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A Study on Cementation Process of Lead from Brine Leaching Solution by Aluminum Powder

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Abstract

Hydrometallurgical recycling of lead from zinc plant residue which occurs at leaching plant has been investigated. After determination of optimum parameters in the brine leaching stage, the pregnant solution was proposed on cementation process by Aluminum powder and parameters (time, temperature, initial pH of solution, initial lead content of solution, Al:Pb fraction, stirring velocity) were investigated and optimized.

Keywords

Lead Recovery, Brine Leaching, Cementation, Aluminum Powder

Subject Areas: **Material Experiment, Metal Material**

1. Introduction

Lead is commonly produced by pyrometallurgical techniques involving considerable environmental pollution. Pollution control can be improved by combined hydrometallurgical routes through implementation of closed loop operations. Increasing demand for copper, lead and zinc has led to worldwide efforts for utilization of low and off-grade ores of the above metals. One such ore is the zinc plant residue which cannot be treated economically by conventional pyrometallurgical techniques because of difficulties associated in producing individual concentrates from the ore [1] [2].

During the conventional zinc hydrometallurgical roast-leach-electro win process, lead and silver are reported in the neutral leach residue. Lead concentrates in the form of $PbSO_4$ in the residue [1].

Besides the alkaline and acid extraction techniques mentioned above, some pyrometallurgical recovery processes and chloride leaching processes have been employed [3]-[7].

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Lead sulphate can be converted to lead hydroxide by leaching with sodium hydroxide or lead carbonate with sodium carbonate [8].

$$PbSO_4 + Na_2CO_3 = PbCO_3 + Na_2SO_4 \quad (1)$$

These two products are not suitable for charging into the sinter machine due to their exothermic reaction during sintering. High cost of sodium hydroxide and sodium carbonate makes these routes unattractive [9].

Because of the availability of improved corrosion resistant materials of construction, considerable efforts have been made to develop chloride routes for lead production as alternatives to existing methods.

Using either NaCl or $MgCl_2$ or $FeCl_3$ for brine leaching has been reported [10].

Lead can be recovered by electrolyze of brine solution. It should be mentioned to crystallization and production of lead chloride and reduction by hydrogen can lead to production of lead [10] [12].

Zinc, iron or aluminum can be used to cement out lead and silver from the brine leach solution. It has been found that the process of cementation was slow in the case of zinc and iron whereas the aluminum was fast. So, aluminum has been used to cement out lead from the brine leach solution [10].

In cementation reactions, a metal in solution is reduced at the surface of a less noble substrate metal which dissolves anodically. These reactions are electrochemical in nature similar to those occurring in electrochemical corrosion processes. The half cell reactions and reduction potentials for lead and aluminum are as follows [13] [14]:

$$Al^{3+} + 3e = Al \qquad E_0 = -1.66\ V \quad (2)$$

$$Pb^{2+} + 2e = Pb \qquad E_0 = -0.126\ V \quad (3)$$

$$Pb^{2+} + Al = Al^{3+} + Pb \quad (4)$$

The overall reaction $Pb^{2+} + Al = Al^{3+} + Pb$ results from subtraction of Equation (2) from (3) and $\Delta E_0 = -0.126\ V - (-1.66\ V) = 1.534\ V$.

2. Experimental

2.1. Materials

Zinc plant residue of National Iranian Lead and Zinc Co.'s (NILZ) after brine leaching and water washing was used for all tests. The metal contents of feed were determined by using an Atomic Absorption Spectrometer (Perkin-Elmer, 300). The leachates were acidified with nitric acid to prevent precipitation of metals. Merk hydrochloric acid was used to acidify the brine solution. In cementation stage, aluminum powder with 99.5% purity was used.

2.2. Experimental

All the tests were carried out in the 1 L glass beakers to optimize the parameters. The plastic material shaft was used to avoid cementation of lead. To prevent evaporation during the tests, top of the beakers was covered. All solutions for cementation were obtained by leaching of secondary zinc plant residue (obtained after filtration of acid leaching and water washing of zinc plant residue) in the 300 g/L NaCl brine solution at time 30 min and temperature 30˚C. Aluminum powder was added suddenly to the solution and the effects of cementation temperature (40˚C, 50˚C, 60˚C, 70˚C), time of cementation (10, 20, 30, 40, 60, 90 min), initial pH of solution (1, 3, 4, 5, 6), aluminum content (1, 1.5, 2 stoichiometry × Pb), stirring speed (50, 100, 150 rpm) and initial lead content of brine solution (5.63, 11.77, 16.36 g/l) were investigated.

3. Results and Discussion

Cementation recovery of lead in Equation (4) was determined as Equation (5) in each time of sampling.

$$3PbCl_2 + 2Al = 2AlCl_3 + 3Pb \quad (4)$$

$$\%Rc = (M_o - M)/M_o \times 100 \quad (5)$$

In Equation (5):

Rc is the cementation efficiency.
M_o is the initial lead content at t = 0.
M is the lead content of solution in specified time.
Product of cementation is in the spongy form and during cementation floats at the top of the beaker.

3.1. The Effect of Aluminum Adding on the Cementation Recovery

The results of aluminum addition at the initial pH = 4 on the lead recovery are shown in **Figure 1**. With addition of aluminum powder, pH of solution decreases.

The results show that the rate of lead cementation increases with raising the amount of Al at the same time and lead content of solution remained negligible after 90 min.

According to Equation (4), increasing of aluminum causes reaction progress.

With addition of aluminum, contact surface reaction increases that leads to increasing of lead cementation.

3.2. Effect of Temperature

The results of increasing temperature on the recovery of lead are shown in **Table 1** and **Table 2**.

The results show that increasing temperature has small effect on the lead recovery.

Small increase in the cementation recovery is because of increasing in the diffusion of reduced metal on the formed film of oxidized metal surface (**Table 1**, **Table 2**).

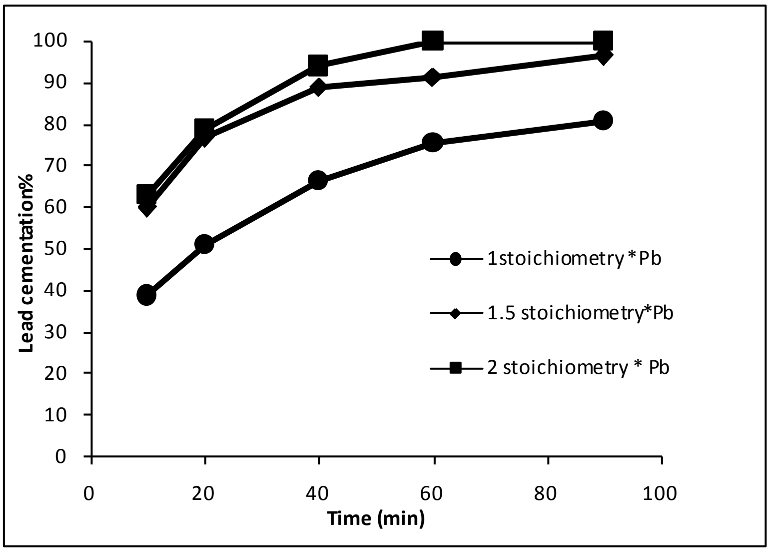

Figure 1. Effect of Al addition on lead cementation, T = 50˚C, pH_{in} = 4, Stirring Velocity = 100 rpm.

Table 1. Effect of temperature on the cementation rate at pH_{in} = 4, Stirring Velocity = 100 rpm, Al:Pb ratio = 1.5 (stoichiometry).

	T = 40˚C	T = 50˚C	T = 60˚C	T = 70˚C
Time (min)	Lead recovery %	Lead recovery %	Lead recovery %	Lead recovery %
10	59.59	62.51	64.41	-
20	76.65	78.89	79.54	77.11
30	-	84.7	-	-
40	86.74	88.74	90.11	93.27
60	96.76	-	96.28	99.49
90	99.96	-	98.79	99.89

3.3. Effect of Stirring Velocity

Some exams were carried out to examine the effect of stirring velocity on the cementation of lead. **Table 3** shows the effect of stirring velocity on the lead cementation at T = 30˚C.

According to lead cementation by adding the aluminum powder, in fewer stirring velocity, the remained aluminum powders were surrounded by the precipitated lead particles, so contact surface decreases for the cementation reaction.

In high stirring velocity, according to Equation (6) oxygen leads to decrease in the cementation recovery (**Table 3**).

$$Pb + 2H_2 + 1/2O_2 = Pb^{2+} + H_2O \tag{6}$$

3.4. Effect of Initial pH of Solution on the Recovery of Lead

The results of initial pH of the solution before addition of Aluminum powder on the lead recovery are show in **Table 4**.

The results show that increasing of pH from 4 to 6 decreases the cementation efficiency.

Increasing initial pH of solution before cementation, causes in precipitation of some lead as hydroxide.

It should be mentioned that with increasing of initial pH of solution, some Aluminum precipitates as hydroxide without its roll in lead cementation.

At initial pH of the solution less than 4, cementation process delays because of releasing Hydrogen ion according to Equation (7).

$$Pb + 2H^+ = Pb^{2+} + H_2 \tag{7}$$

As increasing of lead content in the solution, causes in reduction of hydrolyze pH, cementation recovery reduces. By the way, it should be prevented of increasing pH before cementation (**Table 4**).

The results show low cementation recovery about a solution with initial pH = 3 in comparison with a solution with initial pH = 4.

Table 2. Effect of temperature on the cementation rate at pH_{in} = 1, Stirring Velocity = 100 rpm, Al:Pb ratio = 1.5 (stoichiometry).

	T = 30˚C	T = 50˚C
Time (min)	Lead recovery %	Lead recovery %
10	52.58	54.11
20	71.92	78.93
40	94.98	97.03
60	99.98	99.99

Table 3. Effect of stirring velocity on the cementation rate at T = 30˚C, Added Al: 1.5 (stoichiometry) × Pb.

	50 rpm	100 rpm	150 rpm
Time (min)	Lead recovery	Lead recovery	Lead recovery
10	37.11	52.58	41.11
20	55.87	78.93	60.56
40	78.54	97.03	78.82
60	81.03	99.8	89.46

3.5. Effect of Initial Lead Content on the Cementation Recovery

Some tests carried out to determine the initial lead content on the cementation recovery. So it was prepared some solutions with different initial lead content.

The results show that with increasing initial lead content, cementation recovery reduces.

According to Equation (8), increasing of lead content, increases driving force of cementation.

$$Pb^{2+} + 2e \rightarrow Pb \qquad E_0 = -0.126 \qquad E = E_0 + RT/ZF\ln[Pb^{2+}] \tag{8}$$

Table 5 shows the initial lead content on the lead recovery.

Investigation by XRD shows Massicot (PbO), Lead (Pb), Halite (NaCl), Litharge (PbO) in the cementation product.

Table 6 shows chemical analyze results that the obtained product has a high purity and hence it can be used as Caldo furnace feed. Final product also is suitable because of its valuable elements such as Silver, Antimony.

4. Conclusions

The cementation of lead with aluminum powder was investigated. According to results, cementation with Aluminum is fast and economical. According to results, temperature has no more effect on cementation recovery. It is proved that rising of initial lead content, increases the recovery of cementation at the same times.

According to results, stoichiometric ratio Al:Pb of 1.5 was found to be optimum for maximum lead recovery.

Table 4. Effect of initial pH of the solution on the cementation recovery (T = 50˚C, Stirring Velocity = 100 rpm, Added Al: 1.5 (stoichiometry) × Pb).

	pH = 6	pH = 5	pH = 4	pH = 3
Time (min)	Lead recovery %	Lead recovery %	Lead recovery %	Lead recovery %
10	44.39	48.52	53.24	47.53
20	62.01	63.29	71.03	63.68
30	-	-	78.79	-
40	81.62	84.48	84.66	81.50
60	95.54	96.89	-	94.06
90	99.93	99.92	-	100

Table 5. Effect of initial lead content on the cementation recovery (Initial pH = 4, T = 40˚C, Stirring Velocity = 100 rpm, Added Al: 1.5 (stoichiometry) × Pb).

Time (min)	Initial pb = 5.63	Initial pb = 11.77	Initial pb = 16.36
10	46.18	55.39	59.597
20	70.4	73.12	76.65
40	90.48	89.87	94.12
60	96.02	96.75	98.17

Table 6. Chemical composition of precipitated product (T = 30˚C, Stirring Velocity = 50 rpm, Added Al: 1.5 (stoichiometry) × Pb).

Element	Pb	Ag	Al	Zn	Co	Cd
%	76.94	0.12	2.49	0.087	Trace	Trace

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References

[1] Jha, M.K., Kumar, V. and Singh, R.J. (2001) Review of Hydrometallurgical Recovery of Zinc from Industrial Wastes. *Resources*, *Conservation and Recycling*, **33**, 1-22. http://dx.doi.org/10.1016/S0921-3449(00)00095-1

[2] Rabah, M.A. and El-Sayed, A.S. (1995) Recovery of Zinc and Some of Its Valuable Salts from Secondary Resources and Wastes. *Hydrometallurgy*, **37**, 23-32. http://dx.doi.org/10.1016/0304-386X(94)00015-U

[3] Wang, M.C. New Hydrometallurgical Process for Lead Production: Conversion-Flotation-Electrowinning (CFE) Process. *Lead and Zinc*, **80**, 785-801.

[4] Jansz, J.J.C. Non-Oxidative Chloride Leaching of Complex Pyritic Zinc-Lead Sulphide Materials. *Lead and Zinc*, **90**, 548-573.

[5] Sandberg, R.G. and Huiatt, J.L. (1986) Ferric Chloride, Thiourea and Brine Leach Recovery of Ag, Au and Pb from Complex Sulfides. *Journal of Metals*, **38**, 18-22.

[6] Sinadinovic, D., Kamberovic, Z. and Sutic, A. (1997) Leaching Kinetics of Lead from Lead (II) Sulphate in Aqueous Calcium Chloride and Magnesium Chloride Solutions. *Hydrometallurgy*, **47**, 137-147. http://dx.doi.org/10.1016/S0304-386X(97)00041-8

[7] Abdollahi, P., Moradkhani, D., Behnian, D. and Yozbashizadeh, H. (2006) Lead Recovery from Iranian Zinc Plant Residue Using Brine Leaching Method. *Proceedings of XXII International Mineral Processing Congress*, Istanbul, 1515-1520.

[8] Arai, K. and Toguri, J.M. (1984) Leaching of Lead Sulphate in Sodium Carbonate Solution. *Hydrometallurgy*, **12**, 49-59. http://dx.doi.org/10.1016/0304-386X(84)90047-1

[9] Raghavan, R., Mohanan, P.K. and Swarnkar, S.R. (2000) Hydrometallurgcal Processing of Lead-Bearing Materials for the Recovery of Lead and Silver as Lead Concentrate and Lead Metal. *Hydrometallurgy*, **58**, 103-116. http://dx.doi.org/10.1016/S0304-386X(00)00108-0

[10] Raghavan, R., Mohanan, P.K. and Patnaik, S.C. (1998) Innovative Processing Technique to Produce Zinc Concentrate from Zinc Leach Residue with Simultaneous Recovery of Lead and Silver. *Hydrometallurgy*, **48**, 225-237. http://dx.doi.org/10.1016/S0304-386X(97)00082-0

[11] Turan, M.D., Altundogan, H.S. and Tumen, F. (2004) Recovery of Zinc and Lead from Zinc Plant Residue. *Hydrometallurgy*, **75**, 169-176. http://dx.doi.org/10.1016/j.hydromet.2004.07.008

[12] Habashi, F. A Textbook of Hydrometallurgy.

[13] Sahoo, P.K. and Rath, P.C. (1988) Recovery of Lead from Complex Sulfide Leach Residue by Cementation with Iron. *Hydrometallurgy*, 167-177.

[14] Pourbaix, M. (1974) Atlas of Electrochemical Equilibrium in Aquaous Solutions. Houston.


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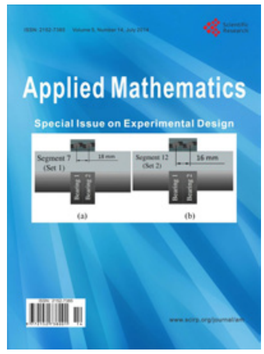
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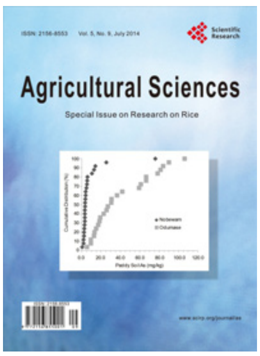
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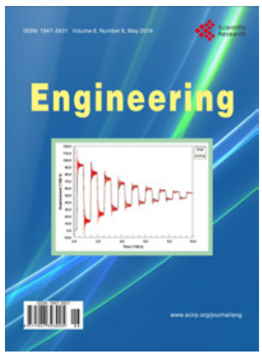
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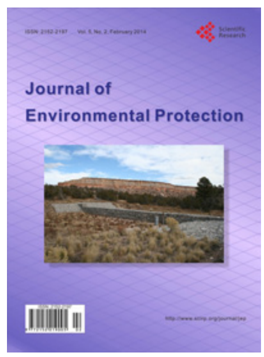
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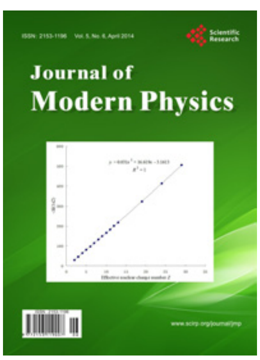
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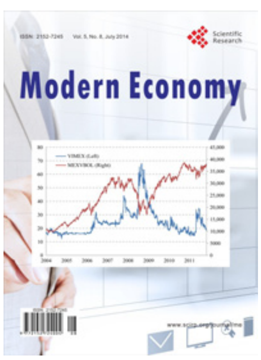
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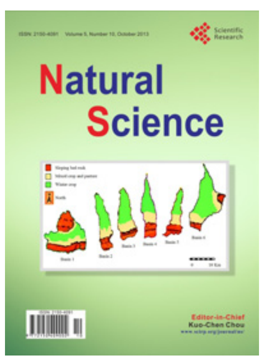
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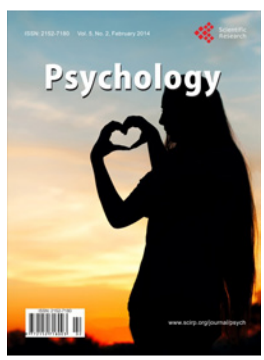
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