EXTRACTION OF IRON FROM AL-HUSSAINYAT IRON ORE USING ACID LEACHING

Adil A. Al-Hemiri, and Ramzi A. Ibrahim
Chemical Engineering Department – College of Engineering – University of Baghdad – Iraq

ABSTRACT

The extraction of iron from Al-Hussainyat iron ore using acid leaching was studied employing hydrochloric acid and sulphuric acid.

In general, the iron extractability increased with:

1. *Increasing acid concentration within the range investigated (15-45%).*
2. *Increasing leaching temperature within the range investigated (70-90°C).*
3. *Decreasing particle size within the range investigated (-200 to +400, -4000 to +710 micron).*

Furthermore, it was found that the solid percentage has no significant effect on the recovery percentage, although increasing solid percentage increases the concentration of iron in the solution.

Hydrochloric acid was found to be more efficient than sulphuric acid giving an iron recovery of 97% without calcination of the ore as compared to 35% recovery using sulphuric acid when the ore is uncalcined and 79% when the ore is calcined.

INTRODUCTION

Iron is generally found in the form of oxides, carbonates, silicates and sulfides. The ore oxides, are by far the most important source of iron.

Although the list of iron-bearing materials is a lengthy one, only a few minerals are of economic interest, (Table 1). The three most important being magnetite, hematite and limonite (Dennis, 1963).

Table (1) List of iron-bearing materials

	Formula	*% Iron*	*S.G.*	*Color*
Hematite	Fe_2O_3	70	4.6-5.3	red, black, gray
Magnetite	Fe_3O_4	72.4	4.9-5.9	black, gray
Limonite	$2Fe_2O_3.3H_2O$	60	4.0-4.8	yellow, red, black
Siderite	$FeCO_3$	48	3.6-3.9	gray, brown, yellow
Goethite	$Fe_2O_3.H_2O$	62.9	4.3	yellow, red, brown, black
Pyrite	FeS_2	46.5	4.9-5.1	brass yellow

In Al-Hussainyat territory, which is located in the western dessert of Iraq more than 200 million tons of pisolitic-ilitie sandstone ore, grading 24-26% iron has been discovered.

The grade of Al-Hussainyat ore is unsuitable for direct reduction using conventional pyrometallurgical techniques. Further more, the complex mineralogy of the ore preclude any efficient upgrading process, e.g. magnetic separation or flotation. Thus the extraction of iron from Al-Hussainyat ore using hydrometallurgical processes mat be more economical than pyrometallurgical techniques.

Generally, the hydrometallurgical processes are consisted of the following steps:

1. Leaching to dissolve the whole, or some part, of a solid, using suitable agent.
2. Purification of the solution.
3. Precipitation of wanted product (Rosenquist, 1983).

In many cases, ores are not always suitable for economic leaching and require thermal pretreatment, viz, calcination and roasting.

The leaching stage occupies an important role in the hydrometallurgical process and several investigation dealt with the extraction of iron acid leaching.

In 1964, Gravenor et al., have presented a process to extract iron from low-grade ores, the process consisted of the following steps:

1. Roast the ore with coal; in a reducing environment.
2. Dissolve the roasted material in HCl acid.
3. Filter to remove insoluble impurities.
4. Crystallize and separate the hydrated ferrous chloride crystals, and
5. Dry the ferrous chloride and reduce in a hydrogen atmosphere at elevated temperature to produce iron powder and hydrogen chloride.

Abdul Wahab et. al., (1992), presented a process to extract iron from Al-Hussainyat iron ore using H_2SO_4 as a leaching agent.

The process consisted of the following steps:

1. Leaching the ore.
2. Reduction of $Fe_2(SO_4)_3$ solution to ferrous sulphate $FeSO_4$ using iron scrap.
3. Evaporation and crystallization of $FeSO_4.H_2O$.
4. Dehydrogenation of $FeSO_4.H_2O$ to produce $FeSO_4$.
5. Decomposition of $FeSO_4$ to Fe_2O_3.

Table (2)

Author	Mineral(s) extracted	Comments
Byerley et al. (1979)	Iron	Leaching of magnetite in aqueous sulfur dioxide.
Lam and Charles (1979)	Iron and Copper	Iron dissolution conform to the shrinking-core product layer diffusion.
Girgin and Oner (1984)	Iron	Study the effect of the grinding mechanism upon the hydrochloric acid leaching of hematite.
Girgin and Turker (1986)	Iron	A comparative study of hematite leaching in iron in non-aqueous and mixed aqueous ETOH-HCl solution.
Al-Ameri	Alumina and Iron	Calcination of the ore before leaching stage has improve the recovery of metal.

Factors Influencing the rate of Extraction

The selection of the equipment for an extraction process will be influenced by the factor which are responsible for limiting the extraction rate. Thus, if the diffusion of the solute through the porous structure of the residual solids is the controlling factor, the material should be in the form of small sized particles so that the distance the solute has to travel is small. On the other hand, if diffusion of the solute from the surface of the particle to the bulk of the solution is sufficiently slow to control the process, a high degree of agitation degree of agitation of the fluid is called for (Coulson and Richardson, 1978).

EXPERIMENTAL PROCEDURE

Experimental Arrangement

The chemicals and equipment are described elsewhere (Ibrahim, 1996).

Ore Preparation

Ground sample of Al- Hussainyat iron ore from The State Establishment of Geological Survey and Mining Iraq. The ore was classified using mechanical sieves. The average chemical composition of the ore is shown in Table (3).

Table (3) Chemical composition of Al-Hussainyat iron ore

Constituent	Wt. %	Constituent	Wt. %
Fe	25.4-26	P	0.028
Fe_2O_3	36.17-37.13	S	0.19
SiO_2	31.0	Mn	0.02
Al_2O_3	18.2	V	0.1
CaO	0.88	Pb	< 0.005
MgO	0.68	Zn	< 0.005
TiO_2	1.3	Cu	< 0.002
NaO_2	0.21	L.O.I	10.1
K_2O	0.12		

Ore Calcination

The calcination process was carried out as follows:

1. A weighted amount of iron ore was placed into a porcelain basin, then the basin was placed in the electrical furnace.
2. The electrical furnace was set at the specified temperature (400, 500, 600, 700 and 900 °C).
3. After the temperature was reached to the desired degree for the specified time (30 min.), the basin was taken out and the iron was weighed again. Finally the ore was preserved into glass jars to avoid contamination with air.

RESULTS AND DISCUSSION

Leaching of Calcined Ore

Experiments conducted to estimate the optimum calcination temperature. The optimum calcination temperature was 500 °C. The effect of temperature, acid concentration, particle size and solid percentage on recovery percentage of iron from calcined ore was such that the recovery percentage is increased with increasing both leaching temperature and acid concentration and decreasing particle size.

Optimum condition the recovery percentage was increased from 35% (before calcination of the ore) to 79% (after calcination).

Leaching of Iron Ore Using HCl Acid

The results of experiments conducted using HCl as a leaching agent, showed that the leachability of iron is increased with increasing both temperature and acid concentration and decreasing particle size and that the recovery percentage is independent of the solid percentage. Also, the percentage recovery becomes constant after 150 minutes. The maximum recovery condition (temp.= 90°C, acid concentration = 25%, particle size = 200 to 1400 micron) was 97%.

Effect of Particle Size on the Leachability of Iron

The recovery percentage of iron is increased with decreasing particle size due to the following reason:

1. Decreasing the particle size will interfacial surface area between the solid and the liquid.
2. Decreasing the particle size will decrease the distance that the solute must diffuse through it.

On the other hand, many investigators implied that the use of very fine particle size may cause subsequent problems in the mixing and filtration stages (Al-Ameri, 1989).

Effect of Acid Concentration on the Leachability of Iron

Leaching using H2SO4 acid

Normally, increasing the acid concentration increases the recovery percentage of the metal, for instance, increasing the acid concentration from 35% to 45% has a little effect on the percentage recovery. Thus calcination of the ore may be useful here and the percentage recovery has been improved after calcination of the ore.

Leaching using HCL acid

Increasing the acid concentration from 15% to 25% has a large effect on the rate of extraction; due to the following reasons:

1. The high diffusivity of HCl through solid particles.
2. The high reaction rate between the acid and iron minerals.

In these experiments, the maximum recovery percentage at optimum conditions was 97% and this result is in agreement with the result obtained by Gravenoret al. (1962).

Due to the high recovery here, calcination of the our is not necessary for the HCL process.

Furthermore, the results are in accordance with the shrinking-core theory which indicates that the diffusion coefficient and the reaction rate are being the controlling steps in the leaching process.

Effect of Temperature on the Leachability of Iron

The recovery percentage increased with increasing temperature to the following:

1. Increasing leaching temperature will increase the rate of reaction between the solvent and the valuable mineral. It was found that the relationship between the rate of reaction and the temperature at which the reaction takes place can be represented by the Arrhenius equation (Parker, 1978).

$$K = A\ e^{(-E/RT)} \qquad (1)$$

where: K is the reaction rate constant.

2. Increasing leaching temperature will increase the diffusion coefficient, since it also follows an Aarrenius-type equation (Jackson, 1986).

$$D = D_0\ e^{(-E/RT)} \qquad (2)$$

This implies that the diffusion of the acid through the solid particle will be increased with increasing the leaching temperature.

Effect of Solid Percentage on the Leachability of Iron

The solid percentage has no significant effect on the concentration of iron in the solution. Many investigators suggested that the solid percentage must nor exceed 25% because high percentage of solid percentage can cause a serious problem in the mixing process (Al-Ameri, 1989).

Leaching of Calcined Iron Ore Using H2SO4 Acid

It can be seen from the previous section that the volatile compounds can be separated from the ore during calcination of the ore. This implies that the porosity of the individual solid particle increased after calcination of the ore and the acid can diffuse more easily through it, and the percentage recovery has been improved from 35% to79% after calcination of the ore.

The results obtained form these experiments are in agreement with earlier investigations that emphasized on the calcination of the ore as a route to improve the recovery percentage of the metal from the leaching stage (Livingstone, 1983; Al-Ameri, 1989).

The maximum recovery at optimum condition, 79% was below the maximum recovery that was obtained by Abdul Wahab et al.(1992) which was 93% since the wet method which was used as an ore preparation stage before leaching is more efficient than the process of calcination, because it removes the clay from the ore. And that the bulk of Al-Hussainyat iron ore is pisolite and oolite which is cemented in clay and ferrugionous claystone, this type of clay makes the diffusion of the acid through the solid particle very difficult.

CONCLUSIONS

1. Increasing the acid concentration.
2. Increasing leaching temperature.
3. Decreasing the particle size.

Furthermore, it was found that the recovery percentage of iron is independent of soild percentage.

Calcination of the ore before the leaching stage is required when H_2SO_4 is used as a leaching agent and maximum recovery percentage was 79%.

When HCl was used as a leaching agent, the process was carried out very efficiently even without calcination of the ore, due to high diffusivity of the acid through the solid particle and the high rate of reaction between the acid and iron minerals, Maximum recovery was 97%.

REFERENCES

1. Abdul Wahab,A.M.(and others), "Extraction of Iron Using H_2SO_4Acid", The state establishment of geological and mining Iraq, Report, No.A2055.1992.
2. Al-Ameri, Z.K., "extraction of Alumina from Iraqi Kaolin by Acid Leaching".M.Sc.Thesis, University of Technology, Iraq, 1989.
3. Byerley, J.J, Remble, L. and Garrida, F., "Copper Catalyzed Leaching of Magnetite in Aqueous Sulfur Dioxide", Hydrometllurgy, 4, PP. 317-336, 1979.
4. Coulson, J. M. and Richardson, J. F. 'Chemical Engineering".
5. Girging, I. And Onr, M.," The Leaching of Hematite with Hydrochloric Acid-Effect of Grinding Mechanism", Yerbilimeleri,II, PP.31-37, 1984.
6. Girgin, I. And Turker,L.. "Leaching of Hematite in Non-Aqueous and Mixed Aqueous EtOH-HCL Solution", Intonation Journal of Mineral Processing ,17, PP.121-130, 1985.
7. Gravenor, G.P.,Govette, G.L. and Rigg, T., "A Hydrometathurgical Process for the Extraction of Iron from Low-Grade Ores", Can.Met. Bull., April, PP.421,1962.
8. Ibrahim, R.A., "Extraction of Iron from Al-Hussainyat Iron Ore Using Acid Leaching", M.Sc. Thesis, Baghdad University, Iraq, 1996.
9. Lam, E. and Charles,W., "Leaching of Low-Grade Oxide Copper Ore Containing Significant Amount of Goethite", IMM, Transaction section,Sep.,PP.C100-104,1979.
10. Rosenqvist, T., "Principle of Extractive Metalhurgy", McGraw-Hill International Book Co., 1983.