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QUANTITATIVE LEACHING OF GALENA

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ABSTRACT. Experiments on the quantitative leaching of lead from galena in hydrochloric acid solutions are reported. The effects of contact time, acid concentration, number of leaching stages, solid to liquid ratio, particle size, temperature, and stirring speed, on the leaching reaction are reported. About 96% of lead was dissolved within 120 min by 8.42 M hydrochloric acid solution at 95 °C. Multi-stage leaching was not so advantageous, but the extent of leaching increased greatly with temperature. The optimum solid to liquid phase ratio and particle size were found to be 1/30 kg/L and -88+53 μm, respectively. Dissolution was enhanced by stirring speed over the range 0 to 400 min^{-1} and reached a steady rate thereafter.

INTRODUCTION

Atmospheric pollution by sulphur dioxide from pyrometallurgy is the main reason for studying the hydrometallurgical treatment of sulphide minerals. Most of these processes offer the possibility of obtaining sulphur in the elemental form [1].

Galena is the principal lead ore mineral being processed today; it accounts for nearly all primary lead production from mineral sulphides. Substantial deposits of galena have been discovered in the Cretaceous sediments of Nigeria. Mineralization extends from Ishiagu through Abakaliki in the south-east, to Anifu, Wase, Zurak, Gwona and Bogide in the north-central. Exploitable deposits occur in Abakaliki and Ogoja zones [2].

The need to obtain sufficiently soluble salts from which the metal can be easily collected by electrowinning suggests the desirability of converting galena into lead chloride. Non-oxidative leaching of galena with hydrochloric acid has been the object of considerable interest in the recent past, since it permits the direct conversion of lead sulphide into chloride:

$$PbS + 2HCl \rightarrow PbCl_2 + H_2S$$

Although other acids may be used, they are unstable, expensive, or exhibit poor kinetics for the dissolution of natural galena. The hydrogen sulphide produced can be converted into elemental sulphur via the Claus process [3].

Hydrochloric acid leaching in the presence of oxidizing agents can be used to prevent H_2S formation. If strong oxidizing agents are used, sulphur may form and coat the galena, which could slow down the reaction. If more gentle or dilute oxidizing agents are used, the sulphur which forms may not coat the galena. Depending on the concentrations of the acid and the oxidizing agent, either sulphur or H_2S will be obtained [4].

The accelerating effect of chloride ion in the HCl solutions used for leaching galena is well known [5-10] and has been employed in processes on a pilot-plant scale. The considerable removal of impurities achieved on crystallizing concentrated lead chloride solutions by cooling is utilized simply and directly in these processes without the need to resort to the lengthy series of operations involved in the pyrometallurgical process [11-13].

about 51% for such a long period of time, this implies that dilute acid solutions are not effective for commercial dissolution of galena.

Table 1. Amounts of lead dissolved at various times.

Time, min	Wt. % of Pb dissolved
10	6.4
20	9.2
30	12.0
60	16.5
120	20.7
180	24.2
240	29.6
360	38.3
480	45.6
600	51.2
720	51.2
900	51.0

Experimental conditions: temperature, 95 °C; S/L ratio, 1/30 kg/L; HCl concentration, 1.19 M; particle size, -88+53 µm; stirring speed, 500 min^{-1}.

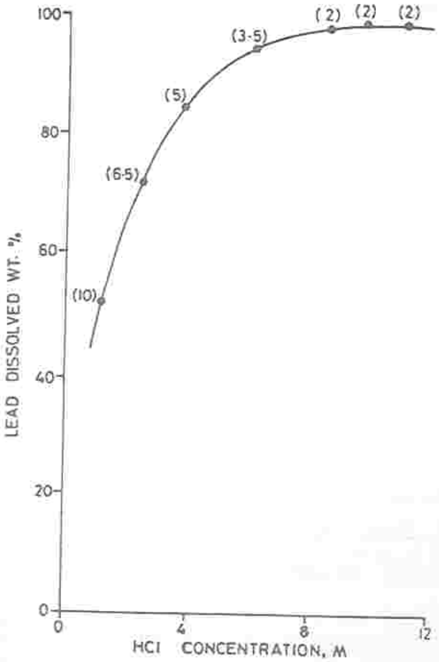

Figure 1. Effect of HCl concentration on lead dissolution. The figures in parentheses indicate corresponding leaching time (h) for maximum dissolution of lead. Other parameters are as in Table 1.

The amounts of lead leached by various concentrations of HCl solutions are presented in Figure 1. Although the percentage of lead dissolved increases with increasing acid concentration, it appears that the time for maximum dissolution is little affected by increase in hydrochloric acid concentration above 8 M. In all cases unreacted acid remained in the leach solution and the free acid increased with increasing initial acid concentration. Since the use of more concentrated acid did not increase the dissolution of lead or decrease the leaching time for maximum dissolution, it is suggested that 8 M hydrochloric acid solution should be used for leaching to obtain about 96% lead dissolution in only 2 h. The use of concentrated acid solutions at high temperatures in leaching is often accompanied by high loss of acid.

Figure 2 shows the cumulative percentages of lead dissolved in successive stages of leaching with 1.19 M hydrochloric acid; ≈98% of lead was dissolved after six stages. Since ≈96% of lead was dissolved after 2 h of leaching (Figure 1) with 8.42 M hydrochloric acid (seven times the concentration of 1.19 M HCl) in a single stage, it is concluded that multi-stage leaching with less concentrated acid is not advantageous; it takes longer time (42.5 h in 6 stages) to produce almost the same extent of dissolution.

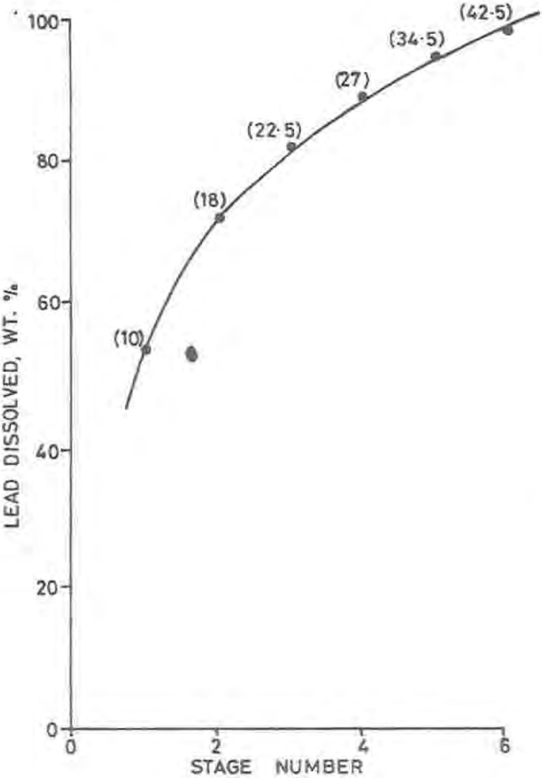

Figure 2. Cumulative weight percentages of lead dissolved in different stages of leaching. The figures in parentheses indicate cumulative time of leaching (h) for maximum dissolution of lead. HCl concentration, 1.19 M. Other parameters are as in Table 1.

The amounts of lead dissolved on leaching galena at various solid to liquid (S/L) ratios are given in Figure 3. Decreasing the S/L ratio considerably increased the equilibrium percentage of the metal; by varying the S/L ratio from 1/5 to 1/60 kg/L, ≈47% to ≈98% dissolution of lead was obtained. However, the time for maximum leaching of lead increased with decreasing S/L ratio. Accordingly, an optimum S/L ratio of 1/30 kg/L is suggested because higher values will result in decreasing percentage of lead dissolved while lower values will require more leaching time. The data in Table 1 and much of the data in Figures 1 and 3 are related more to the stoichiometric deficiencies of acid in the experiments than to any fundamental kinetic factor.

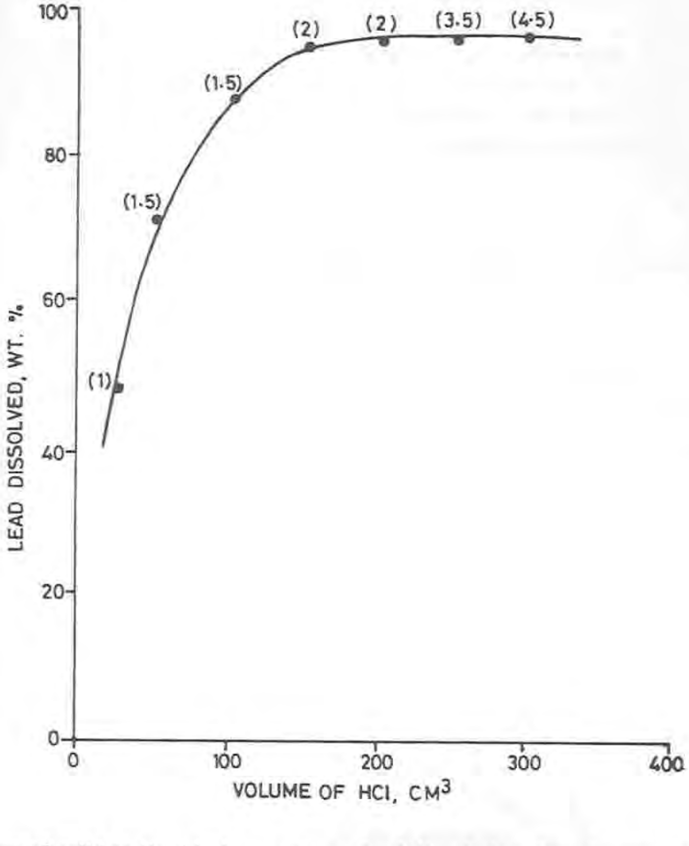

Figure 3. Effect of solid to liquid phase ratio on lead dissolution. The figures in parentheses indicate the time (h) at which maximum lead dissolution occurs. HCl concentration, 8.42 M. Other parameters are as in Table 1.

Table 2 shows the effect of particle size on the leaching of lead. The dissolution is considerably decreased when the particle size is greater than 88 μm. Since the dissolution is little affected (<2% difference) when the particle size ≤88 μm, it is suggested that ≈88 μm should be taken as the optimum since lower values (finer particles) will require more energy (cost) in grinding while higher values (coarser particles) will cause a significant decrease in percentage lead dissolution.

Table 2. Effect of particle size on lead dissolution.

Particle size, µm	Wt. % of Pb dissolved
-180 + 125	73.4
-125 +106	80.6
-106 + 88	87.2
-88 + 53	95.6
-53 + 37	96.4
-37 + 20	97.3

Experimental conditions: HCl concentration, 8.42 M; other parameters are as in Table 1.

The effect of temperature on leaching is shown in Figure 4; lead dissolution is considerably enhanced with increasing temperature. Estimation of the activation energy from the Arrhenius plot for the first 30 min of leaching gave a value of ≈63 kJ/mole, indicating chemical rather than diffusion control.

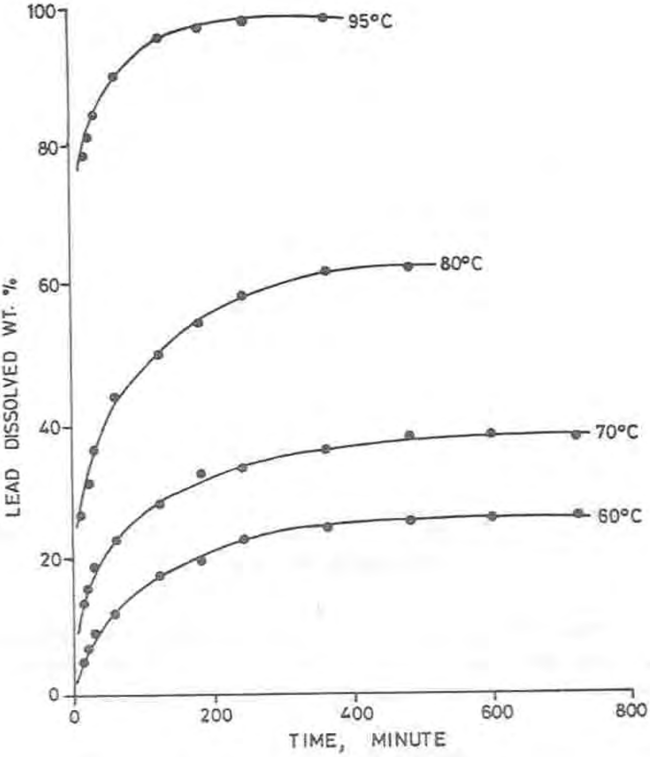

Figure 4. Plots of amounts of lead dissolved *vs.* time for various temperatures. HC concentration, 8.42 M. Other parameters are as in Table 1.

Table 3 shows the effect of stirring speed on the dissolution of lead from galena. The amount of lead dissolved is dependent on the stirring speed over the range 0-400 rpm. Above 400 rpm, the stirring rate no longer has any observable effect on the solid dissolution. In other words, dissolution reached a steady rate at 400 rpm, and a stirring rate of 500 rpm was used in all experiments.

Table 3. Effect of stirring rate on lead dissolution.

Stirring rate, min^{-1}	Wt. % of Pb dissolved
0	76.0
100	85.6
200	89.2
300	92.4
400	95.6
500	95.8
600	95.8
700	95.6
800	95.6

Experimental conditions: HCl concentration, 8.42 M; other parameters are as in Table 1.

CONCLUSION

This study has shown that the Abakaliki galena ore (containing ≈85% Pb) is amenable to hydrometallurgical treatment by leaching with hydrochloric acid. Using a grain size of -88+53 µm, a solid to liquid phase ratio of 1/30 kg/L and by heating at 95 °C with continuous stirring at a rate of 500 min^{-1}, it was possible to leach ≈96% lead with 8.42 M HCl solution within 2 h in a single stage. The extent of leaching increases greatly with temperature but multi-stage leaching is less efficient. These results indicate that the HCl leaching process is effective in converting galena into lead chloride from which the pure metal can be easily electroplated. Furthermore, considerable quantities of impurities can be removed by crystallizing concentrated lead chloride solutions by simple and direct cooling. By comparison the lengthy series of operations involved in the current pyrometallurgical process-roasting (Dwight-LLoyd), and high-speed coal reduction (Water-Jacket) [3], further indicate commercial significance of the HCl dissolution method.

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