[Article ID] 1003- 6326(2002)02- 0313- 04

Extraction of copper from bacterial leach solution using LIX98①

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[Abstract] Extraction of copper from bacterial leach solution using Lix984 had been performed. It was found that the main factors influencing extraction yield of copper are the phase ratio and the concentration of extractant, following the pH of solution and extraction time and the order of factors influencing the separation rate is the pH of solution, the concentration of extractant, the extraction time and the phase ratio. The best conditions obtained by the orthogonal tests are as follows: the extractant concentration 4%, extraction time 3 min, phase ratio 1∶1, pH of solution 2.

[Key words] solvent extraction; bacterial leach solution; copper
[CLC number] TF804.2 [Document code] A

1 INTRODUCTION

Solvent extraction followed by electrowinning (SX-EW) has become a key process in the last two decades for recovery of copper from the bacterial leaching solution of low-grade copper ores. Because of its a lot of characters, the technique will become the main technology of dealing with low-grade copper ore resources in the 21th century[1]. Because the extractant is the base of forming hydrometallurgy process, many medical investigator took on a lot of work for selecting the excellent extractants, while LIX extractants were the most successful and developed by the Henkel Company(In Germany). Some of the foreign extractants, including their brands, composition and invented companies and date were listed in the Ref. [2]. In recent years, a lot of studies about copper solvent extraction in acid or ammoniacal medium using LIX extractants are reported[3~12]. The characteristic parameters of LIX984 were listed in the Ref. [3] and compared with LIX622.

This study has been carried out on selective extraction of copper from bacterial leach solution using LIX984. The purpose of the paper is to obtain the reasonable process parameters by means of conditional tests and orthogonal tests.

2 EXPERIMENTAL

2.1 Materials and experimental method

2.1.1 Materials and reagents

The solution used for the study was an eligible bacterial leach solution that obtained from a dump factory of a Chinese copper mining. The aqueous pH was about 2.4. The composition of leached solutions used for the study are shown in Table 1.

Table 1 Main contents of leached solution of copper

Element	Content/(g·L^{-1})	Element	Content/(g·L^{-1})
Cu	0.463	SiO_2	0.137
Fe	0.527	Ca	0.530
Al	0.680	Mg	0.810

The copper specific extractant and the diluent used for this study were both obtained from the dump leach locale. LIX984 was a mixture of 2-hydroxy-5 nonylacetophenone oxime and 2-hydroxy-5-dodecyl salicylaldoxime. The functional group in extractive reaction of structural formula were hydroxy (—OH) and hydroxyimino group (=N—H).

2.1.2 Experimental method

Copper extraction experiments were carried out in the 250 mL separatory funnels and by mechanical shaking of the appropriate aqueous and organic phases. If necessary the pH values were adjusted by diluent H_2SO_4 and NaOH solution.

2.1.3 Chemical analysis

Copper was analyzed by the AAS (Atomic Absorption Spectrometry) or by other conventional analytical methods. The aquenous pH was mesured by the pH meter of PHS-3C.

2.2 Design of experiment

The study adopted the orthogonal test of four factors and four levels to design the experiments. The inspected factors were the concentration of extractant, phase ratio, extraction time and equilibrium pH of aqueous phase. Factors and levels of orthogonal tests were shown in Table 2. The experiments arranged according to the $L_{16}(4^5)$ orthogonal form and 16 groups in total. On the process of experiment, two indexes were checked which were the extraction

① [Foundation item] Project supported by the Foundation for University Key Teacher of the Ministry of Education, P.R.China
[Received date] 2001-05-08; [Accepted date] 2001-11-08

yield of copper and the separation time and from which the main and the secondary influenced factors could been determined.

Table 2 Factors and levels of orthogonal tests

Levels	Factors			
	Concentration of extractant/ ($g \cdot L^{-1}$) (A)	Time of extraction/ min (B)	Phase ratio (O/A) (C)	pH (D)
1	1	2	1∶1	1
2	4	3	2∶3	2
3	7	5	3∶2	3
4	10	7	1∶3	4

3 RESULTS AND DISCUSSION

On the basis of experimental results and the theoretical analysis, the reasonable process parameters have been determined. The results of orthogonal tests are shown in Table 3.

3.1 Influence of various factors to extraction yield

The variance analysis of factors for extraction rate is shown in Table 4. Where K_i (i= 1~ 4) represented the summation of the experimental results under the level i and the figure represented the effective degree of the various level to the copper extraction yield, and k_i is the average value ($k_i = K_i/4$). R is the range of the results under the various factors and levels and it represented the degree of factors for influencing the copper extraction. The lager the range is, the deeper the influenced degree is. It was shown that $R_C > R_A > R_D > R_B$ from the Table.

From the value of R, the influenced order of the four factors to the copper extraction yield is the phase ratio, the extractant concentration, the pH value and the extraction time. In fact, the increase of the phase ratio and the extractant concentration is adding the quantity of extractant. As a result, to the leach solution of a concentration of copper ion, it is necessary to keep the quantity of extractant enough so that the extraction reaction is completely.

Each factor had the different characters to the extraction yield of copper (Figs. 1~ 4). Fig. 1 shows the copper extraction yield is improved with the

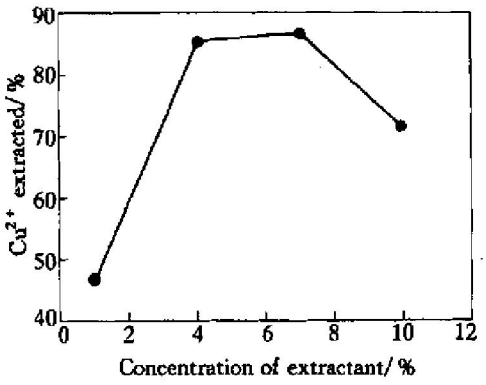

Fig. 1 Relationship between extraction rate and concentration of extractant

Table 3 Results of orthogonal tests

No.	Residual Cu^{2+} / ($mg \cdot L^{-1}$)	Separation time / min	Extracted Cu^{2+} / %	Test conditions			
				A / %	B/ min	C	D
1	414	3	10.58	1	2	1∶1	1
2	305	3	34.13	1	3	2∶3	2
3	1.25	4	99.73	1	5	3∶2	3
4	271	5	41.47	1	7	1∶3	4
5	1.06	5	99.77	4	2	2∶3	4
6	0.52	3	99.89	4	3	1∶1	3
7	114	2	75.38	4	5	1∶3	2
8	153	2	66.95	4	7	3∶2	1
9	3.06	4	99.34	7	2	3∶2	2
10	251	3	45.79	7	3	1∶3	1
11	0.78	3	99.83	7	5	1∶1	4
12	0.41	5	99.91	7	7	2∶3	3
13	408	4	11.88	10	2	1∶3	3
14	1.62	5	99.65	10	3	3∶2	4
15	1.80	3	74.51	10	5	2∶3	1
16	2.66	4	99.43	10	7	1∶1	2

Table 4 Variance analysis of factors for Cu extracted rate

Parameters	Factors			
	A	*B*	*C*	*D*
K_1	185.91	221.57	309.73	197.83
K_2	341.99	279.46	308.32	308.28
K_3	344.87	349.45	365.67	311.41
K_4	285.47	307.76	174.52	340.72
k_1	46.98	55.39	77.43	49.46
k_2	85.49	69.87	77.08	77.07
k_3	86.22	87.36	91.42	77.85
k_4	71.37	76.94	43.63	85.18
R	39.74	31.97	47.79	35.72

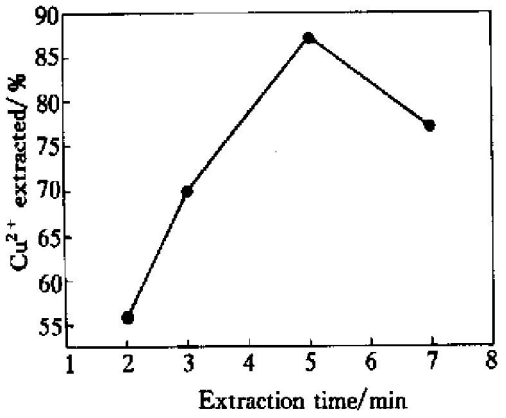

Fig. 2 Relationship between extraction rate and extraction time

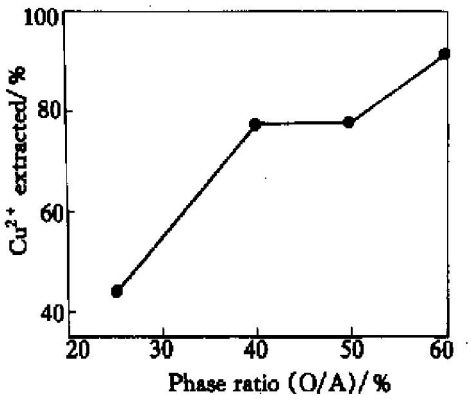

Fig. 3 Relationship between extraction rate and phase ratio

ncreasing of the extractant concentration. But when the extractant concentration is too high, the extraction yield is dropped. It shows that the diluent is very important in the extraction process. The results show that there is less influence of extraction time. On the whole, the extraction yield is increased with the prolongation of extraction time (Fig. 2). From the Fig. 3 the extraction yield was obviously improved when

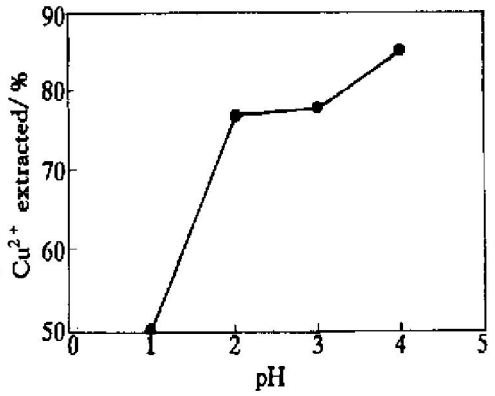

Fig. 4 Relationship between extraction rate and pH

O/A phase ratio is rose. From Fig. 4 the extraction yield is improved when the pH value is increased within the pH range studied.

3.2 Effects of various factors to seperation rate

The variance analysis of factors for separation rate is shown in Table 5. According to the value of difference of the four factors to the separation rate, there was $R_D > R_A = R_B > R_C$. It is shown that the pH is the strongest influence factor and the extraction concentration and extraction time are the second influence factors. With the increase of both the pH value to some degree the separation rate becomes slow subsequently. This may be due to the increase of the colloid-form particles and/or extraction crud with the increase of the pH value, thus the viscosity of solution is increased and the organic phase is separated more difficulty from the aqueous phase.

Table 5 Variance analysis of factors for separation rate

Parameters	Factors			
	A	*B*	*C*	*D*
K_1	26	24	30	34
K_2	32	28	24	30
K_3	26	32	26	24
K_4	24	24	28	20
k_1	6.5	6	7.5	8.5
k_2	8	7	6	7.5
k_3	6.5	8	6.5	6
k_4	6	6	7	5
R	2	2	1.5	3.5

In fact, the Fe^{3+} in the leaching solution occurred series reactions of hydrolization and polymerization, forming polyhydric complex or Fe-SO_4 complex and crud consequently. The reactions may be proposed as

$$Fe^{3+} + H_2O \longrightarrow FeOH^{2+} + H^+ \quad (1)$$

$$Fe^{3+} + 2H_2O \rightleftharpoons Fe(OH)^{2+} + 2H^+ \quad (2)$$

$$2FeOH^{2+} \rightleftharpoons Fe_2(OH)_2^{4+} \quad (3)$$

$$Fe^{3+} + SO_4^{2-} \rightleftharpoons FeSO_4^+ \quad (4)$$

$$FeSO_4^+ + SO_4^{2-} \rightleftharpoons Fe(SO_4)_2^- \quad (5)$$

$$Fe^{3+} + HSO_4^- \rightleftharpoons FeHSO_4^{2+} \quad (6)$$

4 CONCLUSIONS

1) According to the range R, the main factors of influencing extraction rate of copper are the phase ratio and the concentration of extractant, following the pH of solution and extraction time, and the order of factors influencing the separation rate is the pH of solution, the concentration of extractant, the extraction time and the phase ratio.

2) According to the analysis of the various factors, with the increasing of phase ratio and the extractant concentration, the extraction yield of copper is increased. But when the extractant concentration is too high, the extraction yield is decreased. The separation rate and the extraction yield is increased when the pH value is improved within the pH range studied. The extraction yield is increased when the pH value and O/A phase ratio is improved.

3) Within the present experimental conditions, the process is optomized with the extractant concentration of 4%, extraction time of 3 min, phase ratio 1 ∶ 1, pH of solution 2.

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(Edited by ZHU Zhong-guo)