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Flotation experiment research on a polymetallic sulfide ore of Cu, Pb, and Zn in Shanxi province

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ABSTRACT

The most valuable elements in a polymetallic sulfide ore in the Shanxi province are copper, lead, zinc, gold and silver, and the main metal minerals are galena, sphalerite, chalcopyrite, pyrite, and so on. Microscopic images show that gold and silver were not observed in the ore. The polymetallic separation flowsheet of copper/lead bulk flotation – copper/lead separation - priority flotation zinc and pyrite from the bulk flotation tailings was used. The concentrate indexes of the grade of copper, lead, and zinc were 20.87%, 49.91%, and 60.10%, respectively, and the recoveries were 75.59%, 91.62%, and 74.07%. These values were obtained using the suitable technological flowsheet and at suitable conditions. Gold and silver were enriched in the copper concentrate and pyrite products. Copper, lead, zinc, gold, and silver in the ore were effectively recovered, from which excellent economic benefits can be obtained.

Keywords: polymetallic sulfide ore; bulk flotation of copper and lead; separation of copper and lead; priority to floating zinc; recycling by accompanying

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INTRODUCTION

The polymetallic sulfide ore of copper, lead, and zinc is widely found all over the world and is often associated with rare metals such as gold and silver. The economic value of the comprehensive recycling of this of ore is large[1]. The polymetallic sulfide ores of copper, lead, and zinc are usually processed via flotation, and the concentrates of these three metals and sulfur can be obtained. Valuable elements in the ore are recovered by enriching the concentrate products and can be further recovered via smelting[2-4]. In general, the copper sulfide content of minerals is low, whereas those of galena and sphalerite are high. In addition, the pyrite content varies among ores. The concentrate products of copper, lead, and zinc can be obtained via flotation separation. The concentrate products of sulfur can be obtained only when the ore's pyrite content is high. Gold and silver can be recovered from the concentrates of copper, lead, and zinc or from the products of pyrite. The goal of floating pyrite is not to recover sulfur but to improve the recovery of gold and silver when the pyrite content of the ore is low. Flotation separation of polymetallic sulfide ore is a very difficult process because of the complex mineral composition and closely related mineral paragenesis. Various research and data regarding the floatation technology and reagents have been conducted and obtained by numerous domestic and international scholars[5-8].

The major metal minerals are galena, sphalerite, chalcopyrite, and pyrite, whereas the non-metallic minerals are quartz, plagioclase, calcite, dolomite, and chlorite. In addition, the most usable elements found in the polymetallic sulfide ore in Shanxi province are copper, lead, zinc, gold, and silver. The grades of Cu, Pb, Zn, Au, and Ag are 0.49%, 1.22%, 1.95%, 1.78 g/t and 59.06 g/t, respectively. Gold and silver canot be observed using a microscope because they are usually in the form of fine grains or super fine grain inclusions, which also occur in other metal minerals and gangue. The metal minerals in an ore form via two stages - first, pyrite is initially formed, and sphalerite, galena, and chalcopyrite are then subsequently formed. Minerals that are formed in the same period fill each other's cracks, and minerals that are formed earlier fill the fracture of the mineral that formed later, thereby forming a complex structure. Therefore, separating different metal minerals is difficult because they are closely related.

The polymetallic separation flowsheet of copper/lead bulk flotation – copper/lead separation – priority to floating zinc and pyrite (recovering of gold and silver) from the bulk flotation tailings was used based on the ore characteristics. The concentrate indexes of the grade of copper, lead, and zinc were 20.87%, 49.91%, and 60.10%, respectively, and the recoveries were 75.59%, 91.62%, and 74.07%. These values were obtained using the suitable technological flowsheet and at suitable conditions. In the copper concentrate, the grades of gold and silver were 65.32 and 2038 g/t, respectively, and their recoveries were 64.97% and 61.08%, respectively. In the pyrite product, the grades of gold and silver were 12.42 and 358.9 g/t, respectively, and their recoveries were 15.53% and 13.67%, respectively. Gold and silver were both efficiently enriched in the copper concentrate and product of pyrite.

ORE PROPERTIES

CHEMICAL ANALYSIS

The chemical analysis results of the feed are shown in Table 1.

Table 1 the chemical analysis results of the feed

elements	Cu	Pb	Zn	S	SiO2	Au*	Ag*
Content（%）	0.49	1.21	1.95	5.90	46.10	1.78	59.06

** unit：g/t*

COMPOSITION AND CONTENT OF MINERAL

The major metal minerals in the ore were galena, sphalerite, chalcopyrite, and pyrite, and the ore contained low amounts of arsenopyrite and non-metallic minerals, such as quartz, plagioclase, calcite, and dolomite. In addition, a substantial amount of chlorite, sericite, and kaolin clay gangue minerals were also found in the ore; however, their presence is disadvantageous in the recovery of the usable minerals. The mineral composition and content of the ore are shown in Table 2.

Table 2 mineral composition and content of the ore

nonmetallic minerals	quartz	carbonates	sericite	chlorite	talc	kaolin	anorthose
Content（%）	16.91	18.66	9.05	13.57	8.34	5.96	19.89
metallic minerals	galena	sphalerite	pyrite	chalcopyrite	bornite	leucosphenite	
Content（%）	1.56	2.69	1.74	1.17	0.11	0.35	100.00

DISSEMINATION SIZE OF MAJOR METAL MINERALS

The dissemination sizes of the main metal mineral are shown in Table 3.

Table 3 the dissemination sizes of the main metal mineral

Size(mm)	>0.1	0.075 -0.1	0.056 -0.075	0.037 -0.056	0.02 -0.037	0.01 -0.02	<0.01
galena	18.16	36.87	19.56	12.01	7.65	3.96	1.79
sphalerite	53.42	18.67	10.88	6.07	4.99	3.51	2.46
pyrite			24.20	32.38	21.93	10.86	6.63
chalcopyrite			14.78	17.11	21.23	22.27	24.61

ORE STRUCTURES AND CONSTRUCTS

Ore structure:The metal sulfide ores show idiomorphic, hypidiomorphic, or structure-dependent grains. The pyrite particles were the coarsest, followed by that of galena, sphalerite, and chalcopyrite. The metal minerals from the early formation (mainly pyrite) were broken into the size of breccia and formed a cataclastic texture when stress was applied. The minerals of copper, lead, and zinc from the late formation replaced the minerals from the early formation, thereby forming a metasomatic structure.

Ore constructions: The aggregates of the metal minerals were distributed in clumps and formed a massive structure, in which pyrite is the most noticeable. These aggregates were distributed in the gangue mineral matrix with an irregular shape, which leads to the impregnation and complex construction of the spot.Gangue minerals, such as quartz, in the vein or net filled the crystal gap or fissure of the metal sulfide, such as pyrite, thereby forming a vein construction.

Gold and silver were not observed using a microscope because they were probably in the form of fine grains or superfine grain inclusions, which also occur other metal sulfides and gangue. Further research need to be conducted.

FLOTATION TEST

Flotation of copper - lead-zincores presents one of the most complicated problems in base metal metallurgy, due to the similar floatability of copper and zinc minerals. This is especially true when oxidation has caused dissolution of some of the copper, which activates the zinc. Selective flotation in three steps was an early practice on lead-zinc-copper ores. This is now seldom used, as the preferred technique is to float a bulk copper-lead concentrate selectively with depression of zinc and iron, followed by reflotation of the copper-lead tailing for recovery of zinc[9].

The polymetallic separation flowsheet of copper/lead bulk flotation–copper lead separation–priority floating zinc and pyrite from the bulk flotation tailings was used based on the ore properties. The flowsheet principles used in the experiment is shown in Figure 1.

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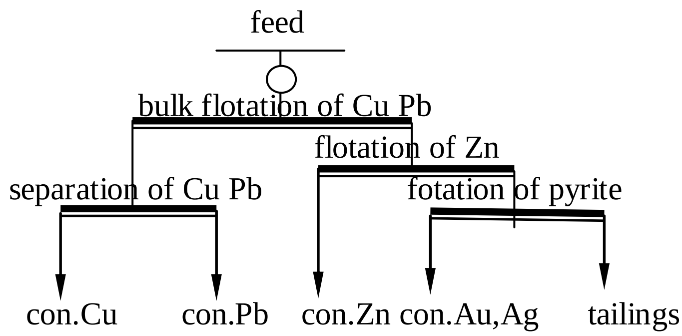


Figure 1 flowsheet principles used in the experiment

MESH OF GRIND TEST

The full disintegration of the metal and gangue minerals an important factor that affects the flotation index. The mesh of grind determines the degree of dissociation between different minerals. An appropriate mesh of grind may help remove more gangue and metal. The mesh of grind test was conducted by rougher the copper/lead bulk flotation with 1500 g/t of lime, 1000g/t of Zinc sulfate, 500 g/t of sodium sulfate, 40 g/t of Z-200, 40 g/t of butylamine aerofloat, and 20 g/t of #2 oil (specific conditions by inspection was used after inspection in the next test). The results are shown in Figure 2.

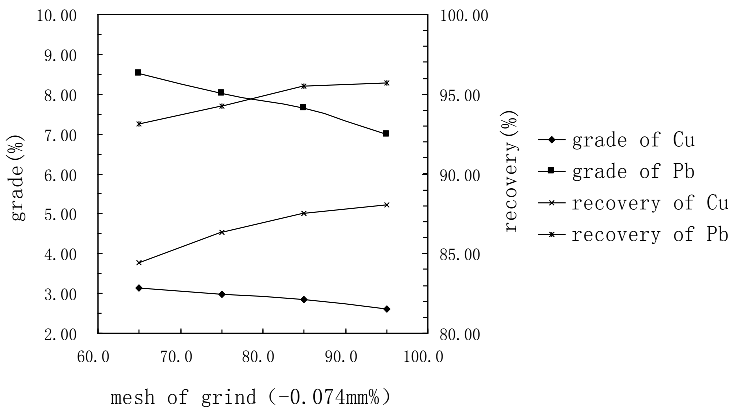
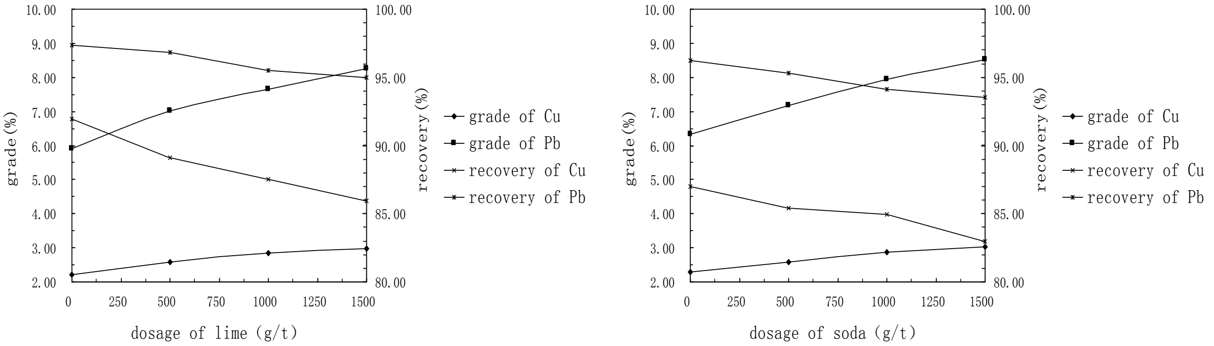


Figure 2 the results of Mesh of grind test

The recovery of copper and lead in the mixed concentrate improved with increasing grinding fineness and decreasing grade of lead and copper. The improvement of the recovery and reduction of concentrate grade were slow with increasing grinding fineness when the content is more than - 0.074 mm 85%. Therefore, a grinding fineness of -0.074 mm 85% was used in the succeeding test.

PH ADJUSTMENT TEST OF COPPER/LEAD BULK FLOTATION

The flotation of the polymetallic sulfide ore of copper, lead, and zinc is generally suitable at alkaline pH conditions. Lime and soda are common agents used in adjusting the pH of the slurry. These agents were used and the effects of their dosage(corresponding to different pH) on the flotation indexes were studied. The results are shown in Figure 3.



A B

Figure 3 the results of dosage of Lime(A) and soda (B)

The results show that the effects of lime were better than those of soda.When the dosage of lime was between 0 and 1000 g/t, the concentrate grade increased with increasing dosage. However, the recovery was reduced. Lime has an obvious depressing effect on pyrite. When the dosage of lime was higher than 1000 g/t, the concentrate grade and recovery decreased. This reduction occurred because when the dosage of lime is high, copper and lead sulfide minerals are restrained, thereby reducing the recovery. At the same time, the viscosity of slurry increased, and the flotation selectivity decreased and gangue mineral inclusion was floated. After comprehensive consideration, lime was used as a pH adjustment agent, and its suitable dosage was 1000 g/t.

THE DOSAGE OF DEPRESSANT TEST IN COPPER/LEAD BULK FLOTATION

Zinc sulfate and the stone acid sodium have excellent depressing effects on sphalerite. A suitable depressant dosage can be better realized using floating copper/lead restraining zinc in copper/lead bulk flotation. The test results of dosage of the zinc sulfate and the stone acid sodium are shown in Figure 4(point 1,2,3 and4,dosage of zinc sulfate and the stone acid sodium are 500 and 500,500 and 1000,1000 and 500,1000 and 1000).

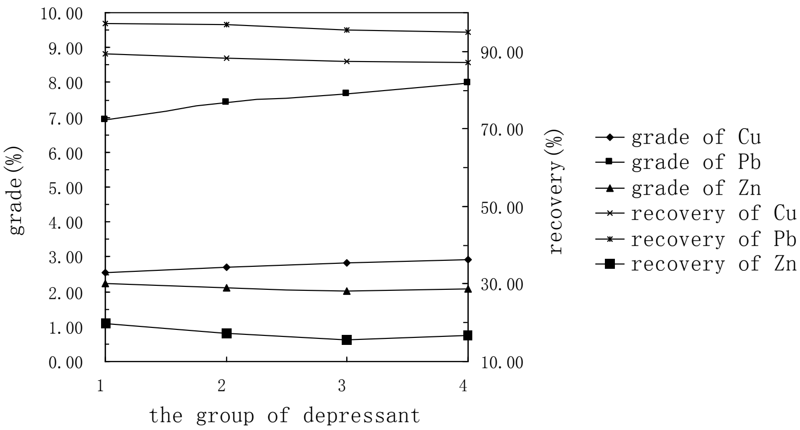


Figure 4 The results of dosage of depressant test

Figure 4 shows that when the dosage of zinc sulfate was 1000 g/t and the dosage of stone acid sodium was 500 g/t, the depressing effects on sphalerite was better.

TEST FOR COLLECTORS KIND AND DOSAGE IN COPPER/LEAD MIXED FLOTATION

The effect of the flotation collector kind was studied using butyl xanthate, Z-200, diethyldithiocarbamate, ethyl xanthate, and butylamine aerofloat(express as 1,2,3,4,and 5 in figure) as the collectorsat conditions of similar yields. The results are shown in Figure 5.

The figure 5 shows that the indexes of copper and lead in the mixed concentrate were better when Z - 200 and butylamine aerofloat were used as collectors. Thus, the combination of Z - 200 and butylamine aerofloat was a suitable flotation collector. The experimental results on dosage of collectors are shown in Figure 6.

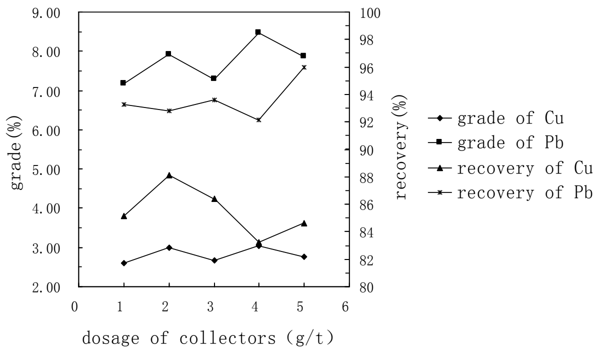


Figure 5 The Test results for collector kind

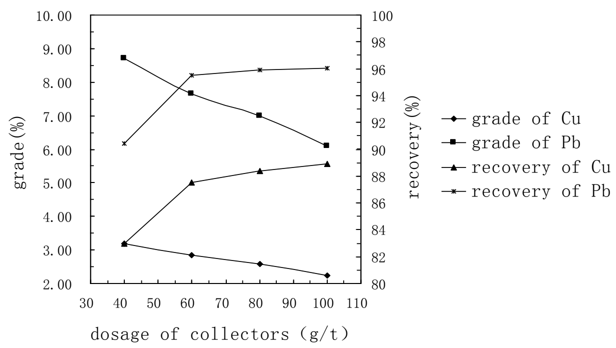


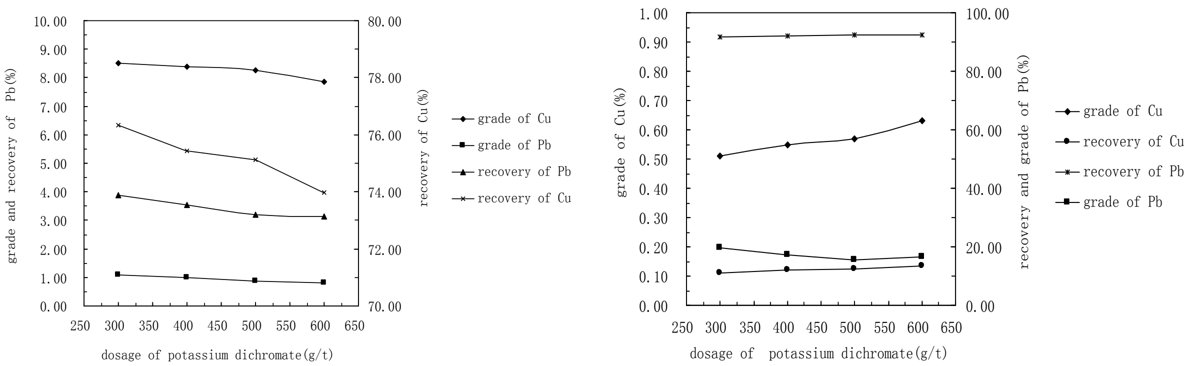
Figure 6 the experimental results on dosage of collectors

From Figure 6 (the dosage of collectors was the sum of Z - 200 and butylamine aerofloat and each accounted for 50%), the recovery of copper and lead gradually increased with increasing dosage of collectors. The suitable dosage of Z - 200 and butylamine aerofloat is 40 g/t.

TEST FOR DEPRESSANT IN SEPARATION OF COPPER AND LEAD

Copper floating and lead restraining are generally used to separate copper and lead in their bulk concentrate. Potassium dichromate is commonly used as an depressant for galena[10]. The dosage of potassium dichromate was studied for the separation of copper and lead.

Activated carbon with a concentration of 400 g/t was used as a removing agent to reduce the effect of the agents on the separation index prior to the separation of copper lead.The experimental results of dosage of depressant in separation of copper and lead are shown in Figure 7.



A **B**

Figure 7 the test results of dosage of depressant in separation of copper and lead
(A:concentrate of Cu, B:concentrate of Pb)

Figure 7 shows that with increasing dosage of potassium dichromate, the grade and recovery of lead in the copper and lead concentrates gradually decreased and increased, respectively. The results showed that potassium dichromate could effectively achieve the separation of copper and lead. If the dosage of potassium dichromate was in excess, the recovery of copper was very low. Therefore, The suitable dosage of potassium dichromate is 500 g/t.

TEST FOR DOSAGE OF SULFATE IN ZINC FLOTATION

The main minerals in the flotation tailings after mixed flotation of copper and lead (rougher for a time and scavenger for a time) were sphalerite and pyrite. Copper sulfate is generally used for the activation of sphalerite. The effect of dosage of copper sulfate on the zinc flotation index was studied with 40 g/t butyl xanthate as the collector. The conditions for flotation are shown in Table 4, and the results are shown in Figure 8.

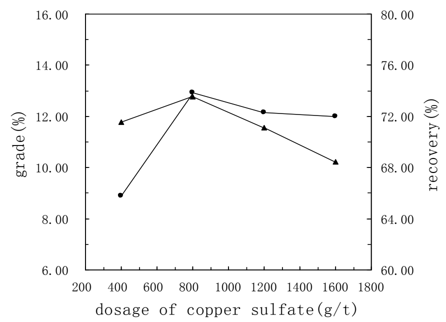


Figure 8 the results of test for dosage of sulfate in zinc flotation

Figure 8 shows that with increasing dosage of copper sulfate, the recovery of zinc concentrate significantly increased. When the dosage of copper sulfate was extremely high pyrite floated and the selectivity of the flotation process decreased. Moreover, the zinc grade decreased. The suitable dosage of copper sulfate was 800 g/t.

COMPREHENSIVE CONDITION TEST

The suitable conditions for the technological and reagents of copper, lead, and zinc were obtained via the flotation condition test. The existing states of gold and silver were not shown ,because they were not observed when analyzed using a microscope. In addition, pyrite in the form of tailings after zinc flotation was recovered to improve the recovery of gold and silver (concentrate of sulfur was not obtained because of the low pyrite content in the ore). The flowsheet of synthesis condition test is shown in Figure 9, and the flotation conditions are shown in Table 4. Table 5 shows the results of the closed-circuit flotation test at synthesis conditions.

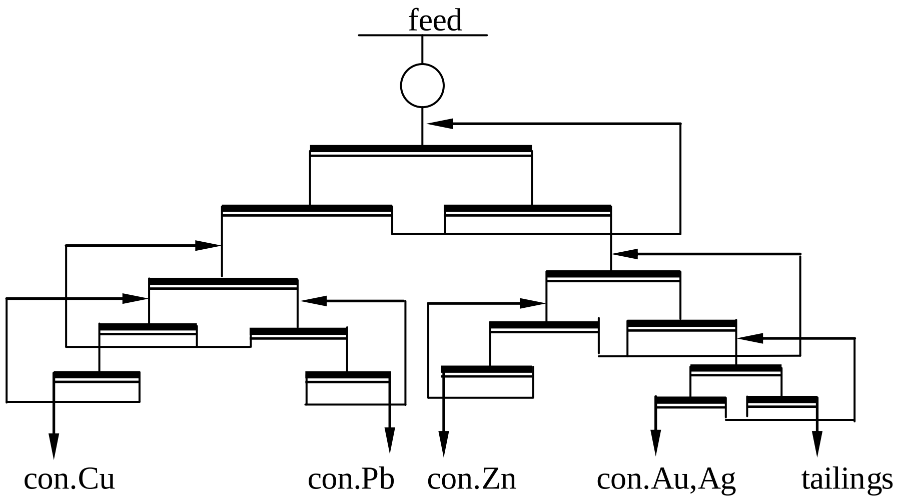


Figure 9 the flowsheet of synthesis condition test

Table 4 the flotation conditions

dosage	bulk flotation of copper/lead			priority to flotation zinc			priority to flotation pyrite			separation of copper and lead		
(g/t)	Rougher	Cleaners	scavengers	rougher	Cleaners	scavengers	rougher	Cleaners	scavengers	rougher	Cleaners	scavengers
Z-200	40		20									20
Butylamine aerofloat	40											
butyl xanthate				40		20	15		15			
2#oil	20		20	20		20	10		10			20
lime	1000	400		4000	200	1000						
Zn_2SO_4	1000	500										
Na_2SO_3	500	250										
Cu_2SO_4				800		800	500		200			
$K_2Cr_2O_4$										500	200	100
activated C										400		
Flotation time	5min	4min	5min	5min	6min	4min	5 min	3 min	4 min	5min	6min	8min

Table 5 the results of the closed-circuit flotation test at synthesis conditions

name	yeild（%）	grade（%）					recovery（%）				
		Cu	Pb	Zn	Au*	Ag*	Cu	Pb	Zn	Au	Ag
Con.Cu	1.77	20.87	1.54	5.04	65.32	2038	75.59	2.23	4.58	64.97	61.08
Con.Pb	2.24	1.49	49.91	6.43	1.31	178.9	6.83	91.62	7.40	1.65	6.79
Con.zinc	2.40	0.84	0.93	60.1	3.03	74.3	4.13	1.83	74.07	4.09	3.02
Con.Au	2.25	0.89	0.35	4.56	12.28	358.9	4.10	0.65	5.27	15.53	13.67
tailing	91.44	0.050	0.049	0.185	0.268	9.97	9.35	3.67	8.68	13.76	15.44
crude	100.0	0.489	1.220	1.947	1.780	59.06	100.0	100.0	100.0	100.0	100.0

** unit：g/t*

Table 6 shows that the copper, gold, silver, lead, and zinc grades from their corresponding concentrates were 20.87%, 65.32 g/t, 2038 g/t, 50.31%, and 60.10%, respectively, and the recoveries of copper, lead, and zinc were 75.59%, 91.62%, and 74.07%, respectively. The product grades of gold and silver were 12.42 g/t and 358.9 g/t, respectively, and the recoveries were 15.53% and 13.67%, respectively, which were achieved via pyrite floating.

CONCLUSION

The valuable component contents of the polymetallic sulfide ore from Shanxi province were high. Copper, lead, and zinc were detected. The major metal minerals found were chalcopyrite, galena, sphalerite, pyrite, and bornite. Moreover, pyrite formed earlier than chalcopyrite, sphalerite, and galena. These metal minerals are closely related and thus, separating these different minerals is difficult. The mineral processing and smelting of this type of polymetallic ore containing gold and silver are difficult.

The polymetallic separation flowsheet of copper/ead bulk flotation – copper/ lead separation – priority flotation zinc and pyrite from bulk flotation tailings was used through a variety of tests and observations. Copper and lead were effectively recovered, and gold and silver were recovered from the copper concentrate at the following conditions: grinding fineness of -0.074 mm 85 %, use of lime as a pH adjustment agent, use of Z–200 as the collector, use of butylamine aerofloat, use of potassium dichromate as the lead inhibitor, and use of zinc sulfate, sodium sulfite, and activated carbon as inhibitors of zinc. In addition, zinc was recovered and pyrite was floated to recover gold and silver by using lime, copper sulfate, and butyl xanthate.Copper, lead, zinc, gold, and silver were recovered and good economic benefits were achieved.

Microscopic images show that gold and silver minerals were not observed in the ore because they may have existed as fine grains or microscopic fine inclusions. Moreover, gold and silver were mainly distributed in chalcopyrite and pyrite and formed fine package because gold and silver can be effectively enriched in the copper concentrate and pyrite products.

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