Pharmaceutical Research, Vol. 10, No. 7, 1993

Characterization of Antacid Compounds Containing Both Aluminum and Magnesium. I. Crystalline Powders

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Received January 28, 1992; accepted December 31, 1992

The composition and antacid properties of 10 samples of crystalline antacids containing both aluminum and magnesium were determined. The composition was found to vary significantly, even within the same type of antacid. For example, three of four hydrotalcite samples exhibit evidence of the presence of a minor phase of amorphous aluminum hydroxide. Almagate and almagcit, which are claimed to be unique compounds, were found to be composed of hydrotalcite, magnesium hydroxycarbonate, and/or magnesium carbonate and amorphous aluminum hydroxide. All three magaldrate samples examined contained a minor phase of amorphous aluminum hydroxide. All 10 samples passed the preliminary antacid test and had high acid neutralizing capacities. However, the rate of acid neutralization varied between samples. In some cases the rate of acid neutralization at a dose of 400 mg was too slow to raise the pH to 3.0 as required by the Rossett–Rice test.

KEY WORDS: hydrotalcite; magaldrate.

INTRODUCTION

Amorphous aluminum hydroxycarbonate gel and magnesium hydroxide gel are frequently combined in antacid products. The effectiveness of this mixture has led to the development of several crystalline antacid materials which contain both aluminum and magnesium. These antacid materials include hydrotalcite (1,2), almagate (3–6), almagcit (7), and magaldrate (2,8). Although all of these antacid materials are used commercially in antacid products, a survey of the literature revealed little about their composition or antacid properties. Thus, a study was undertaken of the composition and antacid properties of these materials.

EXPERIMENTAL

The 10 commercial antacid samples studied are identified in Table I. Samples were tested during the summer of 1990 except for sample J, which was tested during the summer of 1991.

The aluminum and magnesium content was determined by atomic absorption spectrophotometry (Model 2280, Perkin Elmer Corp.) following dissolution in 0.1 *N* HCl. The carbonate content was determined by the gasometric displacement procedure (9). The sulfate content of the magaldrate samples was determined gravimetrically by the precipitation and ignition of barium sulfate (10). The X-ray diffraction patterns were determined using a random powder mount (Model PW3100, Phillips). The morphology was determined by transmission electron microscopy (JEOL 2000 FX), and the elemental composition of particles by energy dispersive spectrometry (Link Analytical). The surface area was measured by nitrogen adsorption (Autosorb 1, Quantachrome Corp.). The antacid properties at a dose of 400 mg were evaluated by the following *in vitro* tests: preliminary antacid test (11), acid neutralizing capacity test (11), Rossett–Rice test (12), and pH-stat titration (Radiometer) (13).

RESULTS AND DISCUSSION

Hydrotalcite. Hydrotalcite occurs naturally as a member of the pyroaurite–sjogrenite mineral group (14–16) but is prepared synthetically by precipitation for antacid use (2). It is composed of alternate layers of anions and cations. The cationic layer is brucite (crystalline magnesium hydroxide) in which aluminum cation substitutes for magnesium cation to produce a stoichiometry ranging from 1 Al:2 Mg to 1 Al:5 Mg. The hydrotalcite that is commercially available for antacid use has a ratio of 1 Al:3 Mg. This substitution gives rise to a positive surface charge which is neutralized by exchangeable anions, chiefly carbonate, in the anionic layer.

The aluminum, magnesium, and carbonate contents of four commercial hydrotalcite samples are shown in Table II. An empirical formula was calculated for each sample assuming that 2 mol of aluminum is present and that hydroxyl and carbonate are the only anions. The empirical formulas calculated for samples A, B, and C are similar to the accepted empirical formula for hydrotalcite. However, the aluminum content of sample D (2 Al:5 Mg) is greater than the accepted 2 Al:6 Mg stoichiometry.

The X-ray diffractograms of all four samples exhibited only the five diffraction bands (7.84, 3.90, 2.60, 2.33, and 1.99 A) which are characteristic of hydrotalcite (2). The absence of any other diffraction bands suggests that the excess aluminum noted in sample D is not present as a crystalline phase such as gibbsite, dawsonite, or boehmite.

The infrared spectra for samples A, B, C, and D show the following common features: hydroxyl stretching frequency at 3500–3552 cm^{-1} (structural hydroxyls and adsorbed water), a band at 1636 cm^{-1} attributed to the deformation band of adsorbed water, and a band in the 1370–1380 cm^{-1} range, attributed to carbonate stretching vibrations. The symmetrical band at 1370–1380 cm^{-1} indicates that carbonate anion is present and is unperturbed in the interlayer space (17).

Samples A, C, and D also show a shoulder feature at about 1495 cm^{-1}. This suggests the presence of carbonate

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Table I. Antacid Samples Studied

Sample	Description	Manufacturer	Lot No.
A	Hydrotalcite, free flowing	Kyowa Chemical Industry	SH 1183
B	Hydrotalcite, very fine	Kyowa Chemical Industry	891 204
C	Hydrotalcite, light	Kyowa Chemical Industry	L-183G
D	Hydrotalcite	Reheis Chemical (Ireland) Ltd.	QC/328
E	Almagate, C300	Giulini Chemie	87-339-30
F	Almagate	Giulini Chemie	86-700032-30
G	Almagcit, C301	Guilini Chemie	87-214-30
H	Magaldrate	Reheis Chemical (Ireland) Ltd.	1457/C
I	Magaldrate, C410	Giulini Chemie	88-939-30
J	Magaldrate, C410	Giulini Chemie	90-154-30

which is coordinated to a metal ion by an unidentate bond (18) and is interpreted to indicate the presence of amorphous aluminum hydroxycarbonate. The Al:Mg ratio for these three samples (Table II) indicates an excess of aluminum. This is further evidence of the presence of an amorphous aluminum hydroxycarbonate phase. The higher hydroxyl stretching frequency (3552 cm^{-1}) and the absence of the 1495 cm^{-1} band in sample B are attributed to the higher crystallinity and purity of the hydrotalcite phase.

The morphology of all four samples was platy, as would be expected for a material having the layer structure of the pyroaurite–sjogrenite mineral group. However, differences between samples were observed as noted in Table III. Samples A and B were composed of symmetrical plates which contained both aluminum and magnesium when examined by energy dispersive spectrometry. However, the plates in sample A ranged from <50 to 275 nm and those in sample B were larger, ranging from 140 to 625 nm. Samples C and D were composed of irregular aggregates of platy particles. The platy particles were similar in size to those observed in sample A. Previous studies have shown that amorphous aluminum hydroxycarbonate also has a platy morphology (19) and, thus, cannot be distinguished from hydrotalcite based solely on morphology. The particles in sample C contained aluminum and magnesium, as expected for hydrotalcite. Sample D was composed of some particles which contained only aluminum, in addition to particles which contained aluminum and magnesium. This observation further suggests that sample D is a mixture of hydrotalcite and some form of amorphous aluminum hydroxide, perhaps amorphous aluminum hydroxycarbonate.

The surface areas are listed in Table III. The values are similar for samples A, C, and D and are approximately five times greater than sample B. This result is consistent with the larger particles observed in sample B by transmission electron microscopy and the previously noted difference in the infrared spectrum of sample B.

Another parameter which can be used to characterize the primary particle size and surface area of crystalline materials is the sharpness of the X-ray diffraction bands (20). The width at half-height (WHH) of the 003 band (7.84 A) was used to quantify the relative size of the primary crystallites. A solid having a large primary crystallite size will exhibit sharp X-ray diffraction bands and will have a relatively small WHH. As shown in Table III, this parameter also indicates that the primary crystallite size of sample B is the largest.

The antacid properties are presented in Table IV. All four samples have similar acid neutralizing capacities and pass the preliminary antacid test. Samples A, C, and D show similar behavior in the Rossett–Rice test, as they all reach pH 3 in less than a minute (lag time) and buffered at pH 3.8–3.9. Sample B did not react rapidly enough at the same dose (400 mg) to raise the pH to 3.0 during the Rossett–Rice test. The slower rate of acid neutralization is probably related to its larger particle size, lower surface area and larger primary crystallite size.

It is interesting to note that hydrotalcite exhibits a buffering pH of 3.8–3.9 (4). In comparison, magnesium hydroxide buffers at pH 8.0–8.5 and amorphous aluminum hydroxycarbonate buffers at pH 3.5–4.0 (21). Thus, hydrotalcite, in spite of having the crystal structure of magnesium hydroxide and containing three times as much magnesium cation as aluminum cation, exhibits similar buffering properties as amorphous aluminum hydroxycarbonate in the Rossett–Rice test.

Table II. Empirical Formula Based on Aluminum, Magnesium, Carbonate, and Sulfate Content

Sample	Aluminum (mmol/100 g)	Magnesium (mmol/100 g)	Carbonate (mmol/100 g)	Sulfate (mmol/100 g)	Empirical formula
Hydrotalcite					$Al_2Mg_6(OH)_{16}CO_3$
A	322	933	222	—	$Al_2Mg_{5.8}(OH)_{14.8}(CO_3)_{1.4}$
B	313	962	205	—	$Al_2Mg_{6.2}(OH)_{15.7}(CO_3)_{1.3}$
C	317	907	210	—	$Al_2Mg_{5.7}(OH)_{14.8}(CO_3)_{1.3}$
D	353	889	217	—	$Al_2Mg_{5.0}(OH)_{13.6}(CO_3)_{1.2}$
Almagate					$Al_2Mg_6(OH)_{14}(CO_3)_2$
E	298	924	303	—	$Al_2Mg_{6.2}(OH)_{14.4}(CO_3)_{2.0}$
F	313	913	308	—	$Al_2Mg_{5.8}(OH)_{13.6}(CO_3)_{2.0}$
Almagcit					$Al_2Mg_6(OH)_{12}(CO_3)_3$
G	299	900	352	—	$Al_2Mg_{6.0}(OH)_{13.2}(CO_3)_{2.4}$
Magaldrate					$Al_5Mg_{10}(OH)_{31}(SO_4)_2$
H	389	782	51	163	$Al_5Mg_{10}(OH)_{30}(SO_4)_{2.1}(CO_3)_{0.7}$
I	369	798	59	153	$Al_5Mg_{10.8}(OH)_{30.9}(SO_4)_{2.1}(CO_3)_{0.8}$
J	437	824	35	153	$Al_5Mg_{9.4}(OH)_{29.5}(SO_4)_{1.8}(CO_3)_{0.4}$

Table III. Elemental Composition by Energy Dispersive Spectrometry (EDS) and Physical Properties

Sample	Morphology[a]	Particle composition by EDS: Total examined	Contained: Al + Mg	Al	Mg	Surface area (m^2/g)	WHH (°2θ)
Hydrotalcite							
A	a	5	5	0	0	79	0.90
B	a	4	4	0	0	15	0.23
C	b	5	5	0	0	83	1.04
D	b	5	3	2	0	72	1.00
Almagate							
E	b,c	5	2	2	1	102	0.86
F	b	4	4	0	0	73	0.86
Almagcit							
G	b	3	3	0	0	97	0.98
Magaldrate							
H	b	4	3	1	0	9	1.50
I	b	5	4	1	0	11	1.27
J	b	4	2	2	0	8	1.36

[a] a, platy; b, aggregates of plates; c, cubic.

pH-stat titration at pH 3.0, 37°C, is a valuable *in vitro* antacid test because it has been correlated with *in vivo* acid neutralization (22). As shown in Table IV, samples A, C, and D reacted more rapidly than sample B as characterized by the time to neutralize 50% of the sample (*T*-50).

Amorphous aluminum hydroxycarbonate and magnesium hydroxide show different behavior when examined by pH-stat titration. Both antacids react rapidly at pH 3.0 or below, but amorphous aluminum hydroxycarbonate reacts very slowly above pH 4.5, while the rate of acid neutralization by magnesium hydroxide is only slightly reduced by raising the pH above 4.5 (23). When the hydrotalcite samples were tested at pH 5.0, they all exhibited a very slow rate of acid neutralization with less than 20% neutralized in 70 min (Table IV). Thus, even though the structure of hydrotalcite is based on magnesium hydroxide and it contains more magnesium than aluminum cations, its behavior in the pH-stat titration test is similar to amorphous aluminum hydroxycarbonate rather than magnesium hydroxide.

A linear correlation ($r = 0.999$) was observed between the rate of acid neutralization at pH 3.0, 37°C, and the primary crystallite size as determined by X-ray diffraction (Fig. 1). A linear correlation ($r = 0.979$) was also noted between the surface area measured by nitrogen adsorption and the rate of acid neutralization at pH 3.0, 37°C. Thus, the X-ray pattern of hydrotalcite is useful both for identification and as a predictor of the rate of acid neutralization.

Almagate and Almagcit. These materials have been recently introduced as unique hydrotalcite analogues (4,7). It is claimed that almagate is different from hydrotalcite, as the interstitial carbonate is coordinated to aluminum and magnesium in the cationic layer. No information on the structure of almagcit was found in the literature.

The aluminum, magnesium, and carbonate contents of three samples of almagate and almagcit are presented in Table II. The empirical formulas calculated from the chemical analysis were very similar to the accepted empirical formulas.

The X-ray diffraction bands of the three samples are presented in Table V along with the reference X-ray diffraction pattern of almagate and hydrotalcite. It is clear that the diffraction pattern of the three samples and the almagate reference diffraction pattern contain the five X-ray diffraction bands which are characteristic of hydrotalcite and, in addition, contain other diffraction bands. The X-ray diffraction bands are divided into two groups in Table VI. One group, which is referred to as the major phase, represents the X-ray diffraction bands which are characteristic of hydrotalcite. The second group, termed the minor phase, includes all of the X-ray diffraction bands not associated with hydrotalcite. The reference X-ray diffraction patterns for hydromagnesite and dypingite, two magnesium hydroxycarbonate minerals, as well as nesquehonite and lansfordite, two magnesium carbonate minerals, are included in Table VI. These and other related minerals are very unstable, e.g., lansfordite readily alters to nesquehonite upon dehydration at 10°C; nesquehonite alters easily to hydromagnesite via an intermediate phase similar to dypingite [$Mg_5(CO_3)_4(OH)_2 \cdot 5H_2O$]. These systems usually consist of several phases whose composition is extremely sensitive to variations in water content, partial pressure of CO_2, and temperature. Since all of the X-ray diffraction bands that are not associated with hydrotalcite can be identified with the X-ray pattern of hydromagnesite, dypingite, nesquehonite, or lansfordite, it is hypothesized that the almagate and almagcit samples are mixtures of hydrotalcite and magnesium hydroxycarbonate and/or magnesium carbonate.

As in the hydrotalcite samples, the infrared spectra of the two almagate samples show hydroxyl stretching frequencies in the 3450-cm^{-1} region due to structural hydroxyls and adsorbed water and a band at 1636 cm^{-1} attributed to the deformation band of adsorbed water. Bands at 1482 and 1420 cm^{-1} are attributed to the carbonate stretching frequencies of a dypingite phase (25). The band at 1368 cm^{-1} is due to free carbonate in the interlayer space of hydrotalcite. In addition to intense bands at 660–670 cm^{-1}, there are four or

Table IV. Antacid Properties

Sample	PAT	ANC (mEq/400 mg)	Rossett–Rice test[a] Lag (min)	R–R time (min)	Buffering pH	pH-stat T-50 (min), pH 3, 37°C	% neutralized in 70 min, pH 5, 37°C
Hydrotalcite							
A	3.9	11.8	0.4	9.7	3.8	3.4	16.2
B	3.8	12.1	a	a	a	13.4	4.7
C	3.9	11.9	0.3	10.6	3.9	1.3	19.8
D	4.0	11.4	0.2	7.5	3.8	1.8	15.6
Almagate							
E	4.0	11.3	1.0	6.6	b	3.5	28.2
F	4.0	11.2	1.6	6.2	b	4.6	25.5
Almagcit							
G	4.0	11.2	a	a	a	6.1	24.3
Magaldrate							
H	3.7	10.0	0.2	4.2	b	1.1	20.8
I	3.9	10.2	0.4	3.6	b	2.5	30.2
J	4.0	9.9	1.0	5.0	b	1.5	20.8

[a] a, pH did not reach 3.0; b, a constant pH was not observed.

five distinct small bands between 700 and 550 cm^{-1}. These are likely related to the dypingite phase (25).

It has been claimed that almagate is a new crystalline antacid that is different from hydrotalcite. From the X-ray diffraction patterns and infrared spectra, we hypothesized that almagate was a mixture of hydrotalcite and other crystalline phases.

The hypothesis was tested by the pH-stat titration of a portion of sample E at pH 5.5 for 30 min. Hydrotalcite does not react very rapidly with protons above pH 5.0 as noted above, while both magnesium hydroxide and magnesium carbonate compounds react rapidly above pH 5.0. The remaining unreacted solid phase was filtered, dried, and prepared for X-ray diffraction and infrared analysis. The infrared bands at 1482 and 1420 cm^{-1} disappeared, while the 1368-cm^{-1} band for the carbonate in the hydrotalcite phase remained and the infrared spectrum of the treated sample was very similar to that of the hydrotalcite sample B. Additionally, amorphous aluminum hydroxycarbonate does not react at pH 5.5. The presence of a shoulder at 1490 cm^{-1} in the treated sample suggests the presence of a small amount of amorphous aluminum hydroxycarbonate.

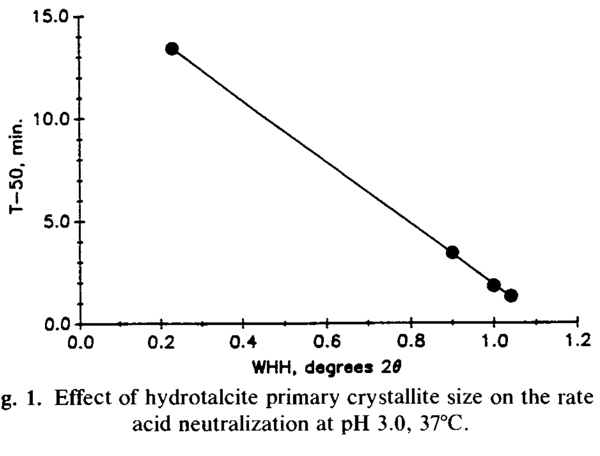

Fig. 1. Effect of hydrotalcite primary crystallite size on the rate of acid neutralization at pH 3.0, 37°C.

The X-ray diffraction pattern of the treated sample exhibited only the five characteristic diffraction bands for hydrotalcite. The infrared and X-ray diffraction studies of the portion of almagate that does not react with acid at pH 5.5 show that almagate is composed of at least two crystalline phases which differ in their reactivity with acid. Thus, it is clear that almagate is not a unique material but is a mixture of hydrotalcite and magnesium hydroxycarbonate and/or magnesium carbonate.

The infrared spectrum of almagcit (sample G) is very similar to the spectrum of the two almagate samples. The previous comments on the infrared spectra of almagate also apply to almagcit. The X-ray diffraction patterns show that the peaks for dypingite are more intense for almagcit than for the almagate samples. Thus, it is concluded that the almagcit sample has a higher content of dypingite (magnesium hydroxycarbonate) than either of the almagate samples.

Examination of the almagate and almagcit samples by transmission electron microscopy revealed aggregates of

Table V. X-Ray Diffraction Pattern of Almagate and Almagcit

Almagate E	F	Almagcit, G	Almagate reference[a]	Hydrotalcite reference[b]
		9.96		
7.82	7.74	7.73	7.61	7.84
		6.468		
5.847	5.84	5.839	5.76	
4.213	4.250	4.210		
3.88	3.85	3.84	3.81	3.90
2.911	2.908	2.910	2.89	
2.58	2.58	2.58	2.57	2.60
2.31	2.31	2.297	2.29	2.33
		2.167		
2.030	2.028	2.028		
1.963	1.956	1.944	1.94	1.99

[a] Source: Ref. 4.

[b] Source: Ref. 2.

Table VI. X-Ray Diffraction Pattern of Almagate and Almagcit in Comparison to Hydrotalcite, Magnesium Hydroxycarbonate, and Magnesium Carbonate

Almagate		Almagcit,	Hydrotalcite	Almagate	Hydromagnesite[c]	Dypingite[d]	Nesquehonite[e]	Lansfordite[f]
E	F	G	reference[a]	reference[b]	reference[g]	reference[g]	reference[g]	reference[g]
				Major phase				
7.82	7.74	7.73	7.84	7.61				
3.88	3.85	3.84	3.90	3.81				
2.59	2.59	2.59	2.60	2.57				
2.31	2.31	2.297	2.33	2.29				
		2.167						
1.963	1.956	1.944	1.99	1.94				
				Minor phase				
						10.8		
		9.96			9.20			
						7.35		7.20
		6.468			6.404	6.45	6.51	
								6.10
5.847	5.84	5.839		5.76	5.79	5.89		
								5.15
						4.45		4.57
4.213	4.205	4.210			4.193	4.21		4.23
							3.86	3.81
							3.56	3.63
					3.323		3.22	3.48
2.911	2.908	2.910		2.89	2.908	2.93	3.02	
					2.693			
					2.304			
2.030	2.028	2.028				2.18		

[a] Source: Ref. 2.
[b] Source: Ref. 3.
[c] $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$.
[d] $Mg_5(CO_3)_4(OH)_2 \cdot 8H_2O$.
[e] $MgCO_3 \cdot 3H_2O$.
[f] $MgCO_3 \cdot 5H_2O$.
[g] Source: Ref. 24.

platy particles and an occasional cubic particle (Table III). Energy dispersive spectrometry revealed nine particles containing aluminum and magnesium, two particles containing only aluminum, and one particle containing only magnesium. The presence of particles containing only aluminum suggests the presence of amorphous aluminum hydroxide. The presence of a particle containing only magnesium supports the conclusion based on the X-ray diffraction pattern that these samples are a mixture of hydrotalcite and magnesium hydroxycarbonate and/or magnesium carbonate.

The surface areas of both the almagate and the almagcit samples were quite high, ranging from 73 to 102 m^2/g (Table III). The width at half-height of the 003 band (7.7–7.8 A) of hydrotalcite is also presented in Table III. These values are similar to the values for hydrotalcite samples A, C, and D.

The antacid properties of the almagate and almagcit samples are presented in Table IV. All three samples exhibited similar values for the preliminary antacid test and acid neutralizing capacity. The almagate samples raised the pH above 3.0 at a dose of 400 mg in the Rossett–Rice test but did not exhibit a buffering pH. The almagcit sample did not raise the pH to 3.0 in the Rossett–Rice test at a dose of 400 mg.

The rate of acid neutralization at pH 3.0, 37°C, as measured by pH-stat titration (Table IV) was rapid, although the almagcit sample had a slower rate of acid neutralization than the two almagate samples.

The rate of acid neutralization was slow at pH 5.0, 37°C, although all three samples exhibited a significantly faster rate of acid neutralization than was observed for the four hydrotalcite samples (Table IV). This behavior is consistent with the conclusion that the almagate and almagcit samples are a mixture of hydrotalcite and magnesium hydroxycarbonate and/or magnesium carbonate.

A linear relationship was not observed between either the primary crystallite dimension or surface area and the rate of acid neutralization at pH 3.0, 37°C, for the almagate and almagcit samples. The presence of a second crystalline phase of magnesium hydroxycarbonate and/or magnesium carbonate may obscure the linear relationship observed for hydrotalcite.

Magaldrate. Magaldrate has the same structure as hydrotalcite but contains sulfate as the major anion in the anionic layer (2). Because sulfate anion is larger than carbonate anion, the interplanar spacing of magaldrate is 8.8 A when dried, in comparison to 7.56 A for dried hydrotalcite (17). The degree of substitution in the cationic layer is greater in reference magaldrate, producing a stoichiometry of 1 Al:2 Mg, in contrast to the 1 Al:3 Mg stoichiometry in reference hydrotalcite. The positive charge of the cationic layer is thus greater for magaldrate than for hydrotalcite. This also requires more exchangeable anions in the anionic layer of magaldrate.

The aluminum, magnesium, sulfate, and carbonate contents of three commercial magaldrate samples are shown in Table II. It is interesting to note that a significant amount of carbonate anion was present in each sample even though the accepted empirical formula recognizes only the presence of hydroxyl and sulfate anions in the anionic layer (8).

An empirical formula for each sample was calculated assuming the presence of 5 mol of aluminum and enough hydroxyls to produce a neutral compound. Sample J contained more aluminum than the 5 Al:10 Mg ratio of the accepted empirical formula and also than the 1 Al:2 Mg stoichiometry for the maximum substitution of aluminum for magnesium for this type of compound. Sample I contained more magnesium than the accepted empirical formula but was within the 1 Al:2 Mg to 1 Al:5 Mg ratio allowed for this type of compound.

X-ray diffractograms of all three samples in the hydrated state exhibit diffraction bands at 10.8, 5.5, 3.7, 2.6, 1.9, and 1.5 A which are characteristic of hydrated magaldrate due to the presence of water in the interplanar space (17).

The infrared spectra of samples H, I, and J all show bands at 3450 cm^{-1} which are hydroxyl stretching frequencies arising from structural hydroxyls and adsorbed water. The band at 1636 cm^{-1} is the deformation band of molecular water adsorbed on surfaces. The band at 1363 cm^{-1} is attributed to exchangeable carbonate in the anionic layer. Sharp bands at 1107 and 617 cm^{-1} are due to the sulfate anion in the anionic layer.

Transmission electron microscopy (Table III) revealed that all three samples were composed of aggregates of platy particles. However, particles that contained only aluminum were identified in all three samples, suggesting the presence of amorphous aluminum hydroxide.

The surface areas of the magaldrate samples (8–11 m^2/g) are much lower than those of the hydrotalcite samples (Table III). The line broadening of the major X-ray diffraction band (Table III) indicates that the relative primary crystallite size of the three samples follow the order $I > J > H$.

The antacid properties are tabulated in Table IV. All three samples pass the preliminary antacid test and have similar acid neutralizing capacities. The samples also exhibit similar behavior in the Rossett–Rice test, although a buffering pH was not observed. All three samples had a very fast rate of acid neutralization at pH 3.0, 37°C, and a very slow rate of acid neutralization at pH 5.0, 37°C (Table IV). Thus, like hydrotalcite, the antacid properties of magaldrate are more like those of amorphous aluminum hydroxycarbonate than those of magnesium hydroxide.

In contrast to hydrotalcite, a linear relationship was not observed between the rate of acid neutralization of the magaldrate samples at pH 3.0, 37°C, and the primary crystallite size ($r = 0.321$) or the surface area ($r = 0.817$). The magaldrate samples all exhibited low surface areas in comparison to the hydrotalcite samples, but the magaldrate samples had very rapid rates of acid neutralization at pH 3.0, 37°C. The high rate of acid neutralization may be due to the larger interplanar spacing caused by the presence of sulfate anions in the anionic layer, which permits protons to reach the cationic brucite layer more readily. As a result, the relationship between primary crystallite size or surface area and rate of acid neutralization is of less importance for magaldrate than for hydrotalcite.

ACKNOWLEDGMENT

This work was supported in part by Bayer AG.

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