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Solid Phase Extraction Method for the Recovery of Gold from the Cyanide Solutions

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In this work, a new method for the recovery of gold from the cyanide solution with graphitized carbon black as sorbent was studied. The recovery of gold was preformed by passing the cyanide solution through the graphitized carbon black cartridge and eluted the absorbed gold from the cartridge with 2.0 mol L^{-1} thiourea solution as eluant. An enrichment factor of 320 was achieved and the routine ion (Ag, Ni, Cu, Zn, Fe, Co) do not interfered with the gold recovery. The absorption capacity was calculated to be 32 mg g^{-1} for the gold standard solution and 24 mg g^{-1} for the industrial gold cyanide leaching solution. This method can be applied to the recovery of gold from real industrial gold cyanide solution with good results.

Key Words: Recovery of gold, Graphitized carbon black, Solid phase extraction, Cyanide solution.

INTRODUCTION

The majority of industrial procedures for recovery of gold from auriferous ores begin with a leaching process known as cyanidation, which yields solutions containing the gold cyanide complex $[Au(CN)_2]^-$. This is then usually absorbed onto activated carbon and subsequently eluted to produce[1,2] a concentrated solution of $[Au(CN)_2]^-$. By this procedure, the sorbent properties should meet certain requirements[3,4]. It was found that the specific surface area of sorbent strongly affects the gold sorption, specific surface area of commercial sorbent prepared from coconut shells reaches 1000 m^2 g^{-1} and their capacity for gold in sorption from solutions with a gold concentration of 1.0 mg L^{-1} is about 1 %. Sorbents should also be abrasion-resistant and high mechanical strength is important, because the fragile sorbent is easily grindable material and the loss of gold-containing sorbent with ore will be intolerably high.

Attempts are made to prepare alternative sorbents from liquid products of shale treatment and petroleum residues, technical hydrolytic lignin, furfural and also from wastes of production of phenol-formaldehyde resins, coal-tar raw materials, petroleum coke and wood residue with carbonization and ultra-high-frequency activation. However, the mechanical strength of the above sorbents is still insufficient[5,6].

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The graphitized carbon black is a new sorbent which widely used in solid phase extraction[7-9]. This sorbent obtained from heating carbon blacks at 2700-3000 ºC in an inert atmosphere. The graphitized carbon has an average specific surface of 1200 m^2/g and a uniform pore structure with mean porosity of 75 %. It is considered to be both reversed-phase and ion-exchanger due to the presence of positively charged groups on their surface. However, the application of graphitized carbon black for the recovery of gold in cyanide solution had not been reported yet. In this work, we studied the sorption of gold with graphitized carbon black in cyanide solution. The results showed that graphitized carbon black has good sorption capacity for gold and has good mechanical resistance to wear. Compared to that of activated carbon (a fragile easily grindable material), the disadvantage of the loss of gold-containing sorbent will be avoided and the ratio of gold recovery was greatly improved.

EXPERIMENTAL

A Teflon cartridge (1.5 cm length and 1.0 cm in diameter, Fig. 1) packed with 1.0 g of the graphitized carbon black was used for solid phase extraction.

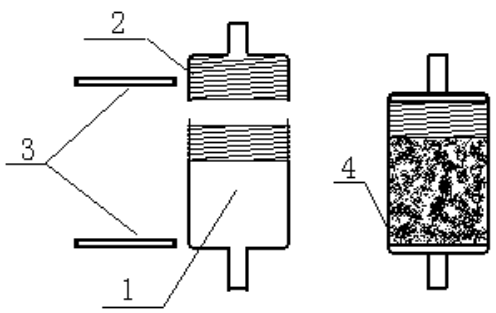

Fig. 1. The SPE cartridge (1) Tube for fill in the sorbent, (2) Screw cap for sealing the tube),(3) Sieve plate, (4) graphitized carbon black

The Carbopack™ B graphitized carbon black (60-80 mesh) was obtained from Sigma-Aldrich Corporation (USA). 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 $KAu(CN)_2$ in 200 mL of 0.01 mol L^{-1} sodium hydroxide solution and diluted to the volume of 1.0 L. The working solutions were prepared by diluting this stock solution. Industrial gold cyanide leaching solution (the concentration of gold is 11.2 mg L^{-1} with pH 11.2) was obtained from Yunnan Jinbaoshan Corporation. The foreign ions in this solution are Ag 7.62 mg L^{-1}, Ni 2.87 mg L^{-1}, Cu 1.87 mg L^{-1}, Zn 46.12 mg L^{-1}, Fe 1.38 mg L^{-1} and Co 0.84 mg L^{-1}. Thiourea solution (2.0 mol L^{-1}) was prepared by dissolving 152.4 g of thiourea in water and diluted to the volume of 1.0 L.

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) 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 graphitized carbon black 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 11.2 mg L^{-1}. A 100-4000 mL of solution was passed through the cartridge at a flow rate of 20.0 mL min^{-1}. After finishing the sample solution, a volume of 10 mL of 2.0 mol L^{-1} thiourea 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 percent 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

First of all, to obtain the best quantitative recoveries of $[Au(CN)_2]^-$ from cyanide solution, many parameters such as pH of the sample solution, sample volume, the concentration of washing solution, sample flow-rate through the cartridge, capacity of the graphitized carbon black and the effect of matrix on the preconcentration step should be studied.

In the optimization steps, 1.0 g of graphitized carbon black was used. The influence of pH of sample solution on the preconcentration of $[Au(CN)_2]^-$ was studied. The $[Au(CN)_2]^-$ can not keep stable when pH below 9.4. For this purpose, 200 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 solid sorbent. 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 graphitized carbon black is around 9.5 -12.5. Therefore, a pH 11.0 medium was used for the preconcentration step.

For eluting the $[Au(CN)_2]^-$ from the solid phase sorbent, after the extraction of 20 mg gold by the graphitized carbon black sorbent, the gold ion was eluted with various potential eluants. The results are summarized in Table-1. The thiourea solution was founded to be the best eluant. Therefore, a 2.0 mol L^{-1} thiourea solution was selected as eluant.

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 200 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} thiourea solution and the Au(I) content was measured using FAAS. The results showed that using a sample flow rate over 22 mL min^{-1} can caused a decrease of the Au(I) ions recoveries. Therefore, a sample flow rate of 20 mL min^{-1} was used for further studies.

TABLE-1
EFFECT OF DIFFERENT ELUANT ON THE RECOVERY OF GOLD

	Eluant volume	2 mL	4 mL	6 mL	8 mL	10 mL	12 mL
Recovery of gold (%) using different eluant	HNO_3 (0.5 mol L^{-1})	23.8	35.2	46.7	54.7	62.2	76.1
	HNO_3 (2.0 mol L^{-1})	25.5	40.0	51.5	59.1	68.1	84.5
	HNO_3 (4.0 mol L^{-1})	30.3	46.4	61.2	76.9	83.0	90.2
	Thiourea (0.5 mol L^{-1})	63.9	87.2	88.7	89.5	91.0	94.1
	Thiourea (2.0 mol L^{-1})	68.6	90.6	95.9	98.2	–	–
	Thiourea (4.0 mol L^{-1})	75.0	92.2	96.9	97.7	–	–
	KSCN (0.2 mol L^{-1})	23.9	31.5	35.1	40.7	50.7	63.7
	KSCN (1.0 mol L^{-1})	26.1	35.4	41.4	46.7	56.0	63.8
	KSCN (2.0 mol L^{-1})	29.9	39.5	49.7	61.3	76.8	88.5
	$Na_2S_2O_3$ (0.2 mol L^{-1})	36.0	60.6	87.3	91.1	91.8	93.4
	$Na_2S_2O_3$ (1.0 mol L^{-1})	38.5	64.7	88.9	91.8	92.0	91.5
	$Na_2S_2O_3$ (2.0 mol L^{-1})	41.6	68.9	91.1	92.2	93.0	92.8

The effect of flow rate of eluant on desorption efficiency of Au(I) ions from the cartridge was also checked in the range of 2.0-10.0 mL min^{-1} with thiourea solution. The results showed that the recovery of gold was maximized when using elution rates up to 3.5-8.0 mL min^{-1}. Therefore, 5.0 mL min^{-1} was selected.

The capacity of the graphitized carbon black for absorption of Au(I) was checked by passing 10 mg L^{-1} Au(I) through the cartridge (containing 1.0 g of graphitized carbon black). The metal ions were stripped off the graphitized carbon black with 10 mL 2.0 mol L^{-1} thiourea solution and measured by FAAS. Under the condition of gold recovery ≥ 95 %, the absorption capacity was calculated to be 32 mg g^{-1}. The cartridge has high capacity for the recovery of gold. The enrichment factor of 320 was achieved (3.2 L of gold solution pass the cartridge and can eluted from the cartridge with 10 mL of gold solution).

Reusability of the graphitized carbon black was checked by using the same solid phase for sorption-desorption of Au(I) ions for 100 times. The maximum change in the performance (sorption capacity) of the solid phase sorbent after the repeated use was less than 2 %. This indicated that the repeated use of the sorbent is feasible.

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, Cl^-, NO_3^-, HCO_3^-, CO_3^{2-} and SO_4^{2-}, 10-fold Zn^{2+}, Fe^{2+}, Ni^{2+}, Pd^{2+}, Cu^{2+}, Co^{2+}, Cr^{3+}, 2-fold Ag^+, Pb^{2+} do not interfered with the gold recovery. The results confirm that the sorbent is highly selectivity for gold recovery.

The recovery of gold from an industrial gold cyanide leaching solution (Au 11.2 mg L^{-1}, Ag 7.62 mg L^{-1}, Ni 2.87 mg L^{-1}, Cu 1.87 mg L^{-1}, Zn 46.12 mg L^{-1}, Fe 1.38 mg L^{-1}, Co 0.84 mg L^{-1}) was also investigated. Under the condition of gold recovery ≥ 95 %, the absorption capacity was calculated to be 24 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 could be applied for the recovery of gold from the cyanide solution. The graphitized carbon black has a high abrasion-resistant than that of activated carbon. It can use for more than one hundred times and the loss of gold-containing sorbent was avoided. For 10 mg L^{-1} of gold solution, an enrichment factor of 320 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 interfere with the gold recovery. The selectivity of this method is high. The absorption capacity was calculated to be 32 mg g^{-1} for gold standard solution and 24 mg g^{-1} for the industrial gold cyanide leaching solution. This method is 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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