods

2.1 Materials
The materials required for this study are Gold(III) chloride trihydrate (HAuCl₄·3H₂O) (Sigma-Aldrich, ≥99% purity), di-2(ethylhexyl) phosphoric acid (D2EHPA) (Acros, ≥99% purity), isodecanol C₁₀H₂₁OH (≥90% purity), iron (Fe³⁺) (≥92% purity) and iron(III) sulphate (Fe₂(SO₄)₃) (≥92% purity)

2.2 Methods

2.2.1 Preparation of aqueous and organic phase

The aqueous phase is the mixture of gold solution and acidic thiourea solution. 0.2g of HAuCl₄·3H₂O is dissolve in distilled water in 1.0 L volumetric flask to prepare the gold solution. Later the gold solution is mixed and agitated with measured amount of thiourea and Fe(III) solution. The aqueous phase gold initial concentration are fixed at 100ppm.

2.2.2 Extraction procedures

The extraction of gold is carried out based on the shake-out test. The percentage extraction (%E) of Au(III) is calculated using equation;

\[ %E = \frac{[Au]_{f,Aq} - [Au]_{i,Aq}}{[Au]_{i,Aq}} \times 100 \]

Where [Au]ₖ,Aq is the initial Au(III) concentration in aqueous phase and [Au]ₙ,Aq is the final Au(III) concentration in the aqueous phase.

3. RESULT AND DISCUSSION

3.1 FTIR Spectroscopy Analysis

Synergist system of D2EHPA-isodecanol and kerosene as diluent is used extract the gold. Figure 1 is the FTIR analysis before the gold extraction took place. Whereas Figure 2 shows the FTIR after the extraction took place. As shown in Figure 1 the spectrum shows that O-H stretching vibration peak was disappeared. This phenomenon demonstrates that in the presence of isodecanol, dimeric D2EHPA dissociates into two monomeric D2EHPA molecules, its dissociation led to an increase in the capacity of D2EHPA. To validate that extraction of gold took place in organic phase. Figure 2 shows that O-H and C-Cl stretching vibration present at frequency 3700-3100 and 800-600 that absence in the first spectrum exist in the current spectrum [4][5]. The appearance of these two component shows that extraction took place because the gold extracted contain water and chloride that is gold(III) chloride trihydrate (HAuCl₄·3H₂O)
3.2 Effect of pH on Percent of Extraction

The mixture of aqueous phase contained thiourea, Fe (III) and Au with the concentration of 100 mg/L (100 ppm) whereas organic phase as extractant consists of D2EHPA, isodecanol and kerosene as diluent. The parameter chosen is the various pH that has been adjusted from 1.5 to 2.5. As shown in
Figure 3. The highest Au(III) extraction was obtained at pH = 2.5 with 96.7% extraction. While at pH 2.0 the percent of extraction is 94.6% and pH 1.5 is 92.09%. Therefore, the percent extraction below and above pH 2 were slightly lower which is 2%.

![Figure 3. Percent Extraction of Gold VS pH](image)

The initial pH reading from all the sample usually were at pH 2.4, therefore some of the samples were needed to add hydro chlorine acid to decrease pH and some need add droplet of sodium hydroxide (NaOH) to increase of pH, but if the pH was further increased in the pH of aqueous feed may result in precipitation of the metal [6]. This was mention by Po-Ching Lee that increase of pH level will result in the dissolution of D2EHPA [7]. According to N.Gonen et al [8] thiourea could be decomposed readily at high pH values and the Fe$^{3+}$ as the oxidizing agent might be precipitate as Fe(OH) by hydrolysis at the pH values greater than 3.

### 3.3 Effect of Ratio on Percent of Extraction

In this experiment, it can determine which phase plays an important role in extracting gold between single and synergist extraction. The aqueous phase mixture consists of gold Au(III), thiourea and Fe(II). For Figure 4 the organic phase are single extraction so the mixture includes D2EHPA and kerosene as diluent. While for Figure 3 the organic phase are synergist extraction so the mixture includes D2EHPA-isodecanol and kerosene as diluent. There were 6 samples were conducted with the different ratio which are 1:1, 1:2 and 2:1. Referring Figure 4 for single reaction it shows that ratio 1:2 has 90.1% percentage extraction which is the highest extraction percentage. Follows by the ratio 1:1 and 2:1 which percentage extraction are at 90.1% and 89.5%. While for the synergist reaction the data shows that ratio 1:2 has 99.4% percentage extraction, which is the highest extraction percentage. Follows by the ratio 1:1 and 2:1 which percentage extraction are at 94.63% and 90.48%.
The data shown prove that when the ratio of synergist mixture organic phase that consist of D2EHPA, isodecanol and kerosene is more than the aqueous phase, can resulting in a higher percentage extraction. The reason is extractant availability will increase due to the amount of the organic phase. Synergistic able to extract more because two type of extractants are combined. The present of isodecanol in organic phase make the %E higher than single D2EHPA because that in the presence of isodecanol, dimeric D2EHPA dissociates into two monomeric D2EHPA molecules. The result was influenced by the appropriate amount of isodecanol which react with the D2EHPA and at the same time increase the efficiency of extraction.[9].

4. Conclusion

This study investigate the extraction of Au (III) from aqueous phase solution by using synergistic mixture of D2EHPA-isodecanol and kerosene as diluent. The organo-phosphorus compound are splendid metal ions extractant because they are frequently employed in the solvent extraction process. In this study, D2EHPA-isodecanol is used as synergistic extractant for synergistic extraction system. From the extraction, the parameters such as pH as well as presence of Fe(III) solution and thiourea were investigated to determine the effect of pH towards the %E of Au(III) recovery. The effect of synergistic extraction was also studied with parameter such as ratio to determine the extraction efficiency %E of Au(III). All the parameters mentioned were studied based on fixed variables such as 100 ppm of initial concentration of Au(III), 150 rpm of incubator orbital shaker and 20 minutes of shaking time.

From the study, FTIR result shows the presence of chloride and O-H group, indicate that gold(III) chloride trihydrate was extracted in the process and was migrated from aqueous phase to organic phase. Nex, it can be concluded that to produce the highest yield of %E, the suitable conditions for the synergist D2EHPA-isodecanol extraction system are suggested to be at pH of 2.5 with the presence of Fe(III) solution and thiourea. At these conditions, the maximum of %E for Au(III) is 96.7% respectively. The synergistic D2EHPA-isodecanol extraction system also produce up to 7.8% higher yield than the single D2EHPA extraction system when both system were compared with in effect of ratio on percent extraction. For both system, the %E for Au(III) highest when 2:1 organic: aqueous phase were examine.
and lowest when 1:2 organic: aqueous, this signify that more extractor will increase the extraction process efficiency.

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