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THE SILICATES OF MAGNESIUM

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Magnesium silicates have long been used in medicine. They are mentioned by Dioscorides⁵ in his *Materia Medica*. Some have been prized by geophagists either as table delicacies or as famine foods^{2, 7, 10, 11}; steatite or soapstone, a geological variety of talc, has usually been selected for this purpose. Talc is used extensively to-day in dusting powders, and is sometimes given internally in disorders of the stomach and intestines.

There are numerous natural silicates of magnesium. In the present research the field has been narrowed by the exclusion of double salts containing other bases such as calcium. Disilicates, trisilicates, and tetrasilicates have been included, but not the hexa or higher silicates. Naturally occurring forms considered to be magnesium silicate in association with opaline silica have also been omitted.

TABLE I

		A ^o omic Ratio	Hydra- tion
1. Synthetic orthosilicate (Ebelman) ...	Mg ₂ SiO ₄	Mg Si 2:1	-
2. <i>Fosterite</i> (orthosilicate) ...	Mg ₂ SiO ₄	2:1	-
3. Natricite (dihydrated orthosilicate)	Mg ₂ SiO ₄ 2H ₂ O	2:1	+
4. <i>Serpentine</i> (tetrahydrodisilicate) ...	Mg ₃ Si ₂ O ₇ 2H ₂ O	3:2	+
5. Gymnite (tetrahydrotriorthosilicate)	Mg ₄ Si ₃ O ₁₂ nH ₂ O	4:3	+
6. <i>Enstatite</i> (Metasilicate) ...	MgSiO ₃	1:1	-
7. Synthetic hydrated metasilicate (B. von Ammon) ¹	3MgSiO ₃ 5H ₂ O	1:1	+
8. Aphrodite ...	Mg ₄ Si ₄ O ₁₂ 3H ₂ O	1:1	+
9. Spadaite ...	Mg ₅ Si ₅ O ₁₇ 4H ₂ O	5:6	+
10. <i>Talc or Steatite</i> (dihydrotetra- silicate)	Mg ₃ Si ₄ O ₁₁ H ₂ O	3:4	+
11. Synthetic hydrated silicate (magnisorbent)	Mg ₂ Si ₃ O ₈ nH ₂ O	2:3	+
12. Synthetic tetrahydrotrisilicate (Döbereiner) ³	Mg ₂ Si ₃ O ₈ 2H ₂ O	2:3	+
13. <i>Meerschaum or Sepiolite</i> (tetrahydrotrisilicate)	Mg ₂ Si ₃ O ₈ 2H ₂ O	2:3	+
14. Synthetic hydrated silicate (Lemberg) ¹²	Mg ₂ Si ₃ O ₈ 2H ₂ O	2:5	+
15. Synthetic hydrated silicate (Heldt) ⁹	Mg ₂ Si ₃ O ₇ 2H ₂ O	1:3	+
16. Synthetic hydrated silicate (Haushofer) ⁸	Mg ₂ Si ₇ O ₁₆ 2H ₂ O	2:7	+

Many of the analytical problems are still confused by the phenomena of solid solution, the adsorption of other metals, and by the close physico-chemical association of other colloidal compounds of magnesium and silicon themselves. Two non-hydrated silicates exist—fosterite and enstatite—and there is common recognition of three hydrated entities—serpentine, meerschaum, and talc. In

addition, there are several other mineral and synthetic hydrated forms of reasonable authenticity. In the accompanying list (Table I), which summarizes the present state of knowledge, the compounds have been arranged in the order of their relative magnesium content. The present investigation deals with the antacid and adsorbent properties of the hydrated varieties.

Antacid Action

The availability of the magnesium and the rate at which it can be removed by mineral acids varies from compound to compound. A representative series was examined in the following way. All the specimens were ground until they would pass a 350 mesh sieve. They were left in contact with an excess of N/10 hydrochloric acid for a week, and shaken several times daily. The residual acid was then estimated.

The minerals were used in their native form without previous heating or desiccation, and in calculating the results allowance has been made for loss of weight on ignition, and all percentages and weights refer to the anhydrous substances. Specimens were obtained from different localities, the only selection exercised being rejection of those contaminated by large proportions of carbonates. Synthetic silicates were prepared to correspond as closely as possible with No. 11 and No. 14 in the list, and a third one, referred to as 16A, with a somewhat lower magnesium content than Haushofer's variety (No. 16).

A comparison of the figures in columns 4 and 5 of Table II indicates that talc is useless as an antacid, and that even in silicates of the serpentine series only a small fraction of the magnesium is available. At the other end of the scale (No. 16A), not only is the proportion of magnesium in the molecule too low to be of much service in this connexion, but even this small amount is not completely available at concentrations of acid which could be encountered in the digestive tract. The proportion of magnesium available and the total neutralizing power increase substantially in the meerschaum range, and reach their optimum in No. 11, a synthetic silicate corresponding in composition to the theoretical formula of idealized sepiolite or meerschaum. Its superiority to meerschaum itself is possibly due to the inevitable contamination of the latter with other compounds.

The speed of reaction was studied in the case of the pure synthetic compounds alone. In each case there was a rapid initial neutralization followed by a slower process.

TABLE II.—*Antacid Action of the Silicates of Magnesium*

Silicate	Magnesium Content (Ignited Weight Basis)		HCl equivalent to Magnesium as Determined by Analysis per gram of mineral (Ig- nited Weight Basis)	HCl Actually Neutralized by 1 gram of Mineral (Ig- nited Weight Basis)	Remarks
	By Analysis	Calculated from Theoretical Formula			
	per cent.	per cent.	c.cm. N/10 HCl	c.cm. N/10 HCl	
Serpentine No. 1 ...	20.6	30	169	45	Analysis of Serpentine No. 1 Mg Si Al Fe Ca CO ₂ Ignition loss 20.7 15.7 1.4 8.3 0.8 0.3 14.3 % No. 2 21.2 18.4 2.3 4.4 0.2 0.1 16.2 %
„ No. 2 ...	21.2		173	50	
Talc No. 1 ...	18.9	20	155	4	Meerschaum No. 1 particularly pure. Total Fe, Al, and Ca = 2.5 %
„ No. 2 (purified)	19.1		156	0	
Meerschaum No. 1 ...	20.7	18.6	169	81	No. 2 contained 6% aluminium, which may have neutralized a proportion of acid
„ No. 2 ...	10.2		83	93	
Synthetic No. 11 ...	18.4	—	150	155	Calcium and aluminium found up to 1.4% sufficient to neutralize a proportion of acid
„ No. 14 ...	14.2	—	116	116	
„ No. 16A ...	6.6	—	54	32	With stronger acids—for example, N/1 HCl—the actual neutralizing power equals the calculated

The extent of initial neutralization varied with the magnesium content of the silicate.

Silicate	Mg (dry basis)	Vol. N/10 HCl removed by 1 gram (dry basis) in 1 hour at 24° C.
	per cent.	c.cm.
11	17.5	122.2
14	14.2	77.4
16A	6.6	26.3

Neutralization proceeded more briskly as the strength of the acid was increased.

Silicate	Vol. of HCl (calculated as N/10) removed during two hours		
	N/20	N/10	N/1
11	139	149	154
14	93.4	105.7	115.9
16A	34.3	—	52

At temperatures and acidities approaching physiological values there is a definite speeding up as the temperature rises, but the gradient is not a steep one. At 24° C. 1 gram removed 117 c.cm. N/10 HCl in one hour. At 37° C. 121 c.cm. were removed, and 125 c.cm. at 56°. The lag which occurs in the process of neutralization is well exemplified in Fig. 1, which records the interaction between N/20 HCl (an acidity approximately equivalent to that of gastric juice) and silicate No. 11. A brisk immediate neutralization involved 45 per cent. of the magnesium content of the silicate, leaving 55 per cent. available for later use; 31 per cent. of the base was utilized during the next hour, a further 18 per cent. during the second and third hours. Of the residual 6 per cent. very little remained

after twenty-four hours. By the end of a week practically all the magnesium had passed into solution. The washed and ignited residue then contained on analysis 0.54 per cent. of undissolved magnesium. This neutralization lag occurs no matter how finely the substance may be ground. Possibly acid adsorption precedes chemical interaction, or possibly a surface film of silica forms on the silicate particles and hinders further penetration by the acid, or the gel state which the system assumes offers a serious obstacle to diffusion.

It would appear, therefore, that the hydrated magnesium silicates possess useful antacid qualities which reach their optimum in the synthetic variety, Type 11. In the presence of hydrochloric acid at strengths of clinical interest an immediate substantial antacid action is followed by a slow, progressive neutralization, which continues over a period of many hours.

Within the clinical range the rapidity of this antacid action is regulated (other factors being equal) by the strength of the reacting acid, the bigger demand of a stronger acid being followed by a more rapid utilization of the magnesium content of the silicate.

Adsorption

Many of the silicates under discussion are adsorbent for various substances in solution. W. Suida¹⁶ found that serpentine could be stained by aniline dyes such as fuchsine and methylene-blue. M. Coplans,³ working with asbestos (a group of complex magnesium silicates some of which are closely allied to serpentine), demonstrated not only the adsorption of methylene-blue but the removal of a variety of other substances from solution. These included diastase, pepsin, peptone, egg albumen, starch, cobra venom, strychnine, adrenaline, and the toxins of *B. diphtheriae* and *B. tetani*. Wyzard,¹⁸ studying haemolysis, found that asbestos removed both complement and ambo-

FIG. 1.—Progressive neutralization of acid by magnesium silicate No. 11. (N/20 HCl at 20° C.)

ceptor effectively. Coplans's⁴ researches extended to meerschäum, which he records as adsorbing the virus from glycerinated calf lymph and becoming activated by the process. Meerschäum adsorbs both basic¹⁷ and acidic dyes, but is nevertheless selective in its affinities—for example, when placed in a mixture of methylene-blue and magenta the mineral becomes blue and the liquid red (H. Michel¹⁸).

In the present research preliminary experiments were carried out with methylene-blue.

Method.—First, 0.2 gram of the powder to be tested was added to 15 c.cm. of an aqueous solution of methylene-blue,

FIG. 2.—Progressive adsorption by magnesium silicate No. 11. (Methylene-blue in distilled water, 20° C.)

and the strength of the residual dye in the supernatant fluid was measured by colorimeter. To obtain steady readings it was necessary to allow the dye and adsorbent to remain in contact, with frequent shaking, for a week. The amount of dye removed by the end of the week was more than double that removed in three hours (Fig. 2). This lag occurred no matter how finely the adsorbent was powdered. The lag also occurred when magnesium silicate was used which had stood under water for a week before the addition of methylene-blue, so that it cannot be explained as due to

FIG. 3.—Relationship between weight of dye adsorbed and the strength of dye in equilibrium with it in the supernatant fluid. (Methylene-blue in distilled water, 20° C.) Magnesium silicate No. 11.

augmented adsorptive potency induced by progressive hydration of the silicate. Using solutions of dye varying from 0.1 per cent. to 0.3 per cent., it was possible to plot the curve (Fig. 3) showing the relation between the amount of dye adsorbed and the concentration of the dye in equilibrium with it in the supernatant fluid. This is by no means a straight line. It begins as an almost vertical line, then bends steadily, and at last becomes almost horizontal.

For the measurement of the adsorptive potencies of different substances two end-points are available: (1) The

clearance value—namely, the amount of dye removed up to the point at which a definite blue tinge is discernible in a given depth of residual fluid. If the standard depth be 2 cm. the blue tint is just discernible at a dilution of one in four million. (2) The maximum weight of dye adsorbed at high concentrations of dye in the supernatant fluid corresponding with the horizontal portion of the curve. With certain substances, such as talc and kaolin, the two values are almost identical, but wide divergence occurs with charcoal and most of the hydrated silicates of magnesium. Using clearance values as the index a number of magnesium silicates were assessed, with the following results (Table III). The kaolin figure is given for

TABLE III.—Relative Adsorptive Power of Various Magnesium Silicates

Silicate	Clearance Adsorption Value for Methylene-blue in Distilled Water at 20° C.
	Mg. of dye adsorbed per gram (dry basis)
Serpentine No. 1	12
„ No. 2	9
„ No. 3	3
„ No. 4	6
„ No. 5	3
Talc No. 1	3
„ No. 2	3
„ No. 3 (American)	3
Meerschäum No. 1	38
„ No. 2	33
„ No. 3	32
Synthetic magnesium silicate No. 11 ...	208
„ „ „ No. 14 ...	99
„ „ „ No. 16A ...	53
Asbestos	7
Kaolin (purified "colloidal")	14

purposes of comparison, although kaolin is not a silicate of magnesium. The adsorptive power rose sharply to a maximum in the meerschäum range, the highest value of all being given by the synthetic variety of the same constitutional formula No. 11. All subsequent observations refer to this particular compound, except where the contrary is stated.

Temperature affected adsorption considerably, the maximum amount of dye adsorbable being 42 per cent. greater at 37° than at 20°. The addition of a little alkali up to 0.3 per cent. sodium bicarbonate did not make any appreciable difference, but the addition of a little acid modified the picture substantially. By dissolving the methylene-blue in N/20 hydrochloric acid instead of in distilled water a 40 per cent. improvement was obtained in the maximum adsorptive figure. In the case of synthetic compounds of low magnesium content the phenomenon was reversed. For example, with synthetic silicate 16A, the use of an acid solution of dye reduced the total weight of adsorbed dye by 34 per cent. The interaction is a complex one, the acid being quickly removed by the silicate, after which the system consists not only of water, methylene-blue, and magnesium silicate, but contains, in addition, colloidal silica in suspension and magnesium chloride in solution.

Quantitative data alone do not give any true indication of the relative adsorptive powers of different substances. It is necessary to know their qualitative range. This problem was investigated in relation to dyes, alkaloids, toxins, ferments, and various other substances.

Qualitative Range in Relation to Dyes

In quasi-scientific medical literature the terms "colloid," and "crystalloid," "acidic" and "basic" are applied to dyes with a facility which implies that they represent easily defined and sharply differentiated qualities. Such assumptions are unwarranted. If the ability to pass through a standard dialysing parchment membrane be taken as a test of a crystalloid, at least three groupings are needed—into crystalloid, semicolloids, and colloids.

A representative series of dyes of exceptional purity was obtained through the courtesy of Professor C. S. Gibson. Solutions of 0.1 per cent. of each in distilled water were placed in parchment dialysing tubes suspended in distilled water, and observed after half an hour and twenty-four hours respectively. Rapid tinting of the water outside indicated a crystalloid dye; absence of tinting a colloid. Where diffusion was not perceptible at the end of half an hour, but obvious at twenty-four hours, the dye was given an intermediate classification of "semicolloid." No attempt was made to discriminate between pure crystalloids and those which were mostly crystalloid but also contained a small colloid element.

Basicity was determined from the constitutional formula, each acidic and basic group being given equal significance. With acidic dyes it is usual to satisfy the SO_3 side chain with sodium, and employ the sodium salt instead of the primitive substance. This applies to all dyes examined in the present research. After satisfaction of the SO_3 groups, the balance of the residual groups may be basic or acidic. For classification, therefore, the dyes have been divided into basic dyes and the sodium salts of acidic dyes, the latter group being subdivided into those with residual acidic and those with residual basic preponderance. The dyes were further grouped in accordance with their general chemical nature.

In measuring the adsorbent power of the silicate for these various dyes, 0.2 gram of the powder was added to 12 c.cm. of a 0.1 per cent. solution of the dye in distilled water, and comparison was made between the colour of the original solution, that of the supernatant fluid, and that of the magnesium silicate. Different adsorptive affinities were exhibited for different dyes, and the potency of the silicate in respect of each was recorded numerically on the following basis.

Adsorptive Potency

Supernatant fluid unchanged in colour	...	...	zero.
Slight loss of colour (just perceptible)	...	...	1
Substantial loss of colour but still well tinted	...	...	2
Slight tinge of colour remains (just perceptible)	...	...	3
Colourless (all dye removed)	...	...	4

The various data are incorporated in Table IV.

It is clear that the magnesium silicate in question adsorbs a great variety of dyes of widely differing chemical nature. It shows a strong preference for basic dyes. In fact, all basic dyes examined were adsorbed readily and flocculated the silicate. The acidic dyes, however, were not rejected completely. In certain cases they were adsorbed to a substantial extent—for example, acid green, Congo red, naphthol yellow, quinoline yellow covering four different chemical groups; crystalloid, colloid, and "mostly colloid" substances; and examples of acidic dyes with residual acid preponderance as well as others with residual basic preponderance.

The preference of magnesium silicate for basic dyes is seen significantly in the case of dyes chemically akin but of opposite reaction; for example, in the triphenylmethane series each of the five basic dyes was adsorbed freely, but only one of the four acidic members of the same group. The acidic and basic derivatives of fuchsin

furnish a particularly convincing example. This decided physical affinity for basic dyes is in remarkable contrast with the strong chemical affinity of the silicates for acids as discussed in the section on antacid properties.

TABLE IV.—Aniline Dyes
(Adsorption by Magnesium Silicate No. 11)

Dye	Chemical Group	General Group			Physical State			Adsorptive Potency
		Basic	Acidic	Residual Preponderance of Sodium Salt	Crystalloid	Colloid	Semicolloid	
Methylene-blue ...	Thiazine	B			+			4
Safranine ...	Azine	B			+			3
Indine blue ...	Oxamine	B			+			4
Auramine O ...	Diphenylmethane	B			+			4
Brilliant green ...		B			+			4
Malachite green ...		B			+			4
Victoria blue ...		B				+		4
Methyl violet ...		B			+			3
Basic fuchsin ...	Triphenylmethane	B	A	B	+		+	3
Acid fuchsin (magenta) ...								
Acid green G ...			A	B			+	2
Disulphine blue ...			A	A	+			1
Fast acid violet 103 ...			A	B	+			4
Chrysoidin ...	Azo	B	A	A	+			3
Aminoazo-benzene monosulphonate ...								
Carmoisin W. S. ...	Monazo		A	A	+			1
Chlorazol sky blue FF ...								
Black G. W. ...	Primary diazo		A	A		+		1
Coomassie navy blue 2 R.N. ...								
Congo red ...	Tetrazo		A	B		+		2
Naphthol yellow ...	Nitro		A	A	+			2
Eosine ...	Phthalein	B	A		+			1
Mercurochrome ...								
Quinoline yellow ...	Quinoline		A	A	+			2
Indigo carmine ...	Indigotin		A	A	+			1

Alkaloids

Many alkaloids are removed from solution by magnesium silicate No. 11. Distilled water left in contact with the silicate acquires a pH of about 8.5—that is, slightly on the alkaline side of the neutral point. Brucine was used in determining whether the removal of alkaloids was due to simple precipitation of the liberated base or to adsorption. The base brucine is soluble 1 in 320 parts of cold water. A solution of 0.1 per cent. of the hydrochloride was used containing less than 1 part of the base in 1,000 parts of water. The addition of sodium carbonate to such a solution did not cause precipitation of the base, even after the solution had been heated and recooled.

It was also noted that distilled water left in contact with the silicate for a week, and then cleared, dissolved brucine hydrochloride readily and without subsequent precipitation. The silicate removed brucine from this 0.1 per cent. solution of the hydrochloride to the extent of 32 mg. per gram. The supernatant fluid no longer reacted to Wagner's test for brucine, sensitive to 1 in 500,000, or to Mayer's test, sensitive to 7 in 30,000. The

alkaloid was easily recovered by decomposition of the silicate with hydrochloric acid. Even with less soluble bases the issue was quite clear between adsorption and precipitation of free base. For example, solutions of strychnine hydrochloride were easily freed from alkaloid by the silicate to the extent of securing negative Mayer and Wagner reactions in the supernatant fluid. If, however, the free base was simply precipitated by the addition of caustic soda, the filtrate still contained sufficient alkaloid to give positive reactions with these reagents.

Table V shows the extent to which the various alkaloids were removed from 0.1 per cent. aqueous solutions. Various weighed amounts of the silicate were added to 10 c.cm. of a 0.1 per cent. solution of the

TABLE V.—*Alkaloids*

[Adsorption by Magnesium Silicate No. 11 from Aqueous Solutions at 20° C. (Clearance Values)]

Alkaloid	Weight of Alkaloidal Salt removed by 1 gram Ignited Weight of Silicate
Muscarine	mg. 53
Brucine hydrochloride	32
Solanine	30
Papaverine hydrochloride	28
Strychnine hydrochloride	27
Apomorphine hydrochloride	25
Atropine sulphate	26
Colchicine salicylate	15
Emetine hydrochloride	14
Nicotine	14
Codeine phosphate	13
Dionine hydrochloride	13
Cocaine hydrochloride	12
Morphine hydrochloride	11
Pilocarpine nitrate	8
Veratrine	6

respective alkaloidal salts until an amount was found which freed the solution from the alkaloid in one hour at room temperature. The figures, therefore, are clearance figures. By analogy with methylene-blue, it is to be expected that when fully saturated the silicate would hold far more than these amounts. In the cases of solanine and muscarine the chemical tests were confirmed biologically, an amount of fluid originally containing 10 lethal doses (frog) being entirely innocuous to that animal after treatment with the silicate. A selective affinity for certain alkaloids is discernible. As in the case of the dyes, this is not governed by any obvious chemical kinship between the alkaloids concerned.

Putrefactive Amines.—Histamine was removed from an aqueous solution of the acid phosphate to the extent of a little over 9 mg. per gram of silicate, and tyramine to a slightly less extent.

Colloids

The silicate interacted with many colloids, but did not discriminate sharply between electro-negative and electro-positive varieties. It did not seem feasible to differentiate mutual flocculation from true adsorption. Colloidal ferric hydroxide was taken as an example of positively charged colloid. The solution was rapidly decolorized by the silicate. After acidification the supernatant fluid no longer gave the Prussian blue reaction, but the silicate

responded positively to the same test. As observed under the microscope, all the particles took on the blue colour evenly. Colloidal arsenious oxide was selected as a negatively charged colloid; its colour was quickly removed by the silicate. Kaolin and hydrated aluminium hydroxide were tested in parallel for comparison. Each decolorized the iron solution, but left the arsenic unaffected.

The adsorption of colloidal dyes has already been mentioned. Many other colloids—for example, starch, whey protein, acid albumen and alkali albumen prepared from egg-white, were also removed from solution. The silicate afterwards gave positive reactions and the supernatant fluid negative ones when tested appropriately with iodine or the biuret reagent. The proteoses described by Oriel in the urine of allergic subjects were also adsorbed. The study of the digestive ferments in relation to the silicates was complicated by considerations of hydrion concentration, and will be dealt with in a later paper.

Toxins

Two very toxic colloids can, however, be discussed here—namely, tetanus toxin, and the toxin of *Amanita phalloides*, which is responsible for most of the deaths following the ingestion of poisonous fungi.

Tetanus Toxin.—An aqueous solution of dry toxin was made to the approximate strength of 1 M.L.D. (20 gram mouse) per 0.1 c.cm., and injected into a series of mice in graduated doses with fatal results (see Table VI). Then 10 c.cm. of the solution were treated with 0.5 gram

TABLE VI.—*Tetanus Toxin*
(Detoxication of Solutions by Magnesium Silicate No. 11)

Mouse	Weight	Injection into Right Flank	Result		
			3rd day	5th day	7th day
A	Grams 25	Toxin solution 0.1 c.cm.	Severe spasm right hind leg	Very ill	Recovering: spasm still noticeable
B	29	0.2 c.cm.	..	Dead	—
C	34	0.4 c.cm.	..	Dead	—
D	27	Toxin solution after magnesium silicate No. 11 0.1 c.cm.	Normal	Normal	Normal
E	26	0.2 c.cm.	..	..	..
F	30	0.4 c.cm.	..	..	..

of magnesium silicate No. 11 and filtered. The filtrate was injected into a second series of mice without causing any disturbance, even when an amount originally containing three times the minimum lethal dose was administered. It follows that 1 gram of the silicate removed at least 140 M.L.D. (mouse units) of tetanus toxin.

***Amanita phalloides* Toxin.**¹⁵—A sterile concentrate of the toxin, very kindly supplied by Professor R. Dujarric de la Rivière, was tested for toxicity by intraperitoneal injection into mice. Two portions were treated with the silicate in the proportion of 1 and 3 grams respectively of the silicate to 5 c.cm. of the toxin concentrate. After filtration they were injected intraperitoneally with uniformly fatal results (see Table VII).

The magnesium silicate is clearly selective in its affinities. It removes tetanus toxin freely from solution, but is without influence over the toxin of *Amanita phalloides*.

One final example of a toxic substance of clinical importance is furnished by a crystalloid mussel poison.¹⁴ A specimen of this most deadly of all known poisons was obtained through the kindness of Dr. Hermann Sommer

TABLE VII.—*Amanita Phalloides* Toxin
(Dujarric de la Rivière)

Mouse	Weight	Intraperitoneal Injection	Result
A	20	Original solution 1 c.cm.	Survived about 2 hours, and then died
B	23	1 c.cm.	Died in 50 minutes
C	21	2 c.cm.	" 25 "
D	25	3 c.cm.	" 15 "
E	29	4 c.cm.	" 25 "
F	24	Toxin solution after treatment with magnesium silicate No. 11 1 gram per 5 c.cm. (Free from soluble magnesium salts) 2.5 c.cm.	Died in 42 minutes
G	27	Toxin solution after magnesium silicate No. 11 3 grams per 5 c.cm. 0.8 c.cm.	Survived
H	23	1 c.cm.	Died in 55 minutes

of California University. A standard solution was made in water, and the minimum lethal dose was measured by intraperitoneal injection into 20-gram mice. Doses ranging from 0.01 to 1 c.cm. were used with rapidly fatal results to each of twenty-five mice, which received doses of 0.04 c.cm. or more. The solution was treated with varying weights of the silicate for one hour, filtered, and injected in amounts corresponding to 5, 12.5, and 25 lethal doses respectively. These mice did not suffer any ill effects until the amount of silicate used to clear 10 c.cm. of the mussel poison solution was reduced to less than 1 gram.

Alkalis destroy the poison, but at pH 8.8 Hellmut Müller was unable to detect any loss of potency in twenty-four hours. The alkalinity of distilled water in contact with silicate No. 11 only corresponds to pH 8.5, and the experiment was completed within three hours, so that the disappearance of the poison cannot be attributed to change in reaction. The details are given in Table VIII,

TABLE VIII.—*Mussel Poison*
(Detoxication of Solution by Magnesium Silicate No. 11)

Weight of Magnesium Silicate No. 11 (Ignited Basis) used to clear 10 c.cm. Mussel-Poison Solution (M.L.D. = 0.04 c.cm.)	Mouse	Intra-peritoneal Injection	Original Toxic Content of Liquid Injected	Result
Grams 5.8	1	0.2	5	No effect
	2	0.5	12.5	"
	3	1.0	25	"
3.6	4	0.2	5	"
	5	0.5	12.5	"
	6	1.0	25	"
2.2	7	1.0	25	"
0.7	8	0.2	5	"
	9	1.0	25	Died in 30 minutes

NOTE:—Mice injected with 0.04 c.cm. of the original solution died in 5 to 20 minutes; with 0.05 c.cm. they all died in less than 5 minutes.

from which it can be calculated that 1 gram of the silicate adsorbs 343 M.L.D. of mussel poison, or that less than 1/20 grain of the silicate is required to neutralize one fatal mouse dose of mussel poison.

It is interesting to note that the residue left after the removal of all the magnesium from the silicate by interaction with an excess of N/10 HCl still removes mussel poison to the extent of 96 M.L.D. per gram of residue (ignited basis).

Summary

The conclusions reached in this paper may be summarized as follows.

ACID NEUTRALIZATION

1. Certain hydrated silicates of magnesium possess strong antacid properties.
2. The power of neutralizing weak acids attains its maximum in the trisilicates.
3. The initial phases of the reaction are quick, but several hours are required for the completion.
4. Within the clinical range of acidities neutralization proceeds more quickly at high acidities than at low ones.

ADSORPTION

1. Synthetic hydrated trisilicate of magnesium exhibits powerful adsorbent qualities. At the saturation point for methylene-blue it is seventeen times as active as colloidal kaolin (room temperature), and at body temperature the disparity is even greater.
2. Its immediate adsorptive activity is considerable, but several days are required for saturation.
3. The range of its adsorptive affinities covers a great variety of substances, including acid and basic dyes, alkaloids, bacterial toxins, putrefactive amines, and food poisons.
4. Adsorption is selective, and a decided preferential affinity was noted for basic dyes—both crystalloid and colloid. It did not adsorb the poison of *Amanita phalloides* ("mushroom" poison), but readily removed muscarine ("mushroom" poison) and Müller's mussel poison from aqueous solution.

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G. L. Moench (*Amer. Journ. Surg.*, November, 1935, p. 310) considers that dilauidid (dihydromorphinone hydrochloride) in proper dosage is an adequate substitute for morphine in gynaecological operations. He finds it about three times as strong as morphine in its narcotizing effect, and perhaps five times as strong in analgesic action. With some types of patient this lack of soporific effect may be detrimental. It inhibits intestinal peristalsis much less than does morphine, and in perineal cases Moench found that the patients were able to empty the bladder voluntarily sooner after dilauidid administration. Except in difficult operations all the women who had had dilauidid had less vomiting and distension, complained less of "gas," and had a softer and flatter abdomen than was the case with women in a control series who had been given morphine. The author satisfied himself that minimum intra-abdominal manipulation and the pre-operative administration of dilauidid will best avoid abdominal distension, but in pelvic inflammation this drug seemed to have no advantage over morphine. Dilauidid does not produce euphoria as does morphine, and the danger of addiction is not so great.