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Utilization of Serpentine Ore for Production of Magnesium Sulphate

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ABSTRACT [ENGLISH/ANGLAIS]

Serpentine ore sample was provided by Egyptian Geological Museum from Egypt Eastern Desert (Barrameya location). It was analyzed by chemical, X-ray diffraction, thermal analysis and infrared analysis to elucidate the chemical and mineralogical composition of the ore. The feasibility of leaching of Mg^{2+} from serpentine ore by sulphuric acid was investigated. The suitable conditions for optimum leaching of Mg^{2+} from serpentine ore were determined by investigating the main factors which affecting the leaching process such as, the particle size of the serpentine ore, the time of leaching, the temperature of leaching solution, the molar ratio between H^+ of the acid and MgO content in the serpentine ore, the liquid/solid ratio and the acid concentration. The kinetic of leaching of Mg^{2+} from serpentine ore by sulphuric acid were investigated in order to prepare magnesium sulphate in pure and analytical grade.

Keywords: Kinetic, industrial, leaching, magnesium, serpentine, sulphate

RÉSUMÉ [FRANÇAIS/FRENCH]

Échantillon de minerai Serpentine a été fourni par Musée géologique égyptien de l'Egypte de l'Est du désert (lieu Barrameya). Il a été analysée par des méthodes chimiques, diffraction des rayons X, analyse thermique et de l'analyse infrarouge pourélucider la composition chimique et minéralogique du minerai. La faisabilité de la lixiviation de Mg2 + à partir du minerai de serpentine par l'acide sulfurique a été étudiée.Les conditions appropriées pour la lixiviation optimale de Mg 2 + à partir de minerai en serpentin ont été déterminés en recherchant les facteurs principaux qui influent sur le processus de lessivage comme, la taille des particules du minerai en serpentin, le tempsde lixiviation, la température de la solution de lixiviation, le rapport molaire entre H + de l'acide et la teneur en MgO dans le minerai en serpentin, le rapport liquide / solide et la concentration en acide. La cinétique de la lixiviation de Mg2 + à partir du minerai de serpentine par l'acide sulfurique ont été étudiés afin de préparer le sulfate de magnésiumdans le grade pure et analytique.

Mots-clés: Kinetic, industrielle, le lessivage, le magnésium, la serpentine, le sulfate de

INTRODUCTION

Magnesium compounds are among the most useful and abundant materials known to the man. Magnesium compounds have wide applications in various industries. The most important industrial magnesium compounds are [1]. Magnesium sulphate, magnesium hydroxide, magnesium chloride, magnesium oxide and magnesium carbonate, which are used in magnesium metal production, textiles, paper processing, ceramics, cement, fertilizers, pharmaceutical industries, and chemical treatment industries. Magnesium comes below hydrogen in the electromotive series [2]. As records with the chemical reactivity of magnesium, it never occur native, but always in the combined state in the form of minerals and salts, which are widely distributed in nature. Preparation of magnesium compounds [3-4] depends mainly on magnesium minerals, which are widespread in the world. The serpentine, rock which is composes largely of serpentine minerals (include three minerals chrysotile, lizardite, and antigorite, all of which have similar compositions based on the presence of the main nucleus $Mg_3Si_2O_5(OH)_4$, and differ slightly in the degree of substitution of Mg by Fe and Al) [5], is of fairly widespread occurrence, being found for example in alpine-type settings and as rocks dredged from the ocean bottom. These rocks usually contain some proportion of chrysotile, either in a low concentration or in the form of disseminated very short fibers. The main commercially occurrences are in Canada, U.S.S.R and Africa [6]. Serpentinetic rocks are widely distributed in different localities in Egypt, namely, in the Eastern Desert (Barrameya, along the Quift-Quseir road. Wadi Gabel El-

Rubshi) [7-9]. In some of these localities, up to 22 localities, small chromite lenses enclosed in the sample rocks may be found [10]. Several studies were carried out on Egyptian serpentine ore, concerning with thermal analysis [7], location in Egypt [8], or mineralogical studies [9], but none of these studies were concerned with investigation of industrial chemical utilization of serpentine rocks as a stock material for magnesium and its compounds. Therefore the present investigation deals with define the optimum conditions which might be used for production of magnesium sulphate in pure and analytical grade which would be used in wide industrial application.

MATERIALS AND METHODS
Raw Material
The representative sample of the ore used throughout the whole investigation was taken from Barrameya location, Eastern desert (Egypt). The provided quantity (~ 20 kg) was sampled according to the usual method of sampling [11] and pulverized in a ball mill. The fraction containing particle sizes of -200+230 mesh (7.4-63μm) fraction was collected by screening. This fraction was subjected to chemical, X-ray diffraction, thermal analysis and infrared analysis to elucidate the chemical and mineralogical composition of the ore.

Chemical Analysis
The chemical analysis of the serpentine sample occur after drying at 110°C for about 3 hours and show that, the ore contains high contents of SiO_2 (38.66%), MgO (39.63%) and low contents of impurities [Fe_2O_3 (6.51%), CaO (1.96%) and Al_2O_3 (0.96%)]. The contents of MgO, CaO, Fe_2O_3, Al_2O_3 and SiO_2 in serpentine ore and in the leaching solutions were quantitative determined [12-13].
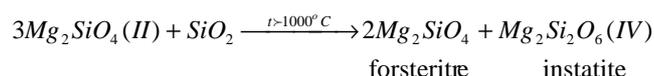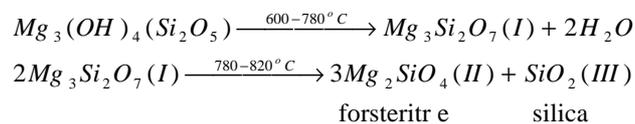
Leaching of Serpentine Ore
4 gm of serpentine ore was added gradually into different volumes of sulphuric acid in the reaction flask. The suspension of the reaction products was immediately filtered after the desired leaching time. The residue was washed thoroughly with distilled water several times. The aliquots of the filtrate were collected and completed to 500 ml in a standard measuring flask with distilled water. Suitable volumes of the filtrate were taken for determination of MgO. The fraction of MgO extracted (x) was calculated by dividing the weight of magnesia (MgO) in the leach solution (filtrate) by the weight of MgO present in the quantity of serpentine ore used in the experiment. The procedures followed for determination of the rate constant, entropy of activation, and activation energy of dissolution for determination of the mechanism of leaching process.

RESULTS
Characterization of Serpentine Ore
It was found from x-ray patterns of the ore Fig. 1 that it is composed of a complex mixture of varieties of serpentine minerals of empirical formula $Mg_3(OH)_4Si_4O_{10}.4H_2O$, $Mg_3(OH)_4(Si_2O_5)$ in addition to talc $Mg_3Si_4O_{10}(OH)_2$ [14]. The presence of Al_2O_3 and Fe_2O_3 in the ore with reasonable quantities gives an indication of the presence of significant substitutions of Si^{4+} with Al^{3+} and Mg^{2+} with Fe^{2+}, Fe^{3+} or Al^{3+}, which can be confirmed from the appearance of the characteristic 'd' spacing of aluminium serpentine $Mg_{4.5}Al_{1.5}(Si_{2.5}Al_{1.5})O_{10}(OH)_8$, $Mg_{4.25}Al_{1.75}(Si_{2.25}Al_{1.75})O_{10}(OH)_8$ and iron substituted antigorite $(Mg,Fe)(Si_2O_5)OH)_4$. Thermal analysis was carried out to confirm the results of the x-ray analysis. The (TGA), (DTG) and (DTA) curves of serpentine sample are schematically illustrated in Fig. 2 and Fig. 3. The (DTA) curve (Fig. 2) shows an endothermic peak at about 600-700°C corresponding to the expulsion of structural water [15-16] (a weak broad, low temperature endothermic peak is showed by serpentine sample is corresponding to the expulsion of water which held on the surface of fine-grained material) and this is followed usually at about 780-820°C by exothermic peak related to formation of forsterite and silica.as indicated:

$$Mg_3(OH)_4(Si_2O_5) \xrightarrow{600-780^oC} Mg_3Si_2O_7(I) + 2H_2O$$

$$2Mg_3Si_2O_7(I) \xrightarrow{780-820^oC} 3Mg_2SiO_4(II) + SiO_2(III)$$
$$\text{forsterite} \qquad \text{silica}$$

$$3Mg_2SiO_4(II) + SiO_2 \xrightarrow{t>1000^oC} 2Mg_2SiO_4 + Mg_2Si_2O_6(IV)$$
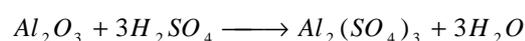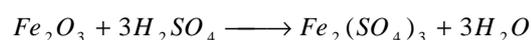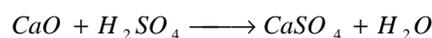$$\text{forsterite} \qquad \text{instatite}$$

Infrared Spectroscopy is especially useful in the investigation of short-range ordering within a mineral group, and becomes of paramount importance when dealing with 'amorphous' material for which X-ray crystallographic data are tenuous. In this investigation, infrared spectra were used for identification of serpentine minerals (antigorite, clinochrysotile and lizardite) where serpentine minerals may be differentiated by Si–O band positions and intensities [17-18]. Serpentines may not be positively identified by infrared spectra in the ranges of 700–500 cm^{-1}, or the 500–350 cm^{-1}, because the lizardite and non-fibrous clinochrysotile infrared spectra are very similar. The infrared spectra of serpentine ore Fig. 4 it reveal that serpentine ore sample composed of a complex mixture of varieties of serpentine minerals are mainly antigorite, clinochrysotile and lizardite.

The feasibility of leaching of Mg^{2+} from serpentine ore with sulphuric acid was studied. The leaching process is based on the dissolution of serpentine ore with sulphuric acid. The amount of reactants was stoichiometrically calculated according to the following equation:

$$MgO + H_2SO_4 \longrightarrow MgSO_4 + H_2O$$

Also, sulphuric acid reacts with other impurities, e.g.

$$CaO + H_2SO_4 \longrightarrow CaSO_4 + H_2O$$

$$Fe_2O_3 + 3H_2SO_4 \longrightarrow Fe_2(SO_4)_3 + 3H_2O$$

$$Al_2O_3 + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2O$$

The main factors which affect the leaching process are the particle size of the serpentine ore, the time of leaching, the temperature of leaching solution, the molar ration between H^+ of the acid and MgO content in the serpentine ore, the liquid/solid ratio and the acid concentration. These factors were investigated.

Effect of Particle Size

The decrease in the particle size leads to an increase in the surface area, which promotes the reactivity. On the other hand, size reduction is a costly process and should be limited, if possible. A series of experiments was carried out using different particle size with 4M H_2SO_4 with stoichiometric mole ratio H^+:MgO equal 3:1, liquid / solid ratio 5:1 ml/g at 25°C for 4h. reaction time. The results obtained are given in Table 1 The results reveal that the MgO leached, % from serpentine ore was increased by decreasing the particle size. This is due to the increase of surface area. The increase in the surface area results in good contact between the sulphuric acid and the whole volume of particles of serpentine ore. The results show that the optimum particle size of serpentine ore is –140+200 mesh fraction where further grinding of the ore to -200+230 mesh fraction leads to insignificant increase in MgO leached, % from serpentine ore.

Effect of Temperature

A series of experiments was carried out in the temperature range 25-60°C to study the effect of temperature on the MgO leached, %. The experiments were performed under the following conditions: Particle size -140+200 mesh fraction, leaching time 4h., liquid/solid ratio 5:1 ml/g H^+ : MgO, mole ratio 3:1, 4:1 and 5:1 and acid concentration 4M H_2SO_4.

These results as in Fig. 5 reveal that MgO leached, % increases with increasing temperature due to decrease the viscosity of leaching solution and so increase the mobility of reacting ions and increase the rate of leaching

Effect of Leaching Time

To study the effect of leaching time on MgO leached; % a series of experiments was carried out at different periods of time under the above conditions for different periods. The results Figs. 6 (a,b,c,d) reveal the increase in MgO leached, % with increasing the leaching time. This is attributed to the liberation of the trapped magnesium cations from the ore cavities. The results also reveal that as the temperature of leaching solution raised the leaching process become faster and so, required short period for MgO leached, %.

Table 1: This table shows effect of particle size of serpentine ore on MgO leached

Particle Size Mesh fraction	MgO Content,%	MgO leached, % by using H_2SO_4
100	39.7	28.71
-100+120	39.8	30.53
-120+140	39.9	34.21
-140+200	39.9	38.30
-200+230	39.9	39.57

Table 2: This Table shows effect of liquid/solid ratio on leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at 25°C

Liquid/Solid Ratio ml/g.	Acid concn. M (mol./l)	MgO leached %
4:1	5.0	45.28
5:1	4.0	43.35
6:1	3.3	38.00
8:1	2.5	34.17
10:1	2.0	30.03

Effect of Liquid/Solid Ratio

To study the effect of liquid/solid ratio on the MgO leached, % a series of experiments was performed at solid/liquid ratios ranging from 4:1 to 10:1 ml/g. To keep H_2SO_4 : MgO mole ratio constant at various liquid/solid ratios, the concentration of H_2SO_4 changes consequently. The results obtained are given in Table 2, reveal that the leaching of MgO decreases as the liquid/solid ratios increase due to the decrease in the concentration of the corresponding acid. At higher liquid/solid ratios, the magnesium salt concentration is low which needs higher energy for evaporation in the crystallization step during production process of magnesium salt. On the other hand, at lower liquid/solid ratio, the obtained solution is saturated

with magnesium salt and the salt crystallizes on standing thus increasing MgO losses during filtration. Moreover, the filterability (filtration rate) was very low due to the high viscosity of the solution.

Effect of H+ : MgO Mole Ratio

The effect of stoichiometric molar ratio of H^+ of the corresponding acid to the MgO content in the serpentine ore sample on the leaching of Mg^{2+} was studied in the range from 3.0 to 6.0 using 4M H_2SO_4. The results obtained are given in Table 3, reveal that increasing the H^+:MgO mole ratio led to increase of MgO leached, %. On the other hand, further increase in the stoichiometric molar ratio led to increasing free acid in the leaching solution, which led to the increase in the consumption of the acid and neutralizing agent in precipitation step.

Table 3: This table shows effect of H+ : MgO mole ratio on leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at 25ºC.

H+ : MgO Mole Ratio	MgO leached% using H_2SO_4
2:1	31.02
2.5:1	34.35
3:1	37.31
3.5:1	40.85
4:1	43.35
5:1	46.95
6:1	47.52

Kinetic Measurements on the Leaching of Mg2+ From Serpentine Ore

The kinetic measurements on the leaching of Mg^{2+} from serpentine ore with different acids were carried out under the experimental conditions mentioned before and he results reveal that the leaching efficiency of Mg^{2+} from serpentine ore increased with increasing temperature, leaching time (during time of reaction) and mole ratio between H^+ : MgO. The results of extraction of magnesia from the ore indicated that the reaction rate equations based on the concept of first order equations against MgO content in the sample ore mathematically appropriate for expressing and correlating the experimental results. As can be seen from Figures 7 (a,b,c,d) the plots of ln(1-x) vs. time are precisely linear from x ≤ 20% of reaction efficiency with different acids at working temperatures (25, 40, 50, and 60ºC) where (x) is the fraction of MgO leached by the acids and was calculated by dividing the weight of MgO in the leaching solution by the weight of MgO in the serpentine sample used in the experiment. The reaction (leaching process) was found to be pseudo

first order and the rate constant (K_r) were calculated from the slopes of the least squares first order fits as illustrated in Figures (7.a,b,c,d). Where the rate constant were determined according to the rate equation from the relation:

$$K_r = -(slope\,)/C_H$$

The activation energy (E_a) of the reaction is obtained by plotting the log of K_r versus the reciprocal of the absolute temperature as illustrated in Fig. 8, with the measurements of the rates were taken. This was made according to the Arrhenius equation in its integrated form:

$$\log K_r = \frac{-E_a}{2.303\,RT} + cons\,\tan\,t$$

This is a linear relationship in which the slope is equal to $-E_a/2.303R$ where R is the normal notation for the universal gas constant, which equals 8.314 J/mol K. The best lines were plotted using the least squares methods described before [19].

The Eyring enthalpy of activation ΔH^* was calculated from the following equation

$$\Delta H^* = E_a - RT$$

The entropy of activation ΔS^* was calculated as follows

$$K_f = (RKT\,/h)e^{-E_s/RT}e^{\Delta S^*/R}$$

Where K and h stand, respectively for the Boltzmann and Planck's constants, taking the common log of the two sides of this equation we gets

$$2.303\log K_f = 2.303\log(RK/h) + 2.303\log T - E_a/RT + \Delta S^*/R$$

By rearrangement, the equation takes the form

$$\Delta S^*/2.303\,R = \log K_f - 10.753 - \log T + E_a/4.576T$$

In which the entropy is expressed in J/mol K.

Preparation of Hydrated and Anhydrous Magnesium Sulphate

The process of preparation is based on the leaching of serpentine ore with 4M H_2SO_4 for 4 hours at 60ºC to achieve the maximum leaching of MgO from the ore by the acid. The purification of the resulted liquor solution were achieved by raising of the pH value to 8-9 by a suspension of lime or calcined dolomite at 750ºC to ensure the precipitation of Al^{3+}, Fe^{2+}, Fe^{3+}, Ni^{2+}, Co^{3+} and Cr^{3+} as hydroxides [20] . The alkaline filtrate is neutralizedd by means of H_2SO_4 acid at pH 6-7 followed by filtration of the newly precipitate $CaSO_4$ which is formed as a result of interaction of

CaO of serpentine with H_2SO_4 added for adjusting the pH to the neutrality. To ensure the elimination of iron ions by precipitation, Fe^{2+} ion was first oxidized into Fe^{3+} state, in addition to aeration, hydrogen peroxide was used [4,8]. The obtained neutral solution of magnesium sulphate is concentrated by heating, prior to crystallisation. The dried salt was produced by heating magnesium sulphate heptahydrate at 80 ± 20°C until 25% of its weight is lost [20]. The anhydrous salt was produced by heating magnesium sulphate at about 250°C, till constant weight, or by heating above 120°C under reduced pressure. The block flow-sheet for production of magnesium sulphate from serpentine ore is illustrated in Fig. 9

Table 4: This table shows values of rate constant (Kr), apparent activation energy (Ea) and entropy of activation (ΔS^*) of leaching of serpentine ore with H_2SO_4.

T °K	Mole Ratio H^+:MgO	K_r x10^2 g.mol.h^{-1}	E_a Kcal.mol.$^{-1}$	ΔS^* cal.mol.$^{-1}$K^{-1}
298	3:1	2.02	8.037	-43.605
	4:1	2.25	8.879	-40.564
	5:1	2.47	8.930	-40.208
313	3:1	3.99	8.037	-43.641
	4:1	3.58	8.879	-40.958
	5:1	5.20	8.930	-40.261
323	3:1	5.84	8.037	-43.741
	4:1	7.25	8.879	-40.703
	5:1	8.20	8.930	-40.300
333	3:1	8.61	8.037	-43.779
	4:1	10.88	8.879	-40.783
	5:1	12.20	8.930	-40.400

Mean value of Ea = 8.615 Kcal.mol.$^{-1}$; Mean value of ΔS^* = -41.579 cal.mol.$^{-1}$K^{-1}

Table 5: This table shows chemical analysis of produced pure magnesium sulfate.

Oxide %	$MgSO_4.7H_2O$ Pure	$MgSO_4.7H_2O$ Analytical grade
MgO	16.26(found) 16.35(theor.)	15.62(found) 15.72(theor.)
CaO	0.10	0.12
Fe_2O_3	0.08	0.09
Al_2O_3	0.08	0.10
Yield	96-97	91-93

The preparation of analytical grade salts which can be used in pharmaceutical purposes [21] was achieved by dissolving of the pure precipitated basic carbonate of

magnesium in the sulphuric acids. The neutral solutions of the produced salt were purified from the traces of transition elements by extraction with successive portions of a strong dithizone solution until the toluene extracts no longer changes colour [22-]. The chemical analysis of pure and analytical grade magnesium sulfate is present in Table 5.

Figure 1: This figure shows X-ray diffraction patterns of serpentine ore (measured by using Cu *Ka* irradiation and nickel filter) where A, As, C, S= Antigorite, Antigorite serpentine, Clinocrysatile, Serpentine (6-layers ortho), L, lizardite, L1 Aluminum serpentine and T=Talc, respectively.
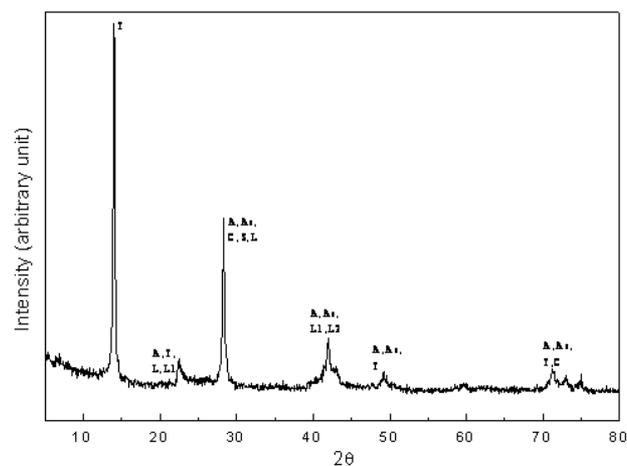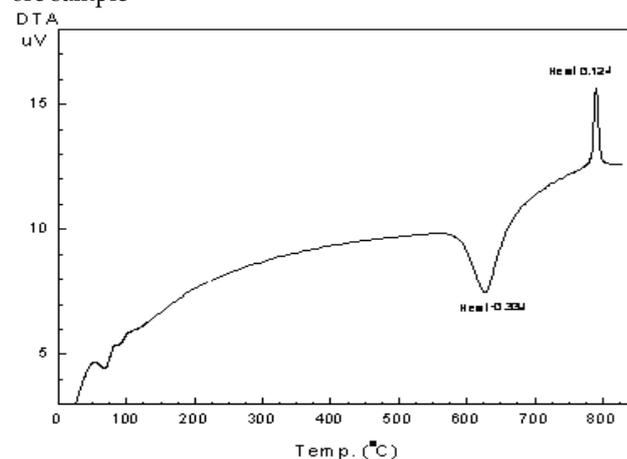

**Figure 2:** This figure shows (DTA) curve of serpentine ore sample

DISCUSSION

The feasibility of leaching of Mg^{2+} from serpentine ore with sulphuric acid was studied. The main factors which affect the leaching process are the particle size of the serpentine ore, the time of leaching, the temperature of leaching solution, the molar ration between H+ of the acid and MgO content in the serpentine ore, the

liquid/solid ratio and the acid concentration. These factors were systematically studied. On general the leaching of Mg^{2+} from serpentine ore with different acids increase with the decrease in the particle size and increases with increasing temperature, leaching time and increasing the H+:MgO mole ratio. The computed values of activation energies for the leaching process are given in Table 4, were less than reported one [4-19]. The observed difference may be attributed to the difference between the structure of serpentine ore under investigation and that of serpentine ore studied by other investigators [4]. The presence of significant quantity of aluminium serpentine such as $Mg_{4.5}Al_{1.5}(Si_{2.5}Al_{1.5})O_{10}(OH)_8$ and iron substituted serpentine, such as $(Mg,Fe)_3Si_2O_5(OH)_4$ led to an increase in the susceptibility towards acid attack, due to the weakening in the three dimensional silicate network [23]. In other works, the fraction of the tetrahedral sites occupied by aluminium increase the possibility of decomposition of framework silicates. Generally, the bonds between aluminium, iron and oxygen are weaker than those between silicon and oxygen and thus show more susceptibility toward acid attack as is the case of the serpentine ore under investigation [24-25].

Figure 3: This figure shows (TGA) and (DTG) curves of serpentine ore sample
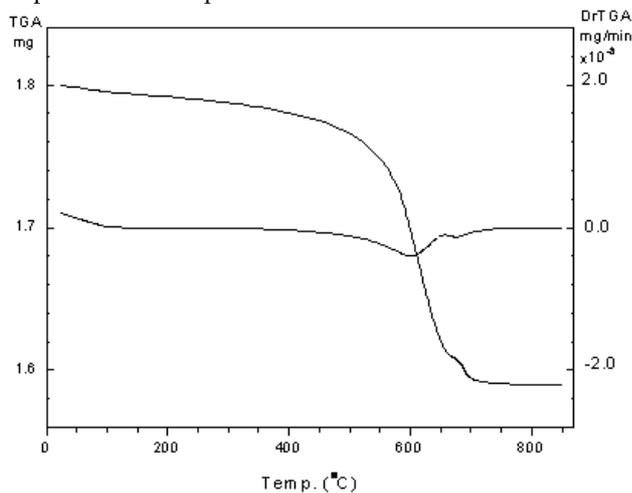
The leaching of serpentine ore in sulphuric acid solutions, a heterogeneous reaction, was found to follow the shrinkage core model [25]. This model assumes that the reaction rate is controlled by one of the following three steps, diffusion of acid through a film surrounding the particle, chemical reaction on the surface of the particle, and diffusion of the products back through the film. The fact that, the degree of stirring of a reaction mixture did not affect on the dissolution rate which

eliminated the need to consider the diffusion step as the rate-determining step. The values of the activation energies are considered important parameters for determination of the mechanism of the heterogeneous reaction. According to Glasstone et al. [26], diffusion-controlled have activation energies range from 1.9 to 6 Kcal/mol, whereas that characteristic for a surface chemical process is considerably higher. It therefore, follows from the activation energy value that the rate of dissolution of magnesia in H_2SO_4 acid solutions was controlled by a chemical reaction on the surface of the particle of serpentine ore. Preparation of magnesium salts of pure and analytical grade are investigated from Egyptian serpentine ore ($Mg_3(OH)_4Si_4O_{10}.4H_2O$) which occurs in the eastern desert of Egypt with commercial reserves.

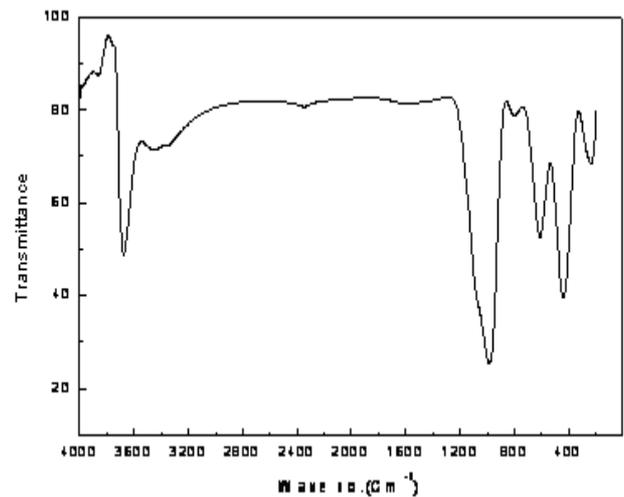**Figure 4:** This figure shows Infrared spectra of serpentine ore sample

Figure 5: This figure shows effect of temperature on leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different H^+: MgO mole ratio 3:1, 4:1 and 5:1.
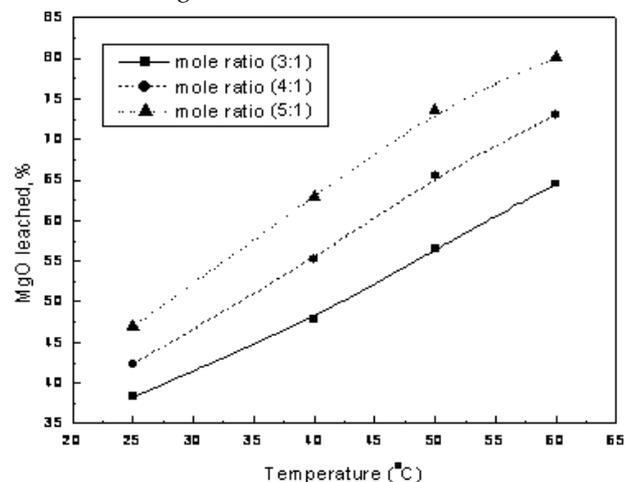
Figure 6(a): This figure shows effect of leaching time on leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different H^+ : MgO mole ratio 3:1, 4:1 and 5:1 at 25°C.
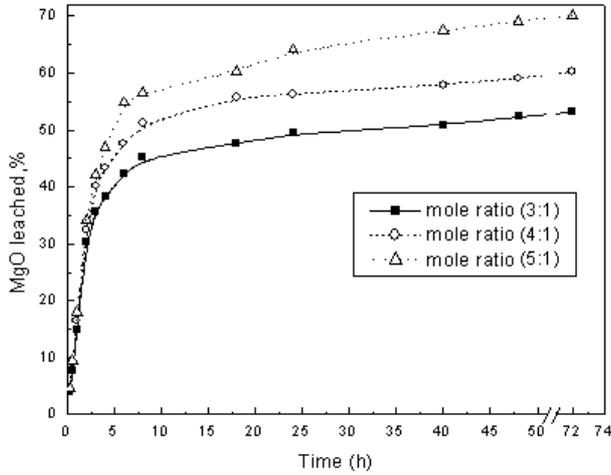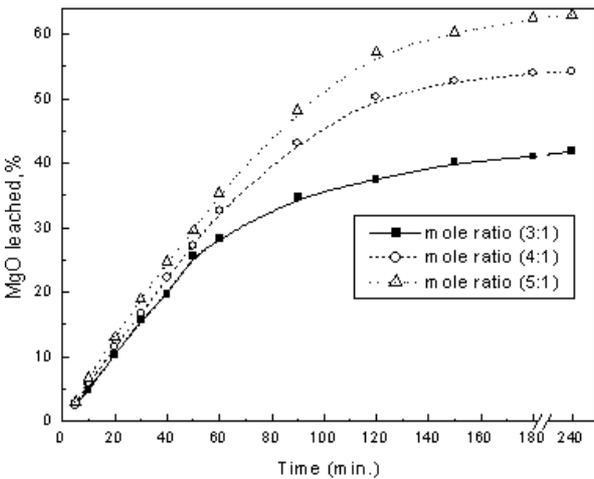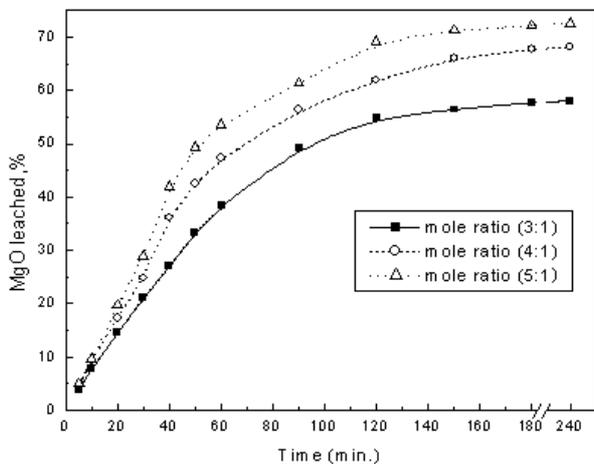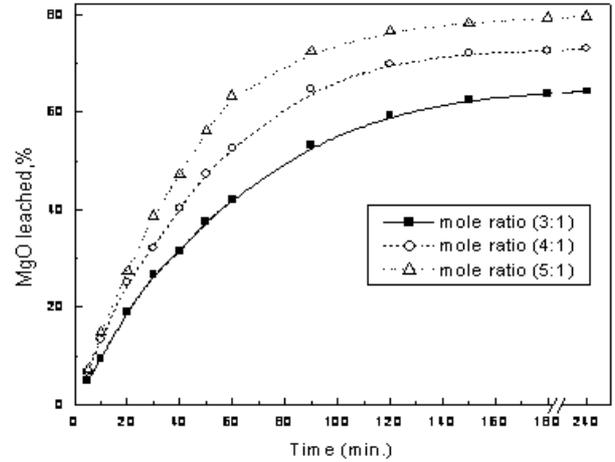

Figure 6(b): This figure shows effect of leaching time on leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different H^+ : MgO mole ratio 3:1, 4:1 and 5:1 at 40°C

Figure 6(c): This figure shows effect of leaching time on leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different H^+ : MgO mole ratio 3:1, 4:1 and 5:1 at 50°C

Figure 6(d): This figure shows effect of leaching time on leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different H^+ : MgO mole ratio 3:1, 4:1 and 5:1 at 60°C

Figure 7(a): This figure shows Pseudo-first order plots of leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different H^+ : MgO mole ratio 3:1, 4:1 and 5:1 at 25°C
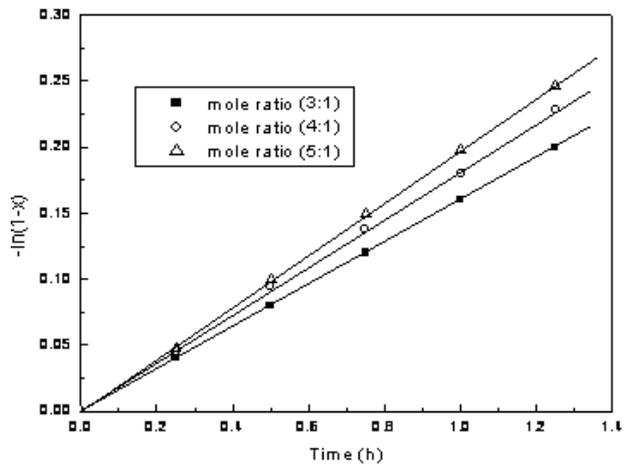

Figure 7(b): This figure shows Pseudo-first order plots of leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different H^+ : MgO mole ratio 3:1, 4:1 and 5:1 at 40°C.
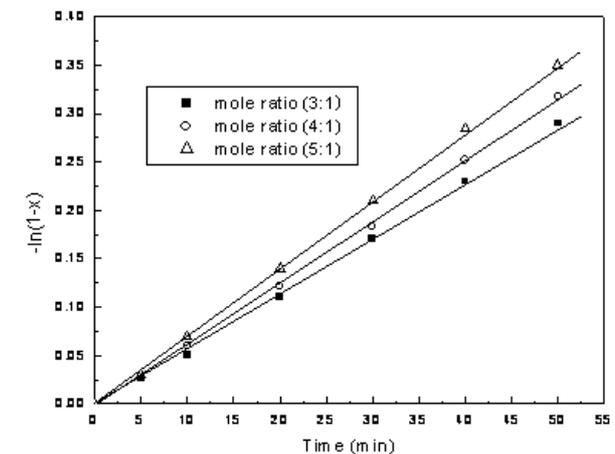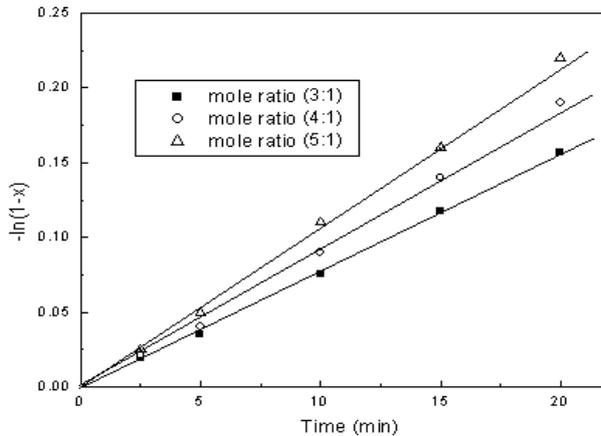
Figure 7(c): This figure shows Pseudo-first order plots of leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different $H^+ : MgO$ mole ratio 3:1, 4:1 and 5:1 at 50°C

Figure 7(d): This Figure shows Pseudo-first order plots of leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different $H^+ : MgO$ mole ratio 3:1, 4:1 and 5:1 at 60°C
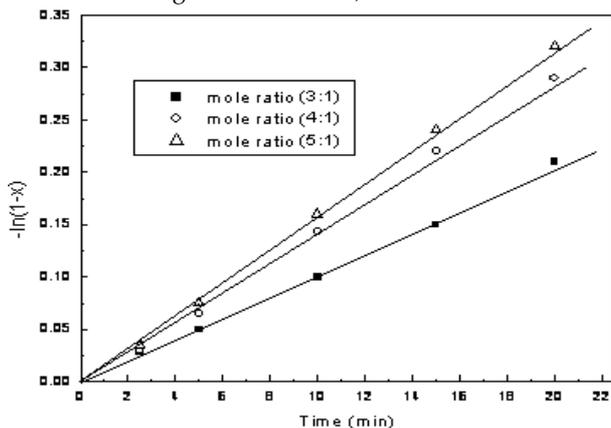

Figure 8: This Figure shows Plotting of log K_r against $1/T$ for leaching of Mg^{2+} from serpentine ore by using H_2SO_4 at different $H^+ : MgO$ mole ratio 3:1, 4:1 and 5:1
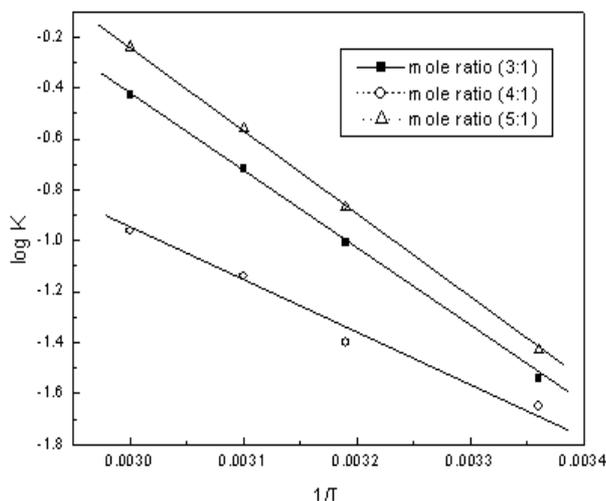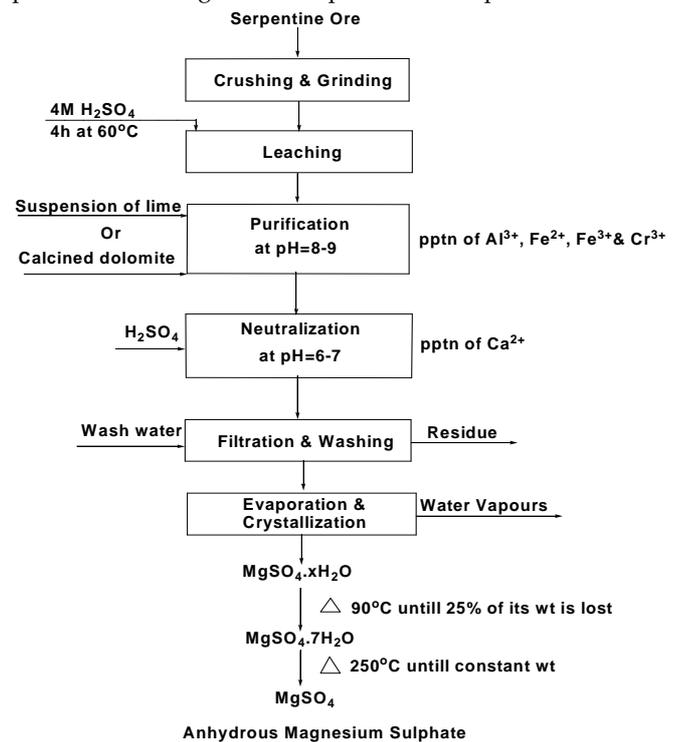

Figure 9: This figure shows the block flow-sheet for production of magnesium sulphate from serpentine ore

CONCLUSIONS

This study clearly indicates the suitable conditions for optimum leaching of Mg^{2+} from serpentine ore, that were determined by investigating the main factors which affecting the leaching process. The kinetic of leaching of Mg^{2+} from serpentine ore by sulphuric acid indicated that the reaction rate equations based on the concept of first order equations. Finally, preparation of hydrated and anhydrous magnesium sulphate in pure and analytical grade can be obtained from leaching serpentine ore by sulphuric acid

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CONFLICT OF INTEREST

No conflict of interests was declared by authors.

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