

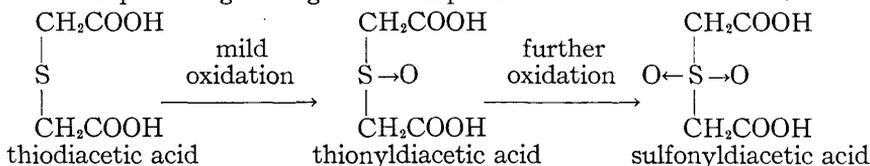
# THIONYLDIACETIC ACID<sup>1</sup>

HAROLD G. ODDY AND VANCE H. DODSON,<sup>2</sup>

Department of Chemistry, University of Toledo,  
Toledo, Ohio

## INTRODUCTION

Thionylodiacetic (thionylglycolic) acid can be classified as a sulfoxide, being derived from thiodiacetic acid by mild oxidation of the sulfur atom present. Stronger oxidation or continued oxidation produces the more stable sulfone. The relationship existing among these compounds can be shown as follows:



In 1909, Gazdar and Smiles (1) prepared thionylodiacetic acid by dissolving thiodiacetic acid in excess hydrogen peroxide (concentration not stated) and allowing the solution to stand at room temperature for forty-eight hours, followed by evaporation of excess water. The sirupy residue became solid, they state, on being kept under diminished pressure over sulfuric acid. Their product, which was "evidently pure," melted at 79–80° C. An analysis for carbon and hydrogen agreed reasonably well with the theoretical value but neither a sulfur analysis nor an equivalent weight determination were reported. In 1923, Jonsson (2) prepared this compound in a similar manner, though he dissolved the thio acid in acetone prior to addition of 30% aqueous hydrogen peroxide in excess. After an evaporation in vacuo, the crystalline mass was washed free of impurities with ethyl ether. His product melted at 119° C. Finally, Larsson (3) reported, in 1940, that he obtained thionylodiacetic acid by the oxidation of thiodiacetic acid using bromide water. His yield was low and the product melted at 109° C. It is evident from these conflicting records that the identity of thionylodiacetic acid cannot be considered as definitely established. This investigation was undertaken to evaluate various methods that had been reported for its preparation and to study its physical and chemical properties. It appears likely that the lack of agreement in the literature regarding this compound resulted, at least in part, from its unstable nature, and therefore all possible precautions were taken to insure a minimum amount of decomposition.

## METHODS OF PREPARATION

Literature references relative to the preparation of sulfoxides indicate that they are most conveniently obtained by mild oxidation of the corresponding sulfides. In general, 30% hydrogen peroxide has given excellent results (4), although other oxidizing agents including nitric acid, chromic acid, potassium permanganate, the halogens and perbenzoic acid have been successfully used. In this paper, investigation has been limited to the oxidizing effect of hydrogen peroxide, nitric acid and potassium permanganate upon thiodiacetic acid.

The studies of Gazdar and Smiles and of Jonsson were repeated first, since in both instances the favored reagent, hydrogen peroxide, had been used. A 25-gram sample of freshly prepared thiodiacetic acid was dissolved in 30 ml. of 30% hydrogen peroxide and the solution allowed to stand for 48 hours at room temperature.

<sup>1</sup>Presented at the meeting of the Ohio Academy of Science, Toledo, Ohio, on May 7, 1948.

<sup>2</sup>Presented as a thesis in partial fulfillment of the requirements for the Master of Science degree.

Evaporation in vacuo over sulfuric acid yielded 3 grams of solid product, slightly yellow in color and melting at 100–105° C. Upon washing the product with small amounts of ice-cold acetone, it became pure white and melted sharply at 119° C. (corr.) with decomposition. A quantitative analysis yielded 19.37% sulfur (calculated value for thionylodiacetic acid, 19.29%) and an equivalent weight determination was found to deviate less than 1% from the calculated value of 83.1 for the desired dibasic acid. The yield, using this procedure, was only 11% of theoretical, and it was noted that considerable heat evolved when acid and peroxide were mixed. Moreover the yellow solid showed the presence of rather large amounts of sulfate ion as an impurity.

Repetition of the above procedure except for cooling of the reaction flask in crushed ice as the reactants were mixed, yielded 7.5 grams (27% yield) of white product melting at 119° C. and showing only traces of sulfate ion. Several more trial runs were made in order to note the effect of varying several conditions such as the solvent used for the reaction, the optimum length of reaction time, the optimum concentration of hydrogen peroxide and the solvent most suitable for washing the product. One series of experiments in which the reactants were permitted to stand for time intervals up to 30 days indicated that oxidation was virtually complete in 48 hours and, in fact, yields began to decrease after 10 days standing. It is worthy of mention that the only instance in which there was the slightest evidence for the formation of a substance, such as Gazdar and Smiles reported as melting at 79–80° C., occurred following a 30-day reaction time between thiodiacetic acid and 30% hydrogen peroxide. A small amount of a white solid was obtained following the usual in vacuo evaporation. It was insoluble in water but soluble in acetone and, upon recrystallization from that solvent, melted at 79–80° C. It was extremely unstable above its melting point, exploding with considerable violence. A qualitative examination indicated the absence of sulfur and of acid properties. This compound was not identified though its properties were indicative of a labile organic peroxide.

As a result of these experimental data, we recommend the following procedure for the preparation of thionylodiacetic acid. Dissolve 20 grams of thiodiacetic acid in 60 ml. of warm water in a 200 ml. erlenmeyer flask. Cool in an ice-water bath and add slowly 25 ml. of 30% hydrogen peroxide. After the addition is complete, stopper the flask loosely and allow the solution to stand in the cold bath for one hour with occasional agitation by hand and then for 48 hours at room temperature in the dark. Following this period of time pour the solution into an evaporation dish and place in a vacuum desiccator over sulfuric acid. Evacuate and permit evaporation to proceed to dryness. The sulfuric acid may become dark brown but this does not affect the product. Approximately 30 hours is required for this step. The solid residue is washed with small portions of dry ethyl ether, then air-dried. The amount of product should range from 15 to 16 grams representing a 70% yield. The product is white, melts at 119° C. (corr.) with decomposition and gives no test for chloride or sulfate ion.

While the foregoing experiments were in progress, a study of the oxidizing action of nitric acid on thiodiacetic acid was begun. Beckman (5) had reported the preparation of diisooamyl sulfoxide from the sulfide, using fuming nitric acid and Gazdar and Smiles (1) repeated this preparation and found the product to be identical with that obtained from a hydrogen peroxide oxidation. In this investigation, portions of thiodiacetic acid were treated with nitric acid in varying concentration. In trial 1, using fuming nitric acid a vigorous reaction occurred with considerable evolution of heat even when the reaction flask was immersed in an ice-water bath. After the reaction subsided, the reactants were allowed to stand for 48 hours at room temperature. This was followed by in vacuo evaporation to dryness. The residue so obtained was white and quite water-soluble. Both its equivalent weight and its melting point (177–181° C.) suggested that sulfonyldiacetic acid (m.p. 182° C.) was the main product. However, the yield was low and

it is unlikely that any but traces of thionyl diacetic acid could, if formed, withstand the high reaction temperature noted in the early stages of the experiment. Virtually identical results were obtained in trial 2, using concentrated nitric acid and similar reaction conditions, though the yield of sulfonyl diacetic acid was slightly higher. A third trial, with 8N acid, evolved much less heat and was easily controlled. Again the yield was increased but only the sulfone, contaminated with the original thio acid in some quantity, appeared to form. In trials 4 and 5, using 4N and 1N nitric acid respectively, thiodiacetic acid was recovered unchanged. The problem of utilizing sufficiently concentrated acid to promote oxidation of sulfide to sulfoxide without concurrent heat production sufficient to destroy any thionyl diacetic acid which might form, and without concurrent production of considerable amounts of sulfone, was not resolved.

Potassium permanganate has been used in numerous instances to oxidize sulfides to sulfoxides and sulfones. Sulfonyl diacetic acid has been prepared from the thio acid by several investigators, the most recent modification having been reported by Alden and Houston (6) in 1932. Attempts on our part, however, to use permanganate for the production of the intermediate thionyl acid have been unsuccessful.

In some instances the halogens have been used to convert sulfides to higher oxidation products. Earlier mention has been made of Larsson's report (3) that he had made thionyl diacetic acid (m.p. 109° C.) by the action of bromine water on the thio acid. Jonsson (2) records that thionyl diacetic acid and bromine react to produce tetrabromodimethyl sulfoxide (m.p. 52–53° C.) and tetrabromodimethyl sulfone (m. p. 161° C.). Oddy and Dietz (7) have found that when thiodiacetic acid in dilute water solution is treated with bromine an insoluble white solid slowly precipitates out. After recrystallization, it melts at 160–161° C. and analysis indicates that it is tetrabromodimethyl sulfone. This is a confirmation of Jonsson's report. They have found, further, that if thiodiacetic acid is allowed to react with bromine in absolute methyl alcohol solution a product can be isolated which melts at 113.5–115.5° C. and which, according to their analytical data, is tetrabromodimethyl sulfide. In view of these results and of the confirmation given Jonsson's preparation of thionyl diacetic acid by the experimental data in this paper, it is doubtful if the product described by Larsson was thionyl diacetic acid at all. The instability of both thio and thionyl acids in the presence of bromine leads us to believe that his preparation might have been a mixture of these tetrabromo derivatives described above. No experimental work on the oxidizing action of the halogens on thiodiacetic acid was undertaken in this investigation.

#### PHYSICAL AND CHEMICAL PROPERTIES

Thionyl diacetic acid is a white solid, very soluble in water, ethyl alcohol, and dioxane. It is moderately soluble in acetone and practically insoluble in ethyl ether, petroleum ether and carbon tetrachloride. When pure it melts sharply at 119° C. (corr. with decomposition).

X-ray diffraction patterns of powder samples of both thiodiacetic and thionyl diacetic acids were made and the relative intensities of the lines  $\left(\frac{I}{I_0}\right)$  and the interplanar distances ( $d\text{\AA}$ ) were computed. These data are presented in Table I. The line intensities were determined by visual comparison with a photographic grey scale.

The most marked chemical property of this acid is its instability. Upon standing at room temperature it slowly changes to a light yellow color. A 10-gram sample which was set aside for 60 days was found to be almost totally decomposed at the end of that time. Five-gram samples were heated at various temperatures

for 2 hours and, after heating, equivalent weight determinations were made. The results are given in Table II.

In water solution at temperatures above 50° C., the thionyl acid is relatively unstable as it is in cold mineral acid solutions. In hot acid solutions the breakdown is very rapid. Decomposition also occurs under diminished pressure. When placed in vacuo over sulfuric acid, at room temperature, the product yellows rapidly and the sulfuric acid becomes light brown in color.

TABLE I  
X-RAY DIFFRACTION PATTERN MEASUREMENTS OF THIODIACETIC ACID AND THIONYLDIACETIC ACID

THIODIACETIC ACID		THIONYLDIACETIC ACID	
$\frac{I}{I_0}$	dÅ	$\frac{I}{I_0}$	dÅ
0.1	4.410	0.2	9.117
1.0	3.958	0.2	4.641
0.15	3.670	1.0	4.069
0.9	3.334	0.15	3.948
0.4	2.938	0.5	3.780
0.5	2.763	0.15	3.528
0.4	2.653	0.2	2.908
0.8	2.437	0.3	2.728
0.1	2.312	0.2	2.568
0.3	2.204	0.25	2.363
0.25	2.018	0.25	2.281
0.55	1.665	0.15	2.169
0.55	1.562	0.15	1.812

TABLE II  
EFFECT OF ELEVATED TEMPERATURES UPON THE STABILITY OF THIONYLDIACETIC ACID

TEMPERATURE	TIME OF HEATING	EQUIVALENT WEIGHT (Theor. Value, 83.1)	COLOR OF ACID AFTER HEATING
40° C.	2 hrs.	83.5	White
60° C.	2 hrs.	83.4	Light Yellow
80° C.	2 hrs.	83.0	Light Yellow
100° C.	2 hrs.	82.1	Yellow
120° C.	2 hrs.	78.3	Dark Brown Gummy Mass on Cooling

#### DERIVATIVES

##### (a) Salts.

A rather comprehensive investigation of the insoluble salts of thionyl diacetic acid was made. Aqueous solution of the acid was added to solutions of some eighteen common metallic ions. Heavy insoluble precipitates were obtained with Ag<sup>+</sup>, Pb<sup>++</sup>, Hg<sup>++</sup>, and Ba<sup>++</sup>. A small amount of white precipitate formed with Sr<sup>++</sup> and a small amount of a dark brown precipitate was obtained with Cu<sup>++</sup>. In general, these insoluble salts were found to be much more stable than the free acid.

The white barium salt is sparingly soluble in hot water but rapidly dissolves, with decomposition, in hot hydrochloric acid. It crystallizes from water with two molecules of water of hydration.

The silver salt is difficultly soluble in hot water but very soluble in hot nitric acid. Quantitative analysis of the air-dried salt indicates no water of hydration. The salt is bright yellow in color when freshly precipitated but slowly darkens upon exposure to air and light.

Lead acetate solution precipitates a white salt insoluble in both hot and cold water but soluble in hot hydrochloric and nitric acids. A quantitative analysis yielded 55.7% lead (calc. 55.8% Pb.).

A white insoluble mercuric salt is formed with mercuric nitrate solution. It is insoluble in hot and cold water but dissolves in hot hydrochloric acid. Analysis yields 55.1% mercury (calc. 55.0% Hg.).

The precipitates formed with strontium and copper ions were not further investigated.

(b) *Esters.*

Attempts on our part to prepare esters by direct esterification of thionyldiacetic acid with alcohol were unsuccessful. Jonsson reported that he had made the ethyl ester of the thionyl acid by oxidizing diethyl thiodiacetate with 30% hydrogen peroxide but he gave no data concerning his product. We used this method of preparing the methyl and ethyl esters with some success.

Ten grams of diethyl thiodiacetate was dissolved in 10 ml. of glacial acetic acid and 9 ml. of 30% hydrogen peroxide was added. The solution was allowed to stand for 48 hours then evaporated in vacuo over sulfuric acid for another 48-hour period. The residual liquid was dissolved in ethyl ether and partially reprecipitated with petroleum ether. After washing with water, the liquid was again dried in vacuo for 12 hours. The product had a foul odor and undoubtedly was somewhat contaminated but it could not be further purified without decomposition occurring. A quantitative analysis produced 14.3% sulfur and the product was assumed to be diethyl thionyldiacetate (calc. 14.5% S). The following physical characteristics were determined: boiling point, 160° C. (22 mm.) with decomposition; density,  $d_{25}^{25}$  1.112; refractive index,  $n_D^{25}$  1.1667.

Dimethyl thionyldiacetate was prepared in a similar manner and the following physical characteristics determined: boiling point, 105–107° C. (22 mm.) with decomposition; density,  $d_{25}^{25}$  1.331; refractive index,  $n_D^{25}$  1.4805.

#### SUMMARY

1. A study has been made of methods for the oxidation of thiodiacetic acid to thionyldiacetic acid and a modified procedure for the preparation of the latter has been recommended.

2. A number of physical and chemical properties of thionyldiacetic acid have been noted.

3. Several salts and two esters of thionyldiacetic acid have been described.

Acknowledgment is gratefully made for the assistance given us by Mr. Bernard Steierman in the x-ray diffraction studies described in this paper.

#### LITERATURE CITED

- (1) **Gazdar and Smiles.** *J. Chem. Soc.*, **93**: 1834–36 (1908).
- (2) **Jonsson.** *Svensk. Kem. Tids.*, **34**: 192–96 (1923).
- (3) **Larsson.** *Svensk. Kem. Tids.*, **52**: 9–15 (1940).
- (4) **Gilman.** "Organic Chemistry," (2nd Edition), Vol. I, John Wiley & Sons, Inc., New York, 1943, p. 870.
- (5) **Beckman.** *J. prakt. Chem.*, **17**: 441 (1878).
- (6) **Alden and Honston.** *J. Am. Chem. Soc.*, **56**: 413 (1934).
- (7) **Oddy and Dietz.** Unpublished Research.