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# Study on the Recovery of Gold from the Cyanide Solutions with Weakly Basic Anion Exchange Fiber as Sorbent

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The recovery of gold from the cyanide solution with weakly basic anion exchange fiber as sorbent was studied. The effects of different recovery parameters on gold recovery efficiency were studied in detail. The anion exchange fiber was packed into a PTFE cartridge and the gold can be absorbed on this cartridge when the cyanide solution passed through the cartridge. The absorbed gold was eluted from the cartridge with 2.0 mol $L^{-1}$ nitric acid solution as eluant. By this procedure, an enrichment factor above 500 was achieved and the routine ion do not interfered with the gold recovery. The absorption capacity was calculated to be 52 mg $g^{-1}$ for the gold standard solution and 46 mg $g^{-1}$ for the industrial gold cyanide leaching solution. This method can be applied to the recovery of gold from cyanide solution with good results.

**Key Words: Recovery of gold, Weakly basic anion exchange fiber, Solid phase extraction, Cyanide solution.**

## INTRODUCTION

Gold recovery from aqueous solutions has received significant attention because gold is present in appreciable amounts in electronic parts and plating materials[1,2]. Many sorbents have been proposed for gold recovery, including activated carbon, persimmon tannin gel, ion exchange resins, fungal biomass, chelating resin, cyanide-imprinted polymer and the like[1-8].

Ion exchange fiber (IEF) is a new and novel adsorbing and separating material in the form of felts or fabrics. It is composed of many true fibers whose diameter is between 10-30 μm. Compared with the conventional ion exchange resin, ion exchange fiber has large specific surface areas, high adsorption rates, good stability, selectivity and cheapness. Due to all these advantages, ion exchange fiber has received more and more attentions[9-11]. However, the application of weakly basic anion exchange fiber for the recovery of gold in cyanide solution had not been received wide attentions. In this work, we studied the recovery of gold from the cyanide solution with weakly basic anion exchange fiber as sorbent. The results showed that weakly basic anion exchange fiber has high enrichment factor and good sorption capacity for gold recovery.

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## EXPERIMENTAL

Whatman DE 51 weakly basic anion exchange fiber was obtained from Whatman Inc (Clifton, NJ., USA). A 1.0 g of anion exchange fiber packed into a teflon cartridge (1.8 cm length and 1.2 cm in diameter) was used for recovery of gold from cyanide solution. All other solutions were prepared with double distilled water. Otherwise stated, analytical-grade chemicals were obtained from Merck (Darmstadt, Germany).

A stock standard solution of gold (1.0 mg $mL^{-1}$) was prepared by dissolving 1.4618 g of $K[Au(CN)_2]$ in 200 mL of 0.01 mol $L^{-1}$ sodium hydroxide solution and diluted to the volume of 1.0 L. The working solutions (adjust to pH 9.4-12) were prepared by diluting this stock solution.

Industrial gold cyanide leaching solution (the concentration of gold is 15.6 mg $L^{-1}$ with pH 10.4) was obtained from Yunnan Jinbaoshan Corporation. The foreign ions in this solution are Ag 8.92, Ni 3.16, Cu 2.76, Zn 32.5, Fe 3.21 and Co 1.74 mg $L^{-1}$. Nitric acid solution (2.0 mol $L^{-1}$) was prepared by diluting the concentrated nitric acid with water.

**Gold determination:** The gold determination was performed on a Perkin-Elmer model A analyst 600 atomic absorption spectrometer equipped with a model AS-800 autosampler (Norwalk, CT, USA) and furnished with a gold hollow-cathode lamp. The instrument was adjusted according to the standard conditions: Lamp current 4.0 mA, wavelength 242.8 nm, air-acetylene flame (air flow rate 6.0 L $min^{-1}$, acetylene flow rate 1.8 L $min^{-1}$), spectral band width 0.5 nm.

**Procedure:** The weakly basic anion exchange fiber for recovery of gold was tested by using a 10 mg $L^{-1}$ gold standard solution and an industrial cyanide solution from gold-recovery enterprise with a gold content of 15.6 mg $L^{-1}$. A 0.1-5.0 L of solution was passed through the cartridge at a flow rate of 25 mL $min^{-1}$. After finishing the sample solution, a volume of 10 mL of 2.0 mol $L^{-1}$ nitric acid solution was passed through the cartridge in the reverse direction at a flow rate of 5.0 mL $min^{-1}$ to elute the Au(I) ions. The per cent of Au(I) ions absorbed on the cartridge for the concentration of Au(I) was calculated from the amount of Au(I) ions in the starting sample and the amount of Au(I) eluted from the cartridge.

## RESULTS AND DISCUSSION

**Effect of pH:** The influence of pH of sample solution on the preconcentration of gold was studied. The $[Au(CN)_2]^-$ can not keep stable when the pH below 9.4. For this purpose, 500 mL of 10 mg $L^{-1}$ Au(I) as different pH (9.5, 10, 10.5, 11, 11.5, 12, 12.5, 13) medium were passed through the anion exchange fiber sorbent and eluted with nitric acid. Then the Au(I) concentration in eluent solution was checked using FAAS. The results shown that suitable pH for absorption of Au(I) on the weakly basic anion exchange fiber is around 9.5-12.0. Therefore, a pH 9.5-12.0 medium was used for the preconcentration step.

**Effect of eluant:** For eluting the gold from the solid phase sorbent, after the extraction of 40 mg gold by the weakly basic anion exchange fiber sorbent, the gold ion was eluted with various potential eluants (0.1-5.0 mol $L^{-1}$ nitric acid, 0.1-5.0 mol $L^{-1}$ EDTA, 0.1-5.0 mol $L^{-1}$ sodium thiosulfate, 0.1-5.0 mol $L^{-1}$ thiocyanic acid potassium salt, 0.1-5.0 mol $L^{-1}$ thiourea). The results demonstrated that the nitric acid (concentration between 1.0-3.0 mol $L^{-1}$) was founded to be the best eluant and the absorbed gold can eluated from the cartridge completely with 10 mL of 1-3 mol $L^{-1}$ nitric acid. Therefore, a 2.0 mol $L^{-1}$ nitric acid solution was selected as eluant in this experiment.

**Effect of sample flow rate:** The influence of the sample flow rate on preconcentration efficiency of Au(I) ions through the cartridge was also investigated. For this purpose, a volume of 500 mL of 10 mg $mL^{-1}$ Au(I) solution with pH 11 was passed through a series of cartridge at different flow rates. Then the absorbed Au(I) was washed with 10 mL of 2.0 mol $L^{-1}$ nitric acid and the Au(I) content was measured using FAAS. The results showed that using a sample flow rate over 30 mL $min^{-1}$ can caused a decrease of the Au(I) ions recoveries. Therefore, a sample flow rate of 25 mL $min^{-1}$ was used for further studies.

**Effect of eluant flow rate:** The effect of flow rate of eluant on desorption efficiency of Au(I) ions from the cartridge was also checked in the range of 2-10 mL $min^{-1}$ with nitric acid solution. The results showed that the recovery of gold was maximized when using elution rates up to 3.0-8.0 mL $min^{-1}$. Therefore, eluant flow rate of 5.0 mL $min^{-1}$ was selected.

**Enrichment capacity:** The capacity of the weakly basic anion exchange fiber for absorption of Au(I) was checked by passing 10 mg $L^{-1}$ Au(I) through the cartridge (This cartridge containing 1.0 g of weakly basic anion exchange fiber). The Au(I) ions were stripped off the weakly basic anion exchange fiber with 10 mL 2.0 mol $L^{-1}$ nitric acid solution and measured by FAAS. Under the condition of gold recovery ≥ 96 %, the absorption capacity was calculated to be 52 mg $g^{-1}$ for gold. The cartridge has high capacity for the recovery of gold. The enrichment factor of 500 was achieved (5.0 L of gold solution pass the cartridge and can eluted from the cartridge with 10 mL of nitric acid solution).

**Selectivity of method:** The selectivity of this method was investigated by passing different amounts of potential interfering ions plus 10 mg $L^{-1}$ Au(I). The results showed that 100-fold of alkaline and alkaline-earth ions, chloride, nitrate, hydrogen carbonate, carbonate and sulfate, 5-fold of Zn(II), Fe(II), Ni(II), Pd(II), Cu(II), Co(II), Cr(III), 1-fold of Ag(I), Pb(II) do not interfered with the gold recovery. The results confirm that the sorbent is selective for gold recovery.

**Recovery of gold from industrial solution:** The recovery of gold from an industrial gold cyanide leaching solution (Au 11.2, Ag 8.92, Ni 3.16, Cu 2.76, Zn 32.5, Fe 3.21 and Co 1.74 mg $L^{-1}$) was also investigated. Under the condition of gold recovery ≥ 96 %, the absorption capacity was calculated to be 46 mg $g^{-1}$ for this industrial gold cyanide leaching solution. The cartridge also has high capacity for the recovery of gold from real industrial gold cyanide leaching solution.

## Conclusion

The method can be applied for the recovery of gold from the cyanide solution. For 10 mg $L^{-1}$ of gold solution, an enrichment factor of 500 was achieved. This method has high enrichment factor. The routine ion (Ag, Ni, Cu, Zn, Fe, Co) in industrial gold cyanide leaching solution do not interfered with the gold recovery. The selectivity of this method is high. The absorption capacity was calculated to be 52 mg $g^{-1}$ for gold standard solution and 46 mg $g^{-1}$ for the industrial gold cyanide leaching solution. This method has high absorption capacity for gold. This method can also be applied to the recovery of gold from real industrial gold cyanide solution with good results.

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