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Separation of gold(III) from hydrochloric acid solution containing platinum(IV) and palladium(II) by solvent extraction with Cyanex 272 and LIX 63

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ABSTRACT

Solvent extraction experiments were performed to separate Au(III), Pt(IV) and Pd(II) in the HCl concentration ranged from 0.5 to 9 M. Cyanex 272 extracted only Au(III) among the three metals, while both Au(III) and Pd(II) was extracted by LIX 63 in the experimental ranges. The Au(III) in the loaded Cyanex 272 and LIX63 was stripped by either $(NH_4)_2S_2O_3$ or $(NH_2)_2CS$. The concentration ratio of Au(III) to Pd(II) affected the extraction behavior of Au(III) and Pd(II) by LIX 63. The characteristic vibration bands of Cyanex 272 and LIX 63 were proposed by analyzing the FT-IR.

Introduction

Precious metals are important industrial materials due to their excellent chemical and physical properties [1]. The purity of precious metals has an important influence on the application. Therefore, some separation methods such as ion exchange [2–4] and solvent extraction [5–7] have been applied to obtain precious metals with high purity.

Most of gold(III) exists as $AuCl_4^-$ when the concentration of chloride ion is higher than 0.1 M [5]. Table 1 lists the nature of the extractants employed in the extraction of Au(III) from hydrochloric acid solutions. Since solvating, amines and their mixtures are generally employed for Au(III) extraction, the extraction reactions of gold from hydrochloric acid solution by these extractants seem to be either anion exchange or solvation reaction. However, few works have been reported on the extraction of Au(III) from hydrochloric acid solution by cationic extractants. It has been reported that a third phase might be formed during the extraction of Au(III) by amines [8]. Recently ionic liquids like Cyphos IL 109 have been employed for the separation of Au(III) from the solutions with a lower metal concentration or lower acid concentration [9–11]. When solvating, amines and their mixtures are employed to separate Au(III) from Pt(IV) and Pd(II) from strong hydrochloric acid solution [6,12–14], the selectivity of these extractants for Au (III) over Pd(II) and Pt(IV) is not so efficient that either scrubbing or selective stripping is necessary to separate the co-extracted Pd(II) and Pt(IV) from the loaded organic. Cyanex 302 is employed to separate Au(III), Pd(II) and Pt(IV) from the solution where Au(III) concentration is very small (7.5 mg L^{-1}) [15]. According to this work, Au(III) as well as Pd(II) is co-extracted by Cyanex 302 and the extraction of Au(III) decreases rapidly when HCl concentration is higher than 4 M [15]. In the absence of Au(III), Cyanex 301 and LIX 63 showed a selectivity for Pd(II) over Pt(IV) in the HCl concentration range from 0.5 to 9 M [16].

Anode slimes resulted from the electro-refining of copper anodes contain Au as well as Pt and Pd. In order to develop a simple process to separate Au(III), Pt(IV) and Pd(II) from the leaching solution of anode slimes, solvent extraction experiments have been performed in this work. Compared to amines and solvating extractants, few works have been reported on the extraction and separation of Au(III) from hydrochloric acid solution with cationic extractants. Therefore, cationic extractants together with other solvating and amines were employed to investigate the extraction behavior of Au(III) by varying HCl concentration from 0.5 to 9 M. From these preliminary experiments, cationic extractants (Cyanex 272 and LIX 63) were selected as an appropriate extractant for the separation of Au(III) from Pt(IV) and Pd(II). The extraction and separation behavior among the three metals was investigated by

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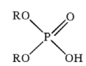
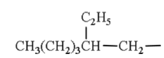
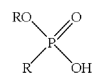
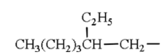
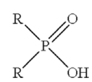
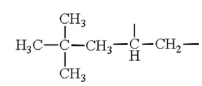
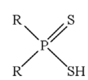
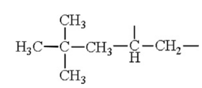
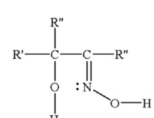
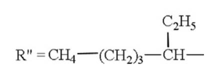
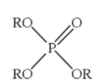
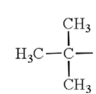
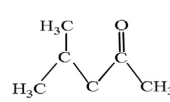
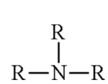
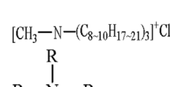
Table 1
Summary on the extraction of Au from chloride media with various extractants.

Extractant	Aqueous	Reaction	Acidity	E.X.	References
Alamine 304	$0.05\,g\,L^{-1}$ Au	Anion exchange	1–8 M	>99%	[19,20]
PONPEs	$0.1\,g\,L^{-1}$ Au	Solvation	1–6 M	>99%	[9]
Cyanex 471X	$0.1\,g\,L^{-1}$ Au	Solvation	1–3 M	98%	[10]
Cyanex 925	$0.005\,g\,L^{-1}$ Au	Solvation	1–6 M	90%	[21]
Cyanex 921	$0.025\,g\,L^{-1}$ Au	Solvation	5–7 M	96%	[22]
Cyanex 302	$7.5\,mg\,L^{-1}$ Au over $10\,mg\,L^{-1}$ Pt, Pd	Anion exchange	0–8 M	>99%	[23]
CTAB	$0.05\,g\,L^{-1}$ Au over base metal ions	Anion exchange	1–5 M	>99%	[24]
Isomeric aliphatic alcohols	2×10^{-3} M Au	Solvation	1–4 M		[11]
Aliquat 336	$0.182\,g\,L^{-1}$ Au, $0.196\,g\,L^{-1}$ Pt, $0.194\,g\,L^{-1}$ Pd	Anion exchange	pH 1–5	>99%	[6]
MBHA DHEHA DHOA	10^{-3} M Au, Pd, Pt, Ph, Cu, Fe, Ni	Solvation	0.5–7 M	>99%	[25]
Cyphos IL 109	$0.1\,g\,L^{-1}$ Au		0.1–4 M	>99%	[5]

DHBT: *N*,*N*-di-*n*-hexyl-*N*′-benzoylthiourea; PONPEs: polyoxyethylene nonyl phenyl ethers; MBHA: *N*-methyl-*N*-butylhexylamide, DHOA: *N*,*N*-dihexyloctainamide, DHEHA: *N*,*N*-di-hexyl-2-ethylhexainamide.

Table 2
The chemical structure of the extractants employed in this study.

Category	Extractant	Structure	R
Cationic	D2EHPA		
	PC88A		
	Cyanex 272		
	Cyanex 301		
	LIX 63		R' = H 
Neutral	TBP		
	MIBK		
	Cyanex 923	$R_3P(O)$ $R_2R'P(O)$ $RR'_2P(O)$ $R'_3P(O)$	R = $[CH_3(CH_2)_7]$ = normal octyl R' = $[CH_3(CH_2)_5]$ = normal hexyl
Amine	Alamin300		R = trioctyl/decanyl
	Aliquat 336 Alamine 336		C_8H_{17} or $C_{10}H_{21}$

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