KINETICS OF GOLD ADSORPTION AND ELUTION WITH C410 RESIN①

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ABSTRACT

The kinetics of gold adsorption and elution with a new type of C410 resin was studied. The experimental results show that the adsorption and elution can be described by the Boyd diffusion equation for liquid films. The adsorption rate of gold decreases with increasing HCl concentration. The diffusion coefficient of adsorption is $K = 4.83\times10^{-4}$ sec^{-1} and the apparent enthalpy of adsorption ΔH is 16.05 kJ / mol. The distribution ratio of gold adsorption increases with the temperature. It is shown that the adsorption were of gold with C410 resin is a heat-absorbing reaction. The elution characteristics of gold with thiourea solution were also studied.

Key words: ion-exchange gold kinetics

1 INTRODUCTION

410 piperidine resin is one of the most effective resins for separation and extraction of gold from HCl solution. The adsorption characteristics and extraction of gold with this resin have been reported, and the kinetics of the adsorption and elution of gold with this resin are studied further in the present work.

2 EXPERIMENTAL

2.1 *Reagents and Instrument*

A GGX−5 model atomic adsorption spectrophotometer was used to determine the amount of gold in solution. Spectrum grade gold was used to prepare a gold storage solution containing 1.0 mg Au^{3+} / mL in a 10 % HCl solution. 410 piperidine resin is of a size of 40 ~ 60 mesh.

2.2 *Experimental method*

The adsorption and elution of gold with 410 piperidine resin was performed using an electromagnetic shaker. A certain amount of gold storage solution was added to the HCl solution containing resin to carry out the adsorption experiments. Before elution the loading resin was washed to neutral pH with deionized water. The concentrations of gold in both the adsorption and elution solution were determined by flame atomic adsorption spectrometry.

3 RESULTS AND DISCUSSION

3.1 *Effect of* HCl *Concentration in Solution on the Adsorption of Gold*

The adsorption curves of gold in HCl solution are shown in Fig. 1. It shows that the gold loading capacity of the resin decreases with increasing the HCl concentration because the competitive exchange of Cl^- and $AuCl^{-4}$ complex anions decreases.

3.2 *Adsorption Rate of Gold*

A $Q-t$ curve is obtained by shaking an adsorption solution in 1.2 mol / L HCl. From

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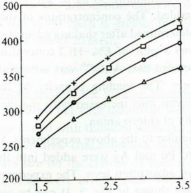

Fig. 1 Adsorption of gold (Q) vs adsorption time (t) in HCl solution

+—0.6 mol / L HCl; □—1.2 mol / L HCl; ○—2.4 mol / L HCl; △—3.6 mol / L HCl

the curve, the adsorption capacity at equilibrium was given. According to Boyd's diffusion equation for liquid films

$$F(t) = 1 - \exp(-\frac{3D}{r_0 \delta \lambda} t)$$

Where $F(t) = Q_t / Q_\infty$, and Q_t is loading gold on the resin at time t, Q_∞ is loading gold on the resin at equilibrium. Let $K = 3D / r_0 \delta \lambda$, where K is the diffusion constant of the liquid film; D is the diffusion coefficient of the species; r_0 is the particle radius of the resin; δ is the film thickness; λ is the distribution coefficient of the species. then $F(t) = 1 - \exp(-Kt)$.

Plotting $-\ln(1-F(t))$ against t, a linear relationship is obtained as shown in Fig. 2. It shows that Boyd's diffusion equation for liquid films can be used to describe the adsorption process, i. e. it is controlled by a diffusion process in the layer. The diffusion constant K of the liquid film is obtained to be 4.83×10^{-4} sec^{-1}. Due to the dependence of δ and λ on the HCl concentration, the HCl concentration has an obvious effect on the diffusion constant of the liquid film.

When $F(t) = 0.5$, $-\ln(1-F) = 0.693 = Kt$, the corresponding $t_{1/2}$ is the half-exchange time,

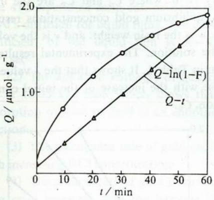

Fig. 2 Adsorption of gold (Q) in a solution of 1.2 mol / L HCl

which directly indicates the rate of the mass transfer.

3.3 *Effect of Temperature on Adsorption of Gold*

The adsorption results in the temperature range 20~40 ℃ are shown in Fig. 3. The slopes of those lines increase with increasing temperature, which means that higher temperatures are beneficial to the adsorption of gold.

According to the distribution ratio of gold adsorption at different temperatures, a plot of lg$D$ versus $1/T$ is shown in Fig. 4. It can be seen that the distribution coefficient D increases with the temperature. According to Gibb's equation

$$\left[\frac{\partial \lg D}{\partial T^{-1}}\right]_P = -\frac{\Delta H}{2.303R}$$

The apparent enthalpy of adsorption is $\Delta H = 16.05$ kJ / mol. ΔH is a positive value, which indicates that the adsorption of gold is endothermic.

3.4 *Distribution Coefficient of Gold Adsorption*

The distribution coefficient of gold adsorption $\lambda = (C_0 - C_P) \cdot v / w \cdot 1 / C_P$, was determined in a 1.2 mol / L HCl solution with 0.02

g dry resin, where C_0 and C_P are the initial and equilibrium gold concentrations respectively; w is the resin weight, and v is the volume of the solution. The experimental results are given in Table 1. It shows that the λ values decrease with the increase of the initial concentration, C_0.

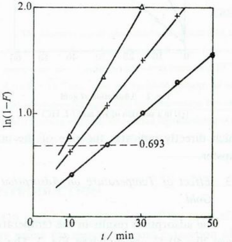

Fig. 3 Effect of temperature on the adsorption of gold in a solution of 1.2 mol / L HCl

○—20 ℃, +—30 ℃, △—40 ℃

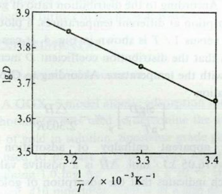

Fig. 4 A plot of lg$D$−1 / T

D—diffusion coefficient; T—temperatuve

3.5 *Selectivity of Resin Adsorption*

0.2 g dry resin was first soaked in different concentration of HCl solution, and then the solution containing 50 μg of Zn^{2+}, Fe^{3+}, Cu^{2+} were added. The concentrations of these ions were determined after shaking adsorption. Fig. 5 shows a plot of $E\%$−HCl concentration. It can be seen that $AuCl^{-4}$ was adsorbed quantitatively. The loading capacity of resin for base metal ions increased with the increasing stability of chloro-anion.

Similar to the above experiments, 50 μg of Au, Pt, Pd and Ag were added into the solution for adsorption tests. The experimental results are shown in Fig. 5. It can be seen that the adsorption of Pt, Pd and Ag decrease with increasing Cl^- concentration. The order of the adsorption of precious metals is Au > Pt > Pd > Ag under certain Cl^- concentrations.

Table 1 The distribution coefficient of gold adsorption in 1.2 mol / L HCl solution

C_0 / mg · mL^{-1}	0.025	0.050	0.075	0.100	0.125	0.150
C_p / mg · mL^{-1}	0.0008	0.00274	0.00554	0.0103	0.0210	0.0340
λ / mg · mL^{-1}	30250	17248	12538	8671	4952	3412

* 35 ℃, v = 20 mL, w = 0.020 g

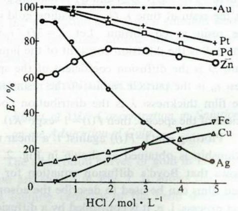

Fig. 5 Selectivity of resin adsorption (E) vs acidity of HCl

3.6 *Effect of Resin Size on the Adsorption of Gold*

A certain amount of gold storage solution and certain size resin (20 ~ 40 mesh) were added to a 1.2 mol / L HCl solution to carry out the adsorption experiments. The experimental results show the adsorption capacity of resin with a size of 40 mesh is greater than that of resin with a size of 20 mesh.

3.7 *Elution of Gold from Loading Resin*

Before elution, the loading resin was washed to neutral pH with deionized water. The gold was eluted with thiourea solution. The effects of thiourea concentration, temperature and resin size on the elution of gold from the loading resin were investigated. The plots of $-\ln(1-F)$ vs t of elution are shown in Figs. 6 and 7.

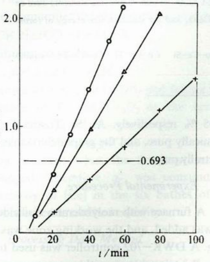

Fig. 6 Effect of thiourea concentration on the elution of gold from the loaded resin at 35 ℃

+—1 % thiourea, △—3 % thiourea, ○—5 % thiourea

It can be seen that the elution rates increase with the increase of thiourea concentration and temperature. The elution rate of resin with a size of 40 mesh is faster than that of resin with a size of 20 mesh.

4 CONCLUSIONS

(1) The adsorption of gold with a new type 410 piperidine resin can be described by Boyd's diffusion for liquid films. The diffusion coefficient of the liquid film is $K=4.83\times 10^{-4}\ sec^{-1}$;

(2) The apparent enthalpy of adsorption ΔH is 16.05 kJ / mol, which shows that the adsorption process of gold is an endothermic reaction;

(3) The adsorption rate of gold decreases with increasing HCl concentration;

(4) The elution rate of gold from the loading resin increases with the increase of the thiourea concentration and temperature.

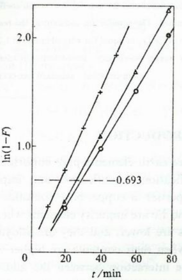

Fig. 7 Effect of temperature on the elution of gold from loading resin in a 3 % thiourea solution

○—20 ℃, △—30 ℃, +—40 ℃

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