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**THE USE OF THE GOLD-LEAF TEST TO CHECK
THE EFFECTS OF CERTAIN POSSIBLE
CONTAMINANTS OF CYANIDE SOLUTIONS**

by

H. H. MCCREEDY, C. C. CLARK & W. A. GOW

EXTRACTION METALLURGY DIVISION

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SUMMARY OF RESULTS

The gold-leaf dissolution test method was used to investigate the effects of various soluble salts, mainly sulphur compounds, on the dissolution rate of gold in cyanide solutions. The soluble salts chosen for the work were those most likely to be found in plant solutions produced in the cyanidation of pyrrhotitic ores. Possible methods of retarding the formation of these salts from pyrrhotite in the cyanidation process, and of minimizing their effects after they are produced, were also investigated.

Of the various sulphur salts investigated, sodium sulphide was the most detrimental to the dissolution of gold. Even concentrations of less than 1 part per million of sulphide ion greatly retarded the gold dissolution rate. The presence of sodium ethyl xanthate, sodium thiocyanate, and sodium thiosulphate were also found to be harmful but to a much lesser degree.

The detrimental effect of pyrrhotite in ores, which is due to the liberation of sulphide ions, is greatly reduced if the pH of the cyanide solution is kept below 11.

Oxidizing agents, such as potassium permanganate or sodium chlorate, in concentrations of 1 part per million, partially counteracted the effect of the sulphide ion.

* Senior Scientific Officer, ** Student Assistant and *** Head, Ore Treatment Section, Extraction Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

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INTRODUCTION

In the cyanide process for treating gold ores, the dissolution of the gold usually proceeds at a reasonably rapid rate if the surfaces of the gold are sufficiently free to react with the solution. However, certain soluble compounds formed with some components of the ore during the cyanide treatment, either may chemically react with the free cyanide ion to form a complex inactive ion, or may affect the surface of the gold to make it resistant to the action of the cyanide solution. The solution is then said to be "fouled". The nature and concentration of these soluble compounds are therefore important.

Previous workers (1, 2) have shown that pyrrhotite in cyanide-lime solution, produces a number of soluble sulphur compounds and that pyrrhotite in ores may cause "fouling" of cyanide solutions. Some of the sulphur from pyrrhotite dissolves and wastefully consumes cyanide by the formation of thiocyanate. When the dissolved sulphur is in the form of the sulphide ion, it is most detrimental to the process⁽³⁾. Control of the solution pH to the lowest practical operating level was shown to be a method of limiting undesirable reactions with pyrrhotite⁽⁴⁾.

In view of the apparent adverse effects of dissolved sulphur compounds, it was decided to investigate the effect on gold dissolution of various sulphur compounds, and also a few other ions that would

possibly be found in operating mill solutions. The method of gold-leaf dissolution rate was used since it had been shown by others^(3, 5) to be highly successful in detecting variations in the dissolving power of cyanide solutions.

EXPERIMENTAL PROCEDURE

Gold-Leaf Test Method

The gold-leaf test is a method of evaluating the dissolving power of cyanide solutions by comparing the dissolution times of uniform amounts of standard gold-leaf in the solutions. As carried out in this investigation, each test was done with a one centimeter square of 23K gold-leaf* adhering to the bottom of a moistened cork stopper. This stopper was fitted into the end of a 20 ml test-tube containing a 10 ml portion of the solution under test. The test-tube was shaken in a horizontal plane on a mechanical shaking device at a rate of five oscillations per second and a stroke of 0.5 inches. The dissolution of the gold was followed visually and the solutions were compared on the basis of the length of time required for complete dissolution of the gold-leaf in each solution. Each test was repeated five times and the average value taken.

* Central Scientific Company, Toronto, Ontario.
Catalogue JC 154, No. 88345.

Solution Analysis

The analyses of the cyanide solutions were carried out by the generally accepted standard methods^(6, 7).

Preliminary Tests and Effect of Some Known Soluble Compounds

To confirm the technique of gold-leaf dissolution tests, preliminary tests with synthetic cyanide-lime solutions were carried out. In these tests, the gold-leaf test pieces were treated with solutions made up with chemically pure sodium cyanide and lime to predetermined concentrations. The concentrations covered the ranges of 0.4 to 1.2 lb NaCN/ton of solution and 0.2 to 1.0 lb CaO/ton of solution. These preliminary tests provided a basis for comparison with other tests where known and unknown ions were present.

Once the relationship between the cyanide and lime concentrations and the time required to dissolve the gold-leaf was established, known amounts of soluble salts were added, and the solutions tested again for gold-leaf dissolving time. Most of the salts and the amounts of them used, were those which would give ion concentrations likely to occur in cyanide solutions that had been in contact with sulphide flotation concentrates of pyrrhotitic gold ores. The possible inhibiting effects of the added soluble compounds were examined at a weak cyanide concentration (1 lb NaCN/ton of solution, similar to most plant practice).

The salts added were as follows:

sodium thiocyanate	0.2 to 1.6 g/l
sodium ethyl xanthate	0.0004 to 0.0016 g/l
calcium sulphate	0.02 g/l
sodium sulphate	0.04 to 0.16 g/l
sodium thiosulphate	0.2 to 1.6 g/l
potassium ferrocyanide	0.2 to 0.8 g/l
sodium sulphite	0.16 g/l
sodium sulphide	0.07 to 2.4 ppm

The effect of oxidizing agents in a cyanide solution containing sulphide ions was tested by the individual addition of 1 ppm KMnO_4 or 1 ppm NaClO_3 to solutions containing 0.5 ppm S and 1 lb NaCN /ton of solution.

The Effect of Cyanide Solutions at Various pH Values on Pyrrhotite Dissolution

To approximate solutions that would be produced from gold mills where pyrrhotite occurred, finely ground pyrrhotite was contacted with cyanide-lime solvent and the resultant solutions were analysed.

Pyrrhotite samples, weighing 250 grams each, were mixed with cyanide solutions of various pH values in a ratio of four liquid to one solid. The initial cyanide strength in all cases was 1 lb NaCN /ton of solution while the pH was varied from 10.5 to 12.4. After a mixing period of two hours at room temperature, the slurries were filtered.

The filtrates were analysed for pH, reducing power, and total dissolved sulphur. No attempt was made to maintain the initial solution reagent concentrations during the test.

RESULTS

The preliminary tests with various cyanide and lime concentrations, over the ranges examined, confirmed that the gold-leaf dissolution rate increased with an increase in cyanide concentration⁽⁸⁾ or a decrease in lime concentration⁽⁹⁾. The fastest time for dissolution of the test gold-leaf was 10 minutes (Table 1 and Figures 1 and 2).

The addition of sodium thiocyanate, sodium thiosulphate, or sodium ethyl xanthate increased the time required to dissolve the gold-leaf. In the presence of 1.6 g sodium thiocyanate/l, 26 minutes was required to dissolve the gold-leaf compared to 11 minutes for a pure cyanide solution with the same cyanide and lime concentrations. Under similar conditions, the addition of 1.6 g sodium thiosulphate/l required 20 minutes for the gold-leaf dissolution. A sodium ethyl xanthate concentration of 0.0016 g/l increased the gold-leaf dissolving time up to 38 minutes. Calcium sulphate, sodium sulphate, potassium ferrocyanide and sodium sulphite in the ranges of concentrations used, had little or no effect on the gold-leaf dissolution time (Table 2.)

Sodium sulphide was found to be most detrimental to the gold dissolution reaction. In the presence of 0.03 ppm of sulphide ion, the time required was doubled to 20 minutes and increased to 220 minutes when 1 ppm of sulphide ion was added. The amounts of potassium permanganate and sodium chlorate used, although not completely effective in neutralizing the effect of the sulphide ion, were effective in counteracting the worst effects (Table 3).

In the series of tests where pyrrhotite was contacted with cyanide solutions at various pH levels, the resultant solutions from tests above pH 11 had a higher reducing power and more dissolved sulphur.

TABLE 1

Effect of Various Lime - Cyanide Concentrations on Gold-Leaf Dissolution

Solution No.	NaCN, lb/ton Solution	CaO, lb/ton Solution	pH	EMF, mv	Average Time for Dissolution of Gold-Leaf, min.
1	0.4	0.2	11.3	-132	23
2	0.6	0.2	11.3	-140	19
3	0.8	0.2	11.3	-148	15
4	1.0	0.2	11.3	-153	11
5	1.2	0.2	11.3	-148	10
6	0.4	0.4	11.7	- 83	26
7	0.6	0.4	11.7	-100	23
8	0.8	0.4	11.7	-100	18
9	1.0	0.4	11.7	-110	16
10	1.2	0.4	11.7	-113	13
11	0.4	0.6	11.8	-138	31
12	0.6	0.6	11.8	-140	27
13	0.8	0.6	11.8	-142	25
14	1.0	0.6	11.8	-147	22
15	1.2	0.6	11.8	-150	21
16	0.4	0.8	11.9	-140	34
17	0.6	0.8	11.9	-140	30
18	0.8	0.8	11.9	-140	27
19	1.0	0.8	11.9	-145	24
20	1.2	0.8	11.9	-150	23
21	0.4	1.0	12.0	-152	37
22	0.6	1.0	12.0	-152	33
23	0.8	1.0	12.0	-152	30
24	1.0	1.0	12.0	-154	29
25	1.2	1.0	12.0	-157	26

TABLE 2

Effect of Some Dissolved Salts on Gold-Leaf Dissolution in Synthetic
Lime-Cyanide Solutions

Additive		Average Time to Dissolve Gold-Leaf, min
Type	g/l	
Nil	0.0	11
Sodium thiocyanate	0.2	12
" "	0.4	14
" "	0.8	18
" "	1.6	26
Sodium ethyl xanthate	0.0004	23
" " "	0.0008	24
" " "	0.0016	38
Calcium sulphate	0.02	11
Sodium sulphate	0.04	11
" "	0.08	11
" "	0.16	13
Sodium thiosulphate	0.2	14
" "	0.4	17
" "	0.8	18
" "	1.6	20
Potassium ferrocyanide	0.2	12
" "	0.4	13
" "	0.8	12
Sodium sulphite	0.16	13

TABLE 3

Effect of Sulphide on Gold Dissolution Time in
Synthetic Lime-Cyanide Solutions

Initial pH	Initial Concentration NaCN, lb/ton Solution	Additive		Average Time to Dissolve Gold-Leaf, min
		Type	ppm	
11	1	S	0.03	20
"	"	"	0.05	28
"	"	"	0.10	50
"	"	"	0.25	80
"	"	"	0.50	130
"	"	"	1.0	220
11	1	{ S	0.5	23
		{ KMnO ₄	1.0	
11	1	{ S	0.5	22
		{ NaClO ₃	1.0	

TABLE 4

The Effect of Cyanide Solutions at Various pH
Values on Pyrrhotite Dissolution

pH	Reducing Power of Final Solution, ml KMnO ₄ /l	Total Sulphur Dissolved, g/l
10.5	88	0.28
11.0	88	0.27
11.5	96	0.31
12.0	184	0.47
12.3	298	0.64

250 g samples of pyrrhotite were treated for 2 hours with 1000 ml of solution at 1 lb NaCN/ton solution.

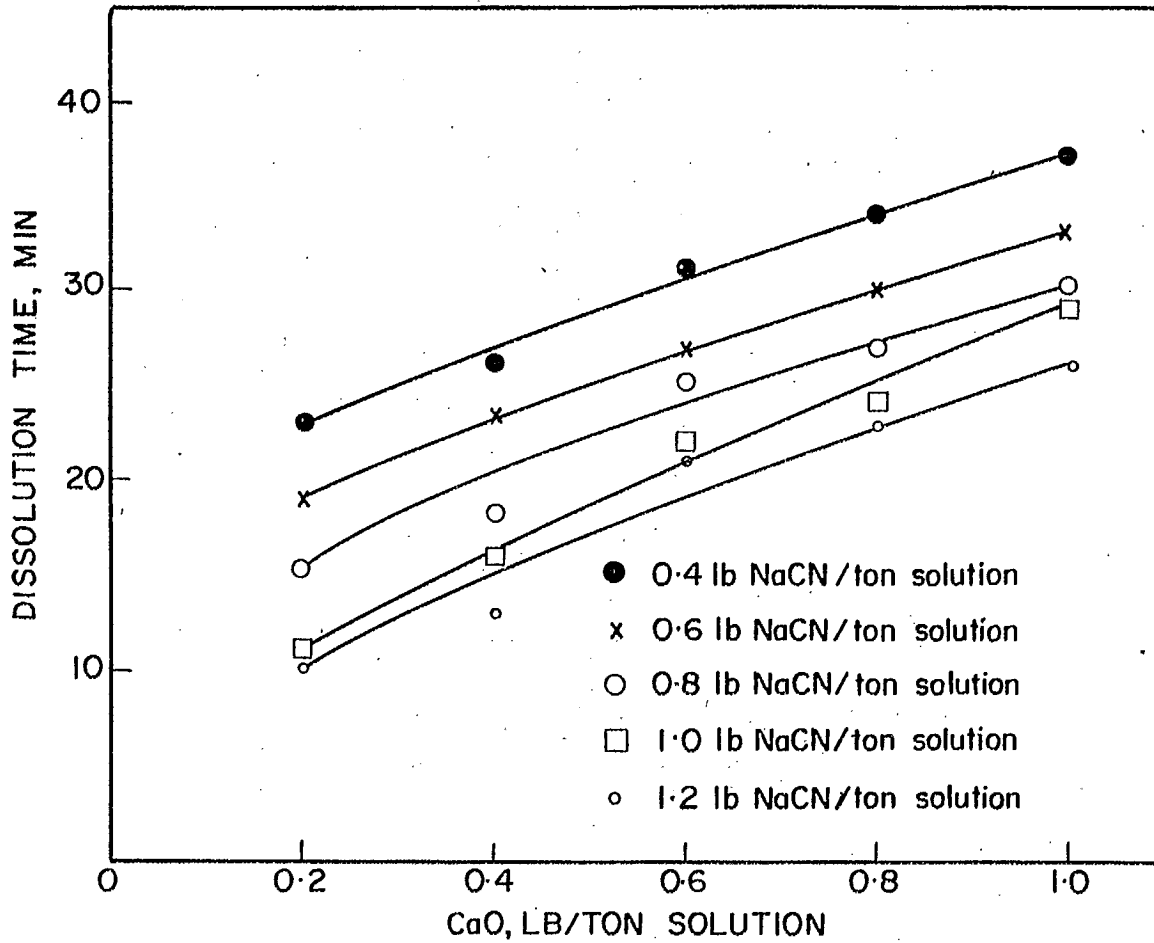


FIGURE 1

RELATION BETWEEN GOLD-LEAF DISSOLUTION TIME AND
LIME CONCENTRATION AT VARIOUS CYANIDE LEVELS

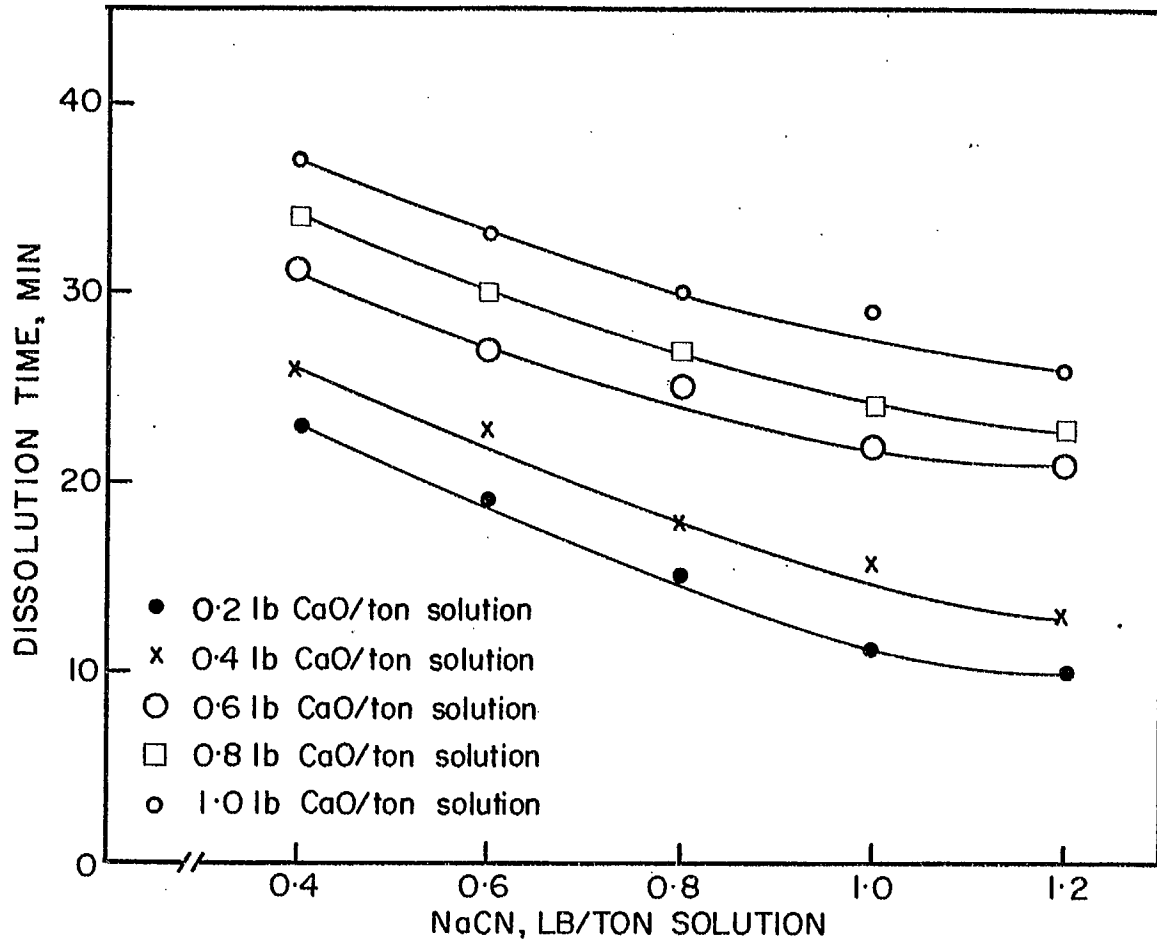


FIGURE 2

RELATION BETWEEN GOLD-LEAF DISSOLUTION TIME AND
CYANIDE CONCENTRATION AT VARIOUS LIME LEVELS

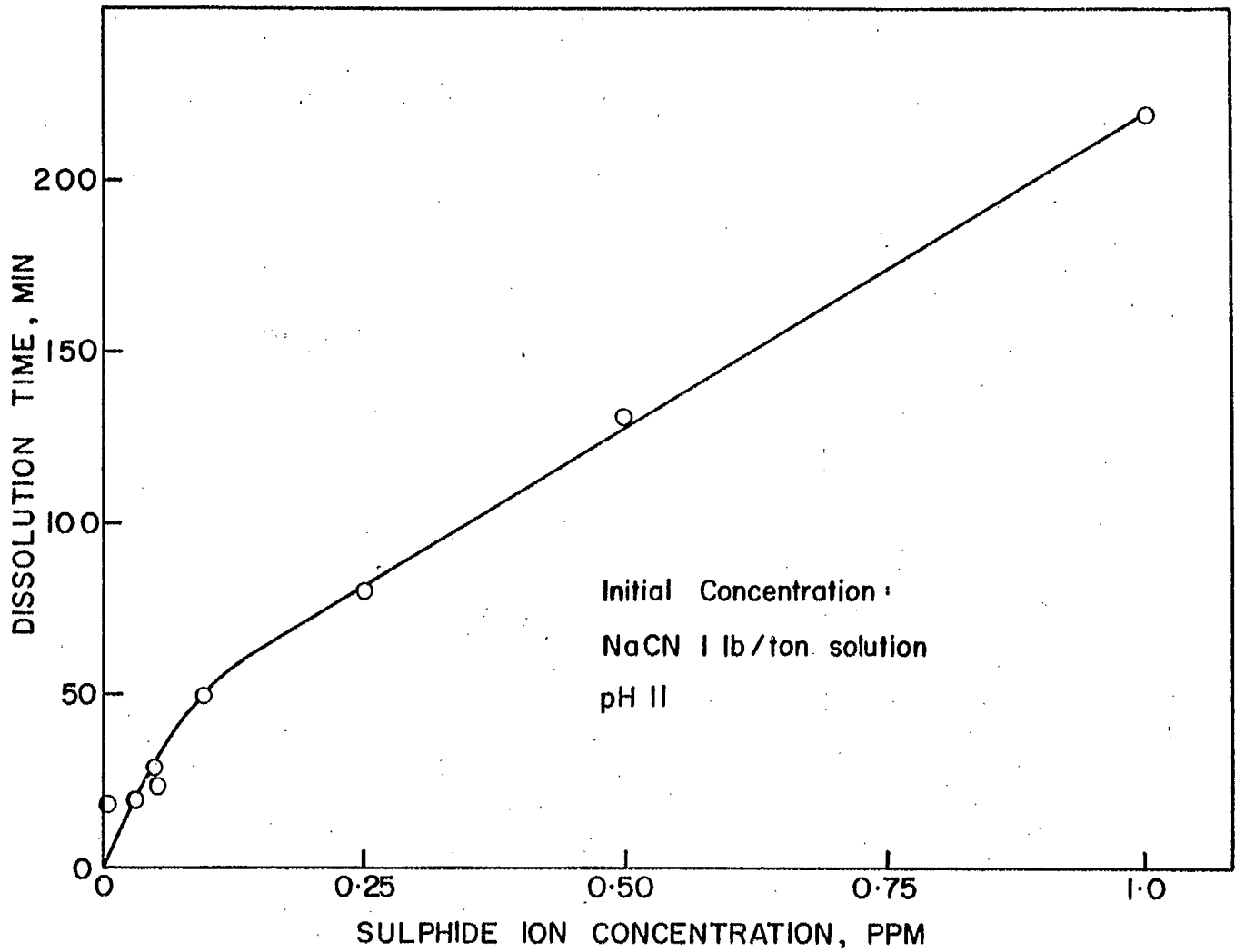


FIGURE 3

EFFECT OF SULPHIDE ION
ON GOLD DISSOLUTION TIME

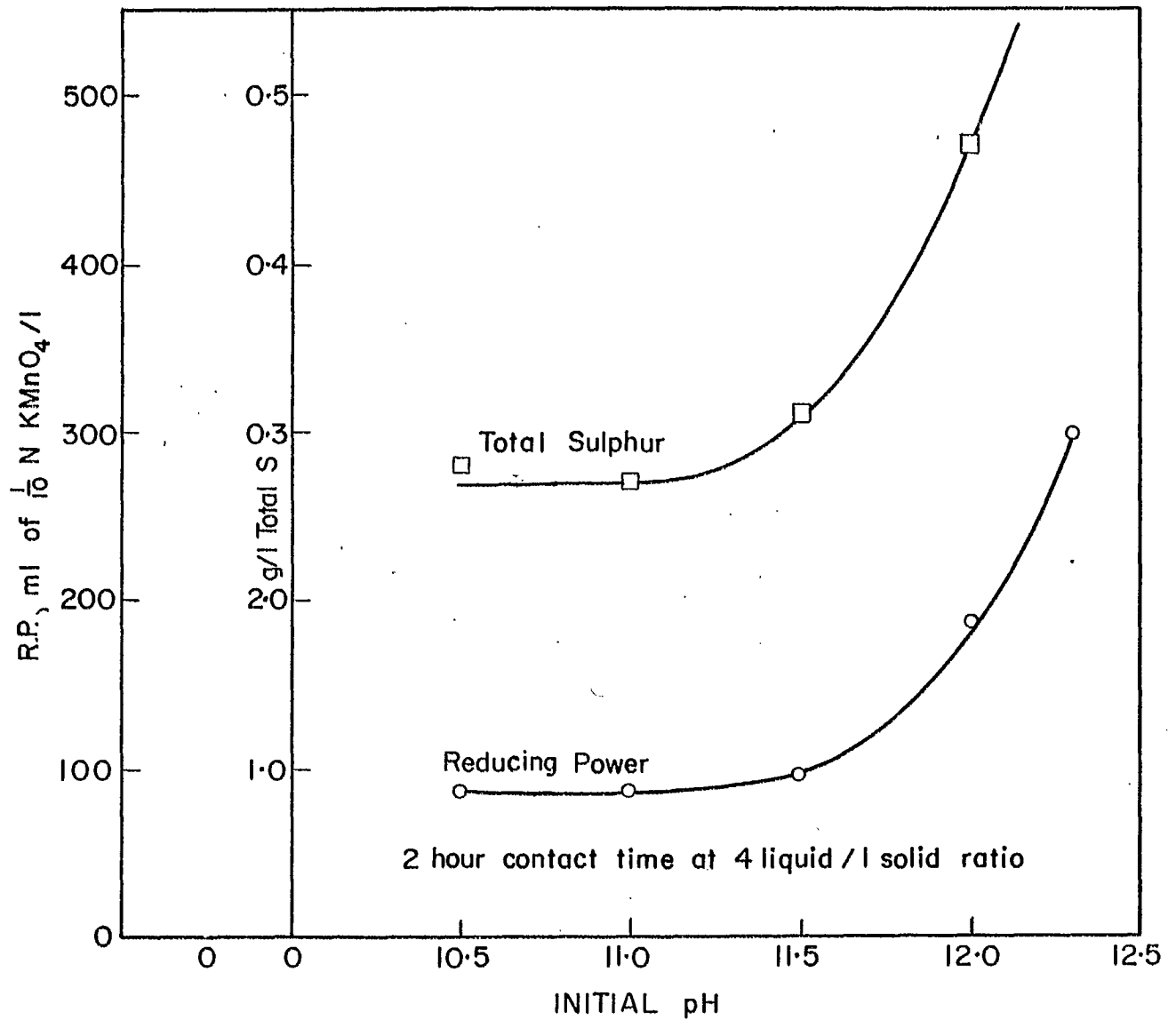


FIGURE 4
 SOLUTION DATA AFTER CONTACT
 WITH PYRRHOTITE AT VARIOUS pH VALUES

DISCUSSION

The gold-leaf dissolution test was a quick and simple method for confirming the effects of some of the variables in cyanidation. In general, fairly good reproducibility of results was experienced, providing care was taken in the selection of the cork stoppers. It was found in exploratory tests that cracks or holes in the cork surface exposed to solution produced anomalies in the rate of gold dissolution. Under normal test conditions, with selected corks, a variation of less than 10% between individual readings was usually obtained.

The inhibiting effects of the sulphide ion have been attributed to a surface phenomenon where the ions partially prevent the interaction of the gold, oxygen, and cyanide⁽³⁾. The addition of potassium permanganate or sodium chlorate largely counteracted the effect of the sulphide ions, presumably by oxidation to a less harmful form.

The pH influenced the rate of decomposition of pyrrhotite with the resulting formation of, probably, complex reducing compounds. The reducing power of the solution varied directly with the amounts of sulphur compounds dissolved. At pH 11 or below, the amount of sulphur dissolved in the cyanide solution was essentially constant. The critical pH value, where further liberation of sulphur begins, is 11.2, as shown in Figure 4. This confirms the fact that an undesirable reaction occurs at about this value⁽¹⁰⁾.

CONCLUSIONS

The effect of some dissolved salts in cyanide solutions on gold dissolution can be readily determined by the quick method of comparing dissolution times of gold-leaf samples.

The presence of sulphide ions was found to be the most detrimental to the dissolution of gold. The addition of either potassium permanganate or sodium chlorate, in very small quantities, to solutions containing sulphide ions, proved to be advantageous in aiding the oxidation of soluble sulphur compounds.

Cyanidation of pyrrhotitic ore requires pH control below 11 to keep the dissolution of pyrrhotite to a minimum and thereby reduce the "fouling" of the cyanide solution.

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