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# GOLD RECOVERY BY WAY OF EXTRACTION AND ADSORPTION FROM JEWELLER'S RESIDUES

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**ABSTRACT**

The gold residues used in this study were obtained from jewellers in Diyarbakır. Thiourea method was applied in order to take the elemental gold from residues into solution medium. Firstly, the samples were roasted at 600°C for eliminating organic originated structures. After the roasting process, only 60% of starting amount of sample were remained. Secondly, the samples were ground up to-110 mesh and-130 mesh and gold analysis were done on this samples. A preliminary study which determined pH, temperature, the $Fe^{+3}$ and thiourea concentrations were reevaluated by changing solid/liquid ratios.

Studies were carried out on samples of 110 mesh and 130 mesh. Solid/liquid ratios were examined. The most suitable extraction yield was found for the solid/liquid ratio of 1/1000 and all the gold was taken into solution.

In this study, furthermore, the adsorption studies were done for the recovery of the extracted gold in thiourea solution using active carbon. The percent adsorptions were calculated from the data obtained. Then, adsorption isotherm was drawn it. It is seen that this isotherm obeyed to the Freundlich isotherm type.

## INTRODUCTION

There are various methods which are applied to recover gold from Jeweller's residues. Although coupellation with lead and cyanide extraction are commonly used, there are disadvantages of coupellation such as loss of high amount of gold and the cyanide being poisonus. The conditions for studying cyanide were determined by others [1], but the recovering value was not mentioned in the study.

In this study, the thiourea method was used. The conditions for the gold recovery from anode slime were determined in previous study [2,3]. Additionally, we carried out this study changing the ratio of solid/liquid. For samples of-110 mesh or less size, when solid/liquid ratio was 1/1000

the recovery was found to be very high. Moreover, the gold extracted into solution was recovered with adsorption by active carbon. As adsorbent was used Merck-2514 (M-2514) which is a commercial active carbon and its physicochemical properties were mentioned in the other studies [4,5] as follow:

a) Surface area ($S_{N2}$): 1160,3 $m^2g^{-1}$

b) Micropore volume: 0,395 $cm^3g^{-1}$

c) Contribution of micropore volume: 91,2% contribution of mesopore volume: 8,8%.

d) % ash: 2,54; pH: 6,74.

e) Numbers of acidity center at surface: $100.10^{20}$ (sites.$g^{-1}$).

## EXPERIMENTAL

The gold residues used in this study were taken from jewelers in Diyarbakır.

Thiourea method was used for gold extraction. For this, samples were roasted at 600°C in order to remove organic materials. Then, these samples were ground to-110 and-130 mesh to put into a homogenous state. After that, gold analysis were done using AAS (Varion Techtron 1200 Model).

The results of the analysis are given in Table 1.

Table 1. The results of analysis of gold samples.

| Sample | % Au | |
|---|---|---|
| -110 mesh | 3.41 | 1.78 |
| -130 mesh | 1.42 | 1.29 |

This study involved two stages:

### 1. Thiourea extraction studies by changing solid/liquid ratios.

At this part of the study, about 100 g sample was roasted at 600°C to remove organic originated materials which took half an hour. After this process, the remaining sample was 60% of the total sample. Then, the sample was ground up to-110 mesh and-130 mesh size. The results of the gold analysis for the sample were given in Table 1.

Thiourea extraction in all experiments were carried out by changing time and solid/liquid ratios but, by keeping, temperature (30°C) $Fe^{+3}$ (2,5 $gL^{-1}$) and thiourea (10 $gL^{-1}$) concentraitons constant [2,3].

The first four experiments used the sample of -130 mesh sized containing 1.42% Au. The conditions for the first experiment was pH: 0.99, amount of sample: 0.400 g, the volume of the extraction solution: 50 mL, and solid/liquid ratio: 1 g/125 mL. The results of the experiment are given in Table 2.

Because of the low percentage of gold obtained at the end of the first experiment, the experiment was carried out by changing the solid/liquid ratios.

The second experiment was done under the following conditions, pH: 0.99, solid/liquid ratio: 1 g/750 mL. The results of this experiment are given in Table 3.

Table 2. The values of gold in the solution by means of extraction.

| Extraction time (hour) | Extraction yield (%) |
|---|---|
| 0.5 | 33.0 |
| 1.0 | 33.4 |
| 1.5 | 47.7 |
| 2.0 | 48.3 |
| 2.5 | 49.0 |
| 3.0 | 57.1 |

Table 3. The values of gold in the solution by means of extraction.

| Extraction time (hour) | Extraction yield (%) |
|---|---|
| 0.5 | 42.4 |
| 1.0 | 83.5 |
| 1.5 | 82.6 |
| 2.0 | 77.9 |
| 2.5 | 85.3 |
| 3.0 | 87.9 |

As seen in Table 3, the highest yield was received for the extraction, time of three hours, which was 87,9%. For the third experiment, the

conditions were; pH: 0,85 and solid/liquid ratio: 1 g/1000 mL. The result of this experiment are given in Table 4.

Table 4. The values of gold in the solution by means of extraction.

| Extraction time (hour) | Extraction yield (%) |
|---|---|
| 0.5 | 80.8 |
| 1.0 | 86.0 |
| 1.5 | 90.2 |
| 2.0 | 91.9 |
| 2.5 | 98.6 |
| 3.0 | 98.6 |

In the fourth experiment for the complete extraction of gold the conditions were taken as pH: 0.80 and solid/liquid ratio: 1 g/1250 mL. The results are given in Table 5.

Table 5. The values of gold in the solution by means of extraction.

| Extraction time (hour) | Extraction yield (%) |
|---|---|
| 0.5 | 78.8 |
| 1.0 | 100.0 |
| 1.5 | 100.0 |
| 2.0 | 100.0 |
| 2.5 | 100.0 |
| 3.0 | 100.0 |

As seen from the Table 5, after one hour extraction time all the gold was taken into solution. There was not any gold in the remaining sample when reanalyzed. This shows that all gold has been extracted. This experiment was repeated, the similar results were obtained.

The sample of -130 mesh containing 1.29% Au was analyzed for solid/liquid ratio of 1 g/1000 mL. After, one hour extraction time yield was 100%.

The following three experiments were done on -110 mesh size (+130 mesh-130 mesh) containing 3,41% Au sample. For the first experiment pH: 1.00, solid/liquid ratio 1 g/125 mL; for the second experiment pH: 0.95, solid/liquid ratio 1 g/250 mL and for the third experiment pH 0.90,

solid/liquid ratio 1 g/1250 mL were taken. The experimental results were given in Tables 6, 7 and 8.

Table 6. The values of gold in the solution by means of extraction.

| Extraction time (hour) | Extraction yield (%) |
|---|---|
| 0.5 | 36.6 |
| 1.0 | 51.3 |
| 1.5 | 48.3 |
| 2.0 | 47.0 |
| 2.5 | 50.0 |
| 3.0 | 50.7 |

Table 7. The values of gold in the solution by means of extraction.

| Extraction time (hour) | Extraction yield (%) |
|---|---|
| 0.5 | 30.5 |
| 1.0 | 48.1 |
| 1.5 | 62.8 |
| 2.0 | 61.8 |
| 2.5 | 63.8 |
| 3.0 | 65.5 |

Table 8. The values of gold in the solution by means of extraction.

| Extraction time (hour) | Extraction yield (%) |
|---|---|
| 0.5 | 100.0 |
| 1.0 | 100.0 |
| 1.5 | 100.0 |
| 2.0 | 100.0 |
| 2.5 | 100.0 |
| 3.0 | 100.0 |

If we examine the last three tables, we'll see that for -110 mesh size sample, the most suitable extraction yield was for the solid/liquid ratio of 1 g/1250 mL (Table 8). As it is seen in Table 8, 100% yield could also be achieved in an half hour's time of extraction.

## 2. The gold recovery from thiourea solution

In this part of the study, gold recovery by active carbon adsorption in solution medium was investigated.

### 2.1. Determination of equilibrium period

Both 0.05 g active carbon which is dried at 110°C for 24 hours and 50 mL solution contained 20.6 ppm Au was stirred continuously at 25°C. Equilibrium concentration ($C_d$) plotted against time (Figure 1) and the equilibrium period was found as 11 hours.

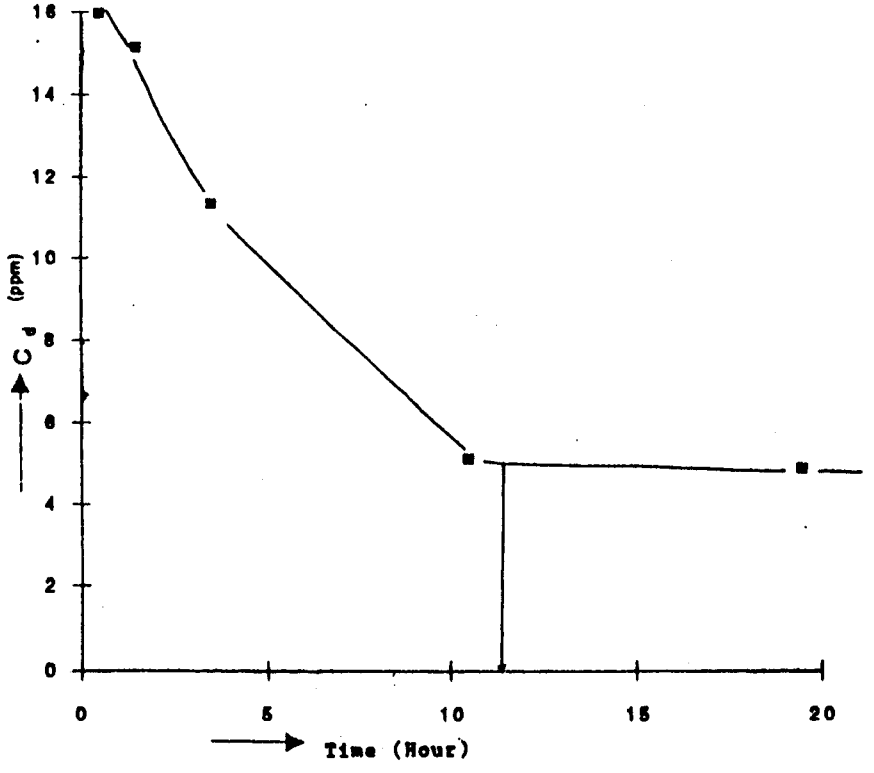


Fig. 1. The Relation between equilibrium concentration and time.

### 2.2. Determination of adsorption isotherm

From the stock gold solution of 62,4 ppm, six different solutions of 50 mL were stirred by adding various amounts of activated carbon for

eleven hours at 25°C and then, the equilibrium concentrations were determined.

All the data related to the experiment are given in Table 9.

Table 9. The results related to the gold adsorptions on the active carbon at 25°C.

| $C_o$ (ppm) | $C_d$ (ppm) | $C_a$ (ppm) | m (g) | $C_a'$ (ppm/g) | % Adsorption $C_o$-$C_d$/$C_o$.100 % |
|---|---|---|---|---|---|
| 62.4 | 0.65 | 61.8 | 0.5518 | 112.0 | 99.0 |
| 62.4 | 4.43 | 58.0 | 0.2833 | 204.7 | 92.9 |
| 62.4 | 6.91 | 55.5 | 0.2044 | 271.5 | 88.9 |
| 62.4 | 12.64 | 49.8 | 0.1364 | 365.2 | 79.8 |
| 62.4 | 31.34 | 31.1 | 0.0502 | 618.6 | 49.8 |

$C_o$: Initial concentration

$C_d$: Equilibrium concentration

$C_a$: Adsorbed concentration

$C_a'$: Adsorbed concentration (per 1 g activated carbon)

m : Amounts of active carbon

Furthermore, it seems that a graph obtained by drawing the values of $C_a$ versus those of $C_d$ resemles the H-type of the isotherms classified by Giles [6] (Figure 2). This shows that the adsorption between the activated carbon and gold occurs as chemisorption.

From the graph of log $C_d$ versus log $C_a$ the linear isotherm resembles the Freundlich type (Figure 3). By using the smallest square method, k and n values were calculated as 174 and 3,096 respectively.

## RESULTS AND DISCUSSIONS

In this study the conditions of taking gold in the jeweller's residues into solution medium and adsorption from solution by active carbon were determined. The most appropriate time and solid/liquid ratios of gold, in order to take into solution were also determined.

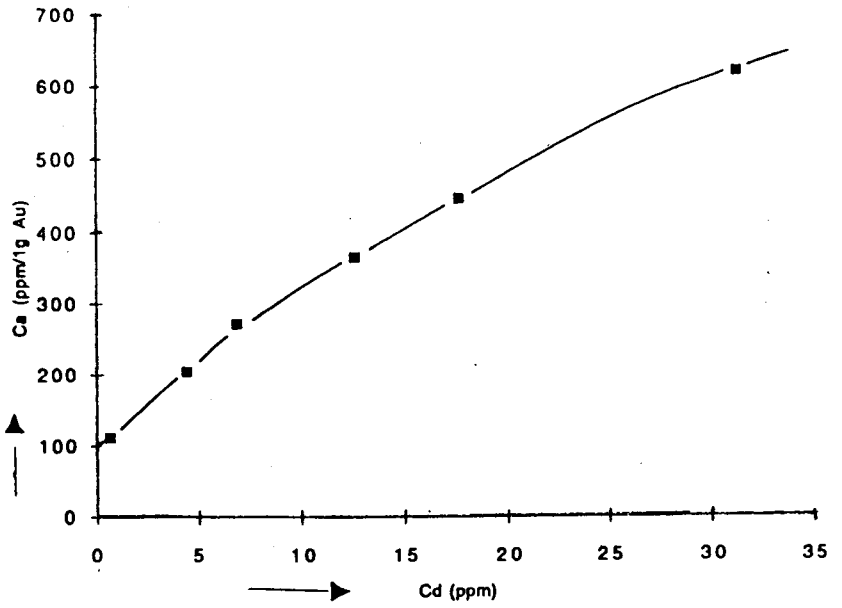


Fig. 2. Isotherm related to the gold adsorption from aqueous thiourea solution on the active carbon at 25°C.

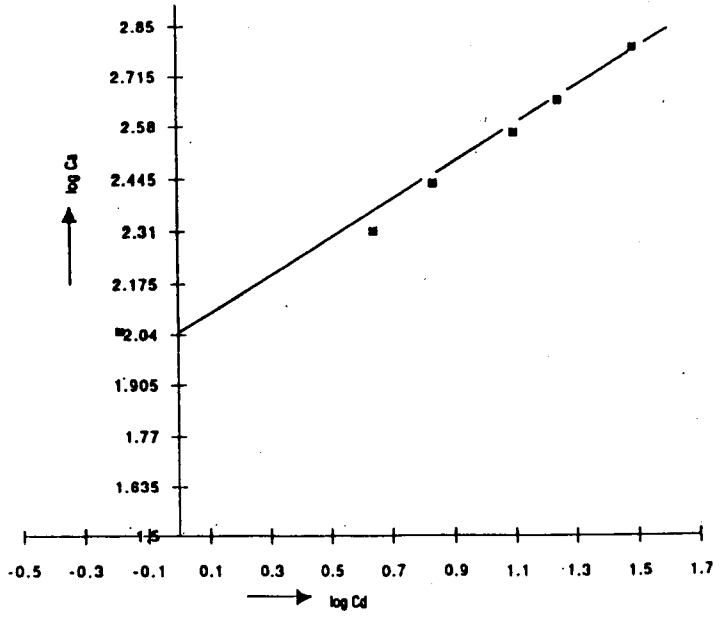


Fig. 3. The Freundlich linear isotherm related to the gold adsorption from aqueous thiourea solution on the active carbon at 25°C.

Extraction processes applied in this study show that 100% yield was achieved in one hour with -130 mesh sized sample containing 1.42% Au at 1 g/1250 mL solid/liquid ratio, whereas, the same yield was achieved in half an hour with -110 mesh sized sample containing 3,41% Au. This shows, in order to get that 1 kg sample of -110 mesh size (working out from the data needs), 12.5 kg thiourea was used, and 3,41 g Au passed in to the solution.

However, with the same amount of thiourea for 1 kg of -130 mesh-sized sample 14,2 g Au can be taken in to the solution. Because of the extraction of 110 mesh size sample happened in a short time, the amount of spoilt thiourea is low. The short duration of extraction time will proved the advantage of reusing thiourea. From this point of view of -110 mesh sized sample will be more usefull in recovery gold.

Equilibrium duration was determined as eleven hours for the second part of the study which involve adsorption process from solution. Adsorption studies wer shown that this process is a chemical adsorption type and the gold was reduced to elementary by active carbon. Therefore, when complex structure of gold in the solution returns to elementary form, the thiourea gets free.

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