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## AROMATIC SULPHURIC ACID.

BY C. M. SMITH AND E. H. HAMILTON.\*

The U. S. Pharmacopœia has for many years listed among its preparations "Aromatic sulphuric acid." For making it the tenth edition directs the gradual and cautious addition of 109 cc. of ordinary concentrated sulphuric acid to 700 cc. of alcohol, with subsequent cooling and addition of 50 cc. of tincture of ginger, 1 cc. of oil of cinnamon, and enough alcohol to bring the total volume to one liter. It is stated that the finished product contains free sulphuric acid and ethyl sulphuric acid together equivalent to not less than 19% and not more than 21% of sulphuric acid, H<sub>2</sub>SO<sub>4</sub>. No statement of the relative proportion of free and ethyl sulphuric acid to be expected is given in the Pharmacopœia and the method of assay described leads only to an estimation of the "total sulphuric acid."

The presence of free sulphuric acid to the extent of 10% or more would bring this product within the scope of the Federal Caustic Poison Act. Therefore, in the enforcement of this act, it was necessary to determine whether the preparation may contain as much as 10% of the free acid. A search of the literature revealed that considerable work had been done on this problem but the results of various investigators were not in agreement and none of them covered exactly the points in which we were interested.

Attfield<sup>1</sup> in 1869 examined certain samples of aromatic sulphuric acid at intervals during a period of two weeks; and says he found no ethyl sulphuric acid at any time, all the acid being free and amounting to about 19%. As will be shown later, this statement is contrary to the findings of other investigators, including the

\* Food, Drug and Insecticide Administration, U. S. Department of Agriculture.

<sup>1</sup> Prof. Attfield, "Note on Aromatic Sulphuric Acid," *Pharm. J.*, 10 (1869), 471.

present writers. Clarke<sup>1</sup> in 1887 examined five samples of aromatic sulphuric acid, reporting from 13.9% to 19.4% free sulphuric acid but these figures were based on the mistaken assumption that direct titration of the product will give the content of free acid, and his results are undoubtedly high. Brown<sup>2</sup> in 1912 discovered that the results obtained according to the assay described in U. S. P. VIII were incorrect and proposed new methods of analysis which appeared to give satisfactory results for both free and combined acid. In 9 commercial samples he found from 6.12% to 13.45% free sulphuric acid and also noted that the proportion of free acid decreased with lapse of time. Brown's methods were criticized by Penniman *et al.*,<sup>3</sup> who also showed that the change in the assay adopted in the ninth revision of the U. S. P. left that method still far from serviceable. They proposed the so-called Maryland method, according to which various commercial samples were found to contain about 27<sup>1</sup>/<sub>2</sub>% total acid and about 11% free acid. In 1920, Kelly and Krantz<sup>4</sup> first proposed the method for total acid which was later adopted in the tenth or present edition of the U. S. P. They reported that they were unable to get anything but very low results by the Maryland method, and made no effort to determine the free acid.

Between 1920 and 1928 Dunicliff and his coworkers,<sup>5, 6, 7, 8, 9, 10</sup> published a series of articles dealing with equilibrium between ethyl alcohol and sulphuric acid or various acid sulphates. They did not consider aromatic sulphuric acid itself, but some of their results have direct bearing on the subject since the ginger and cinnamon probably exercise very little effect on the chemical relationships. In one of their papers they describe their methods for complete analysis including a determination of uncombined alcohol. They adopted the U. S. P. X method for total acid, and arrived at a value for actual free acid by calculation from this and the apparent free acid shown by a direct titration of the product. Their results show that the proportion of free sulphuric acid in a mixture of alcohol and sulphuric acid depends on the relative amounts used, on temperature, and on the age of the mixture. Nearly all of the experiments of Dunicliff and his fellow workers

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<sup>1</sup> E. W. Clarke, "Acid Strength of the Aromatic Sulphuric Acid in Use," *Pharm. Era* (March 1887), 69.

<sup>2</sup> L. A. Brown, "An Improved Method of Assay for Aromatic Sulphuric Acid," *Ind. & Eng. Chem.*, 4 (1912), 512.

<sup>3</sup> W. B. D. Penniman, *et al.*, "The Hydrolysis of Ethyl Sulphuric Acid and the Assay of Aromatic Sulphuric Acid," *Ind. & Eng. Chem.*, 8 (1916), 904.

<sup>4</sup> E. F. Kelly and J. C. Krantz, "Assay of Aromatic Sulphuric Acid," *JOUR. A. PH. A.*, 9 (1920), 775.

<sup>5</sup> Butler and Dunicliff, "The Action of Alcohol on the Sulphates of Sodium," *J. Chem. Soc.*, 117 (1920), 649-667.

<sup>6</sup> Butler and Dunicliff, "Estimation of Alcohol in Mixtures of Alcohol, Sulphuric Acid and Water," *J. Soc. Chem. Ind.*, 39 (1920), 1461.

<sup>7</sup> Dunicliff and Butler, "Ethyl Hydrogen Sulphate," *J. Chem. Soc.*, T119 (1921), 1384-1392.

<sup>8</sup> H. B. Dunicliff, "The Action of Alcohol on the Sulphates of Ammonium," *Ibid.*, 123 (1923), 476-484.

<sup>9</sup> Dunicliff, Sikka and Hoon, "The System: Sodium Sulphate, Sulphuric Acid-Ethyl Alcohol," *J. Phys. Chem.*, 30 (1926), 1211.

<sup>10</sup> Dunicliff, Aggarwal and Hoon, "The System: Ammonium Sulphate-Sulphuric Acid-Ethyl Alcohol," *Ibid.*, 32 (1928), 1697.

were made with 100% sulphuric acid and alcohol, whereas aromatic sulphuric acid is made from reagents, each of which contains approximately 5% water.

Since previous determinations of the free sulphuric acid in aromatic sulphuric acid were unsatisfactory and since the work of Dunicliff *et al.* was not directly applicable to our problem the following experiments were carried out.

In the first series of experiments three mixtures were prepared in the laboratory from concentrated sulphuric acid and 95% ethyl alcohol and were designated A, B and C. "A" was mixed exactly as described in the U. S. P. X under "Aromatic Sulphuric Acid," except that the tincture of ginger and oil of cinnamon were replaced by additional alcohol. "B" and "C" were made from the same quantities of reagents, but in each case the whole quantity of the acid was initially mixed with only a portion of the alcohol, the remainder of the alcohol being added later. After the mixtures had been prepared, they were analyzed, and then each was divided into two portions. One portion of each ( $A_1$ ,  $B_1$ ,  $C_1$ ) was kept on the work-table at room temperature (which averaged about 25° C.), while the other ( $A_2$ ,  $B_2$ ,  $C_2$ ) was set on the back of a steam-bath where the temperature remained close to 37° C. All the solutions were analyzed at the end of 3-, 10- and 23-day intervals. Not only the free acid but the total acid as well was estimated each time in order to see whether the latter appeared to decrease as Brown supposed, a phenomenon which he ascribed to the production of very stable diethyl sulphate. The methods of analysis used were as follows:

1. The U. S. P. X method for total acid, consisting of evaporation of a portion of the sample to dryness with 30 cc. of normal sodium hydroxide solution and back titration of the excess alkali was supplemented by a direct titration to the methyl orange end-point of another portion of the sample. This gives the sum of the free sulphuric and ethyl sulphuric acids, and from it and the total acid figure the free acid may be calculated.

2. Brown's method, according to which the portion of sample upon which the direct titration described under (1) was made is heated to boiling, treated with 2 cc. of concentrated hydrochloric acid, and the sulphate ion precipitated with barium chloride solution. The precipitate corresponds directly to the free sulphuric acid, and from it and the titration figures the total acid is calculated.

3. A cold precipitation method, which was the same as (2) except that the barium chloride solution was added to an aliquot of the sample at room temperature without previous titration, and no hydrochloric acid was added to augment the natural acidity of the preparation. It was hoped that any tendency toward high results for free acid due to hydrolysis of ethyl sulphuric acid in hot solutions (Brown's method) might be avoided.

Methods (1) and (3) were applied in all cases, (2) in only some of them. The total data obtained are too voluminous to report here in full, so that a few generalizations will first be made.

The results obtained for total acid are shown in Table I. No apparent decrease in total acid with lapse of time as reported by Brown and interpreted by him to indicate the formation of diethyl sulphate was evident. Therefore, all values obtained on both subdivisions of each preparation are reported as replicate determinations.

TABLE I.—“TOTAL SULPHURIC ACID” IN MIXTURES OF SULPHURIC ACID AND ALCOHOL.

Sample. Method.	A.			B.			C.		
	1.	2.	3.	1.	2.	3.	1.	2.	3.
Range, %	19.46 to 20.03	19.28 to 19.73	19.60 to 20.40	19.60 to 20.03	19.57 to 19.73	19.79 to 20.22	19.30 to 19.88	19.49 to 19.69	19.65 to 20.19
Average, %	19.72	19.54	19.97	19.78	19.64	20.01	19.69	19.60	19.93

All the methods show that A, B and C are practically identical, as they should be since they were made from the same quantity of reagents. Method (2) gave uniformly lower results and method (3) uniformly higher ones than the U. S. P. method, but the differences are barely significant. Method (2) (Brown's) gave the most reproducible results, the standard deviation for it being about one-half what it was for the other two methods. The Maryland method was not tried.

Considering that there was so little difference in the methods used we selected (1) as the basis for further work, mainly because it represented, practically the average of all three methods and is sanctioned by the U. S. P.

In Table II are given the results for free sulphuric acid, obtained by method (1). Because of the rather poor reproducibility of the method, the results have been rounded off to one decimal place. All samples were also analyzed by method (3) and some by method (2). The results by (2) averaged 0.15% above, and those by (3) 0.25% below the reported figures.

TABLE II.—FREE SULPHURIC ACID IN MIXTURES OF SULPHURIC ACID AND ALCOHOL.

	A <sub>1</sub> .	A <sub>2</sub> .	B <sub>1</sub> .	B <sub>2</sub> .	C <sub>1</sub> .	C <sub>2</sub> .
Specific gravity		0.945		0.945		0.945
Total H <sub>2</sub> SO <sub>4</sub>		19.7%		19.8%		19.7%
Free H <sub>2</sub> SO <sub>4</sub>		16.6%		11.8%		9.2%
<i>On day prepared</i>						
After 3 days	14.1%	9.9%	10.1%	7.6%	8.6%	7.0%
After 10 days	10.7%	5.3%	8.3%	5.2%	7.4%	5.1%
After 23 days	7.8%	5.3%	6.6%	5.2%	6.2%	5.2%

The results in Table II show that even immediately after preparation, the free acid is less than the total, indicating the formation of ethyl sulphuric acid during mixing. The quantity present is dependent upon the proportion of alcohol and acid used in the initial mixing, but in the opposite sense to what might be expected from Dunnington's experiments. This fact is probably explained by the different temperatures which the different mixtures attain. The mixtures which contained the lesser proportions of alcohol attained the higher temperatures during mixing and a high temperature evidently accelerates the formation of ethyl sulphuric acid.

Next it is seen that the free acid does not remain constant, but decreases in all cases and at a faster rate in those preparations kept at the higher temperature. The warmer samples reached a fixed equilibrium value sometime between 3 and

10 days, and the cooler samples were evidently tending toward about the same values. That all samples should approach approximately the same equilibrium value is consistent with the fact that they all contained the same proportion of reagents.

In all the samples except one ( $A_1$ ) the free acid had decreased to 10% or less in 3 days. The one exception, which was the sample prepared according to the directions of the U. S. P. X and kept at ordinary room temperature, passed the 10% mark somewhere between 2 and 3 weeks.

The equilibrium value for free sulphuric acid indicated by Dunnicliff's work for a product containing 20% total acid is approximately 3%. The higher value, about 5.2%, indicated by our work, is no doubt due to the fact that our mixtures contained about 5% water, which was not present in Dunnicliff's preparations.

The following set of curves present in graphical form the data of Table II. The trend of all the curves toward a common value is very evident.

In order to confirm these results as applying to aromatic sulphuric acid itself, 8 samples of this product were purchased in the open market, labeled D to K inclusive, and analyzed. Three of these, I, J and K, were the products of large manufacturing firms, and their ages were consequently unknown. The other five were obtained from retail druggists, by whom they had been prepared. Of these five, three, D, E and F, were obtained from Dr. S. L. Hilton, treasurer of the Board of the United States Pharmacopœial Convention, who kindly furnished us with the dates on which two were prepared and personally prepared the third on the day of purchase. Of the remaining two retail products, one, H, was at least a year old, the other, G, freshly prepared on the day of purchase.

Method of analysis (1) was used for reasons already stated. The brown color of the tincture of ginger rendered the methyl orange end-point in the two titrations somewhat less definite than in the previous set of experiments, so that the results are perhaps not quite so accurate as before. A control experiment with tincture of ginger and oil of cinnamon alone showed that they were so nearly neutral that no correction had to be made for them. The results obtained are given in Table III.

It may be seen that the specific gravities of the samples are nearly all equal to or higher than the value of "about 0.94" quoted by the U. S. P. X. Farther, in

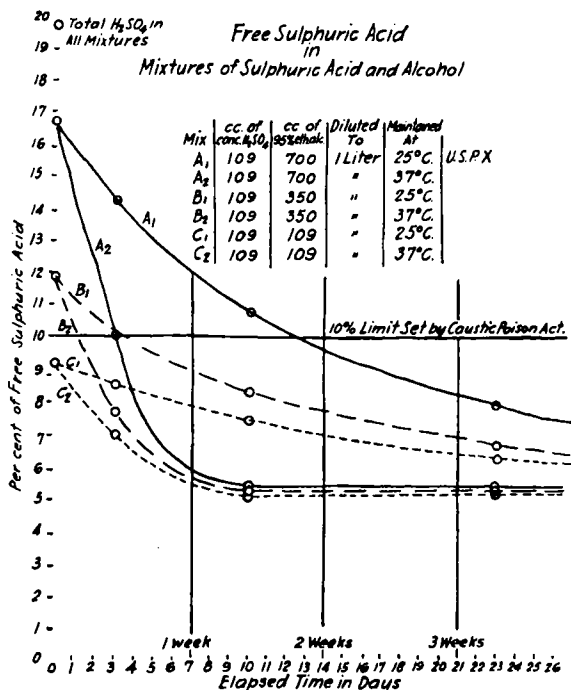


TABLE III.—ANALYSES OF COMMERCIAL AROMATIC SULPHURIC ACIDS.

Date made	D. 7/3/19	E. 9/21/25	F. 5/27/29	G. 5/27/29	H. Unknown but old	I. Unknown	J. Unknown	K. Unknown
Sp. gr.	0.940	0.940	0.942	0.934	0.959	0.951	0.954	0.947
Total H <sub>2</sub> SO <sub>4</sub>	19.8%	19.7%	20.1%	18.5%	20.3%	20.5%	21.6%	20.0%
Free Sulphuric acid	5/28/29	5.2%	5.3%	15.9%	16.5%	7.6%	6.2%	5.3%
	6/4/29			10.1%	11.3%	7.7%	6.3%	
	6/18/29			6.5%	7.5%			

six cases the total acid is within the U. S. P. limits, and in the other two not far removed from them. Several interesting points are evident in connection with the figures for free sulphuric acid. Three of the old samples contained practically the same quantity, 5.2% as our previous experiments had shown to be the equilibrium value. The other old samples showed more than this, and yet a reëxamination of them after a week showed no further change, showing that they too were at equilibrium. A possible explanation is suggested by the fact that these samples had high specific gravity without a correspondingly high content of total sulphuric acid, indicating the presence of more water than usual; a condition causing higher free acid. Samples H and I illustrate these conditions.

The two freshly prepared materials "F" and "G" show a decrease in free sulphuric acid with time, just as was observed with the samples made in the laboratory. The rate of decrease lies between that shown by "A<sub>1</sub>" and "A<sub>2</sub>," probably because "F" and "G," having been made in warmer weather, were maintained at a temperature somewhere between that prevailing with "A<sub>1</sub>" and "A<sub>2</sub>." A content of 10% free sulphuric acid was reached somewhere between one and two weeks.

As the result of all these experiments it may reasonably be concluded that (1) The U. S. P. X method for the assay of aromatic sulphuric acid gives a sufficiently correct value for the "total sulphuric acid" present. From this value and the results of a direct titration of the preparation to the methyl orange end-point the proportion of free sulphuric acid may be calculated.

(2) The proportion of free acid initially present is about 16% H<sub>2</sub>SO<sub>4</sub>, but is subject to considerable variation according to how much the product is permitted to heat during preparation. It decreases with time, the rate of decrease being greater the higher the temperature, and the product, if kept at 25° C., approached an equilibrium limit of about 5¼% H<sub>2</sub>SO<sub>4</sub>. Thus while the preparation contains more than 10% free sulphuric acid initially, it will contain less than 10% after standing. Usually two weeks are sufficient.

#### THERMOMETER MANUFACTURERS.

Congressman Bloom, who sponsored a proposal to have all clinical thermometers tested and certified by the United States Bureau of Standards, has announced that this would entail too much work and difficulty and that the problem of securing only high-grade, accurate instruments can best be solved by permitting their manufacture only by firms licensed to uphold a high scientific standard.

#### CHAIN STORE INQUIRY.

State of Minnesota:  
St. Paul, February 1st.

An investigation of nine groups of chain stores in the City of Minneapolis by the attorney general is sought in a complaint filed by the owner of a grocery store in that city, who alleges that the chain stores are being operated in violation of the Sherman Anti-Trust Act and of the Minnesota statutes.