

Dissolution kinetics of natural magnesite in lactic acid solutions

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Abstract

In this study, the dissolution of magnesite particles in aqueous lactic acid solutions was investigated in a batch reactor employing the parameters of stirring speed, particle size, temperature and acid concentration. The shrinking core model was evaluated to determine the effect of particle size, temperature and concentration. It was also found that the stirring speed did not change the dissolution. Consequently, it was determined that the dissolution rate is controlled by surface chemical reaction. The activation energy of the process was determined to be 50.3 kJ mol^{-1} .

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1. Introduction

Several studies have been performed to determine the dissolution rate of magnesite. Dissolution kinetics of magnesite mineral in aqueous sulfur dioxide was studied by Abali et al. (1992) who found that the dissolution rate is controlled by surface reaction. Kurtbaş et al. (1992) studied the reaction kinetics of natural magnesite with hydrochloric acid and found that the dissolution rate was controlled by chemical reaction. In another study, the dissolution kinetics of magnesite mineral with Cl_2 gas in aqueous media was investigated by Özbek et al. (1999) who determined that the dissolution process is controlled by surface reaction in the temperature range of 12–40 °C and film diffusion for range of 40–70 °C. Raschman (2000) studied the leaching of calcined magnesite using

ammonium chloride at constant pH and it was concluded that the leaching process is controlled by the chemical reaction of MgO with H^+ ions at the liquid–solid interface and by pore diffusion. Demir et al. (2003) investigated the leaching kinetics of magnesite in citric acid solutions and it was found that the dissolution rate was controlled by chemical reaction. Dissolution of magnesite in acetic acid solutions was investigated by Laçin et al. (2005) and it was determined that the dissolution of natural magnesite was controlled by chemical reaction. Raschman and Fedorockova (2004) researched the inhibiting effect of hydrochloric acid concentration on the dissolution rate of magnesium oxide during the leaching of dead-burned magnesite and they found that the dissolution of MgO is controlled by chemical reaction. Although magnesite dissolution was studied in a variety of acidic media ranging from hydrochloric acid to citric acid no study was found concerning the dissolution kinetics of magnesite in lactic acid solutions.

Lactic acid (2 hydroxypropionic acid), the most widely occurring carboxylic acid in nature, is produced commercially for use in pharmaceuticals and foods, in leather

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Table 1
Chemical analysis of the magnesite

Component	Wt.%
MgO	47.30
CaO	0.43
Fe ₂ O ₃	0.25
SiO ₂	0.40
Loss of ignition (at 850°C)	51.62

tanning and textile dyeing, and in making plastics, solvents, inks, and lacquers. Although it can be prepared by chemical synthesis, production of lactic acid by fermentation of glucose and other substances is a less expensive method (Srivastava et al., 2004). Magnesium lactate is the magnesium salt of lactic acid, is produced for food, pharmaceutical, refractory, textile, and cosmetic industries.

The dissolution kinetics of a solid compound depends on the processes taking place at the solid–liquid boundary. The processes are complex and involve both chemical reactions and mass transfer. The solid–liquid reaction can occur at the surface of the solid in the film around the solid or in the liquid bulk phase. Different steps, such as mass transfer, chemical reaction and charge transfer can determine the dissolution rate. The classical models used for solid–liquid reactions are the shrinking particles and shrinking core models. The shrinking core model has been suggested by many authors to be valid for leaching of magnesite (Markus et al., 2004).

In this study, the dissolution kinetics of magnesite in lactic acid solutions was examined according to the shrinking core models, and the best fitted equation to the experimental data was determined.

2. Experimental

The magnesium carbonate ore used in the present study was supplied from a region of Erzincan–Refahiye

Table 2
The parameter values for dissolution of magnesite in lactic acid

Parameter	Value
Temperature (°C)	30, 40, 50, 60 ^a , 70
Acid concentration (mol L ⁻¹)	1.0, 1.5 ^a , 2, 2.5, 3, 4
Particle size (μm)	1425, 725, 512, 338 ^a , 215, 153
Stirring speed (rpm)	500, 600 ^a , 700, 800

^a The constant values used when the effect of other parameters was investigated.

in Turkey. After crushing and washing, the ore was ground and then sieved to different size fractions 1425, 725, 512, 338, 215 and 153 μm using ASTM standard sieves. The chemical analysis was carried out by the standard gravimetric and volumetric methods (Furmann, 1963). The analytical results were given in Table 1. X-ray diffraction patterns of the magnesite ore were obtained using a Rigaku 2000 JCPDS DMAX (29-1490) diffractometer (XRD) with CuKα radiation (30kV and 30mA and automatic monochromator) at a scanning rate 2θ of 2° min⁻¹ (Fig. 1).

Lactic acid, HC₃H₅O₃-2-hydroxy-*d*-propanoic acid, used for leaching experiments was reagent grade (90 wt.% solution in water from Merck Chemicals).

The dissolution process was carried out in a 500-mL cylinder glass batch reactor heated by a thermostat for keeping reactor contents at a constant temperature, equipped with a digital controlled mechanical stirrer, thermometer and a condenser to prevent losses by evaporation (Bayrak et al., in press). For each experiment, 250 mL volume of lactic acid at a definite concentration was transferred into the reactor at the required temperature. The reaction was initiated by the addition of a small amount of magnesite, at time $t=0$, while stirring the contents of the reactor at a certain speed. An amount of sample of the reaction mixture was withdrawn from the reactor at appropriate time intervals, filtered immediately and the Mg⁺² content in

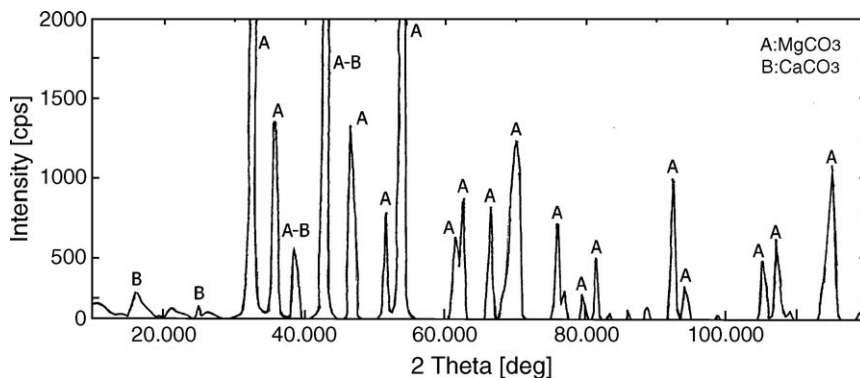


Fig. 1. X-ray diffractogram of the magnesite ore.

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