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# HYDROMETALLURGICAL PROCESSING OF LOW GRADE EGYPTIAN MAGNESITE

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The pressure leaching with carbon-dioxide for the production of high purity magnesium oxide from low grade magnestie oxide from (Halaib) deposit (Eastern Desert) has been studied. It was found that more than 90% of magnesium can be extracted under the following conditions: calcinations temperature 700° C, leaching temperature 50° C, carbon dioxide pressure 600 kPa and leaching time 120 min. The kinetics of the carbonation process was investigated and the activation energy of the process was determined (30 kg/mole).

key words: magnesite, leaching, calcinations, kinetics

## **INTRODUCTION**

Magnesite (MgCO<sub>3</sub>) is a basic raw material for manufacturing of the alkaline refractories. It is used in the iron-steel, cement, glass, sugar, paper, and pharmaceutical industries as well as in the production of many magnesium chemicals (Whaley, 1981; Van Staden, 1994).

Beneficiation of magnesite is carried out using physical and chemical methods. The physical methods of upgrading low-grade magnesite rely on the physical differences between magnesium carbonate and impurities. The chemical beneficiation relies on chemical leaching of magnesite with the use of common inorganic acids such

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as hydrochloric (Tunley, 1992) sulfuric (Treushchenko et al., 1991) and nitric acid (Ekmekyapar, 1989; Li, 1991). The use of these acids in benefication of low grade magnesites have not been commericalised because of complexity of purification and acid generation.

Carbon dioxide (Sheila, 1991; Amer, 1996) has been used as a leaching agent to selectively dissolve magnesia and form soluble magnesium bicarbonate leaving the impurities unaffected. The solution is decomposed by heating to form basic magnesium carbonate, which is next processed to obtain high purity magnesia.

A rapid growth of the steel industry in Egypt and particularly the increased use of oxygen in steel making has created heavy demands for high grade magnesite and refractories. Therefore, an increased attention is being paid in Egypt to the upgrading of low grade and submarginal magnesite by chemical treatment.

In Egypt, magnesite deposits are found in the Southern part of the Eastern Desert in Halaib, Gabal Mudargag and G. El-Mayit. The talc-magnesite deposits of the Barramyia area appear to be of low grade magnesite rocks which, by the removal of talc, might become valuable as a refractory material and in the production of magnesium compounds (Said, 1991).

The extraction of magnesium from magnesite involves a thermal decomposition of magnesite and leaching of the calcinated magnesite in an autoclave under carbondioxide pressure to produce soluble magnesium bicarbonate. The solution is subsequently decomposed by heating to precipitate basic magnesium carbonate, which is then thermally decomposed to produce high purity magnesium oxide.

## MATERIAL AND METHODS

In this study low-grade magnesite (Halaib deposit), from the Southern Eastern Desert, was used. Its chemical composition is given in Table 1. It is clear that magnesite contains 37.2% of MgO while the theoretical MgO content in pure magnesite is 47.82%. This indicates that the studied magnesite samples are of low-grade ore.

The X-ray diffraction analysis indicated, that in addition to magnesite, which is present as a major mineral, there are dolomite  $(Ca,Mg_2,CO_3)$  and antigorite  $(3MgO\cdot 2SiO_2\cdot 2H_2O)$  which are present as minor constituents.

The calcination of magnesite samples was carried out in an electric muffle furnace. Representative samples of magnesite ore (-12+3 mm in diameter) were calcinated at 750°C for 2 hrs, crushed and ground to 100% passing through a 150  $\mu$ m screen for the leaching experiments.

All pressure leaching experiments were performed in a laboratory 2 dm<sup>3</sup> volume autoclave (Amer and Ibrahim, 1997). It had a maximum working pressure of 2 kPa, a temperature of 140° C and a maximum stirring speed of 800 min<sup>-1</sup>. The experiments

were carried out with circulating cold water through the cooling coils of the autoclave. The stirrer used maintained good dispersion of carbon dioxide in the pulp. The slurry samples were taken through a capillary tube, filtered, and chemically analysed.

Constituent	%
MgO	37.32
$\tilde{CO_2}$	50.41
CaO	5.38
$SiO_2$	3.78
$Fe_2O_3$	0.47
$Al_2O_3$	0.36
Cl <sup>-</sup>	0.33
$SO_3$	0.24
Na <sub>2</sub> O	0.22
$MnO_2$	0.14
$K_2O$	0.08
$P_2O_5$	0.05
Moisture	0.39
L.O.I.* (1000° C)	49.75

Table 1. Chemical analysis of representative sample of Halaib magnesite

\*Loss on ignition

## **RESULTS AND DISCUSSION**

## EFFECT OF CARBON DIOXIDE PRESSURE

The effect of  $CO_2$  partial pressure in the range from 200 to 900 kPa was studied.  $CO_2$  was bubbled into the slurry under different partial pressures where the dissolution of magnesium increased with the increase of carbon dioxide pressure and leach time as illustrated in Figure 1.

### EFFECT OF TEMPERATURE

Leaching temperature has a considerable influence on the dissolution of magnesium. Its influence was studied over the temperature range from 20 to 50°C using a CO<sub>2</sub> pressure of 800 kPa, particle size of  $-44 \mu m$  and a solid liquid ratio of 15 g/dm<sup>3</sup>. The results are shown in Fig. 2. It can be concluded that the magnesium conversion increases with the increase of temperature from 20 to 40°C.

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Fig. 1. Effect of CO<sub>2</sub> partial pressure on MgO conversion



Fig. 2. Effect of leaching temperature

The observed decrease of MgO conversion at  $50^{\circ}$  C may be due to a low solubility of MgO and precipitation of basic magnesium carbonate (Sheila et al., 1991).

## EFFECT OF SOLID LIQUID RATIO

Figure 3 ilustrates the conversion of magnesium oxide as a function of solid-liquid ratio at  $40^{\circ}$  C and CO<sub>2</sub> pressure of 800 kPa. For a solid-liquid ratio of 50 g/dm<sup>3</sup>, the

precipitation of basic magnesium carbonate occurs due to a high magnesium concentration.



Fig. 3. Effect of solid/liquid

## EFFECT OF PARTICLE SIZE

The effect of particle size on the dissolution of magnesium is shown in Fig. 4. In these experiments different size fractions of calcinate (from 75 to 50  $\mu$ m, 44-75  $\mu$ m and below 44  $\mu$ m) were leached in the CO<sub>2</sub> atmosphere and all three size fractions showed similar response to dissolution. It can be attributed to the hydration of calcinated magnesite prior to carbonation. The Mg(OH)<sub>2</sub> particles have different surface properties from these of MgO. The Mg(OH)<sub>2</sub> particles are finer than MgO and hence the surface of MgO has no remarkable effect on the rate of magnesium dissolution.

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Fig. 4. Effect of particle size on MgO conversion



The magnesium extraction from calcined magnesite in the presence of  $CO_2$  can be expressed by the following reactions:

$$MgO + H_2O ---> Mg(OH)_2 \quad hydration \tag{1}$$

$$Mg(OH)_2 + 2CO_2 ---> Mg(HCO_3)_2$$
(2)

To determine the reaction rate constant, the following model was used:

$$1 - (1 - \alpha MgO)^{1/3} = kt$$
(3)

where k is apparent rate reaction constant,  $\alpha$  fraction of leached magnesium oxide from magnesite and t reaction time.

Plots of this model equation, using the experimental data of MgO in solution, is shown in Fig. 4. According to Fig. 4. the dissolution is controlled by chemical surface reactions for different particle sizes. Figure 5 shows the Arrhenius plot, while the reaction rate constant k, calculated from the experiments, is shown in Fig. 6. The activation energy of 30 kJ/mol was calculated from the slope. This value falls above the maximum theoretical values for chemical reaction (Krik-Othmer, 1995).



Fig. 5. Plot of  $1-(1-\alpha)1/3$  against leaching time



Fig. 6. Arrhenius plot for determining the activation energy

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## CONCLUSIONS

A selective leaching of magnesium from a low grade Halaib magnesite ore can be achieved by pressure leaching with carbon dioxide. It has been found that the dissolution of magnesium is enhanced by low reaction temperature (40  $^{0}$ C) and high carbon dioxide pressure (800 Pa) in the aqueous carbon dioxide during the leaching process. The kinetic data were analysed in terms of the modified chemical reaction rate equation and the apparent energy of activation of 30 kJ/mol suggests that the rate controlling step is controlled chemically at the surface of the Mg(OH)<sub>2</sub> particles.

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Badano zastosowanie ługowania ciśnieniowego ditlenkiem węgla do produkcji wysokiej czystości magnezytu z ubogiego magnezytu pochodzącego z obszaru Halaiba na Pustyni Wschodniej. Osiągnięto ponad 90-cio procentowy uzysk magnezu stosując następujące warunki: temperatura kalcynacji 700 °C, temperatura ługowania 50 °C, ciśnienie ditlenku węgla 600 kPa oraz czas ługowania 120 min. Badano także kinetykę procesu karbonatyzacji.

słowa kluczowe: magnezyt, ługowanie, kalcynacja, kinetyka