The Formation of 1,6-Dithia-3a-azonia-2,3,4,5-tetrahydropentalene Salt

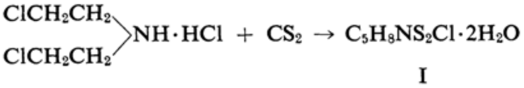
By Shuichi SETO and Yusaku IKEGAMI

(Received February 16, 1963)

The reaction of bis(2-chloroethyl)amine hydrochloride with carbon disulfide in hydrous pyridine, under ice cooling, afforded colorless needles (I), (m. p., 95°C). The present paper deals with the structure of I and with some of its reactions.

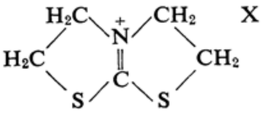
The analytical values of I correspond to those of $C_5H_8NS_2Cl\cdot 2H_2O$, and the yield of its formation reaction is over 90%. I is quite easily soluble in water, but only sparingly soluble in organic solvents. The infrared spectrum of I indicated absorptions at 3405, 3340, 1643 and 1618 cm^{-1} due to the water of crystallization. When left in dry air or in a vacuum desiccator, I undergoes efflorescence with the loss of a part of the water of crystallization.

The addition of an excess of potassium bromide to the aqueous solution of I results in the precipitation of colorless crystals (II) (m. p., 95°C), $C_5H_8NS_2Br\cdot 2H_2O$, which are slightly more sparingly soluble in water than I. The addition of potassium iodide to the aqueous solution of I precipitates more sparingly soluble colorless cubic crystals (III) (m. p., 220°C) (decomp.), $C_5H_8NS_2I$. I forms a picrate (IV) of yellow needles, (m. p., 154°C), $C_5H_8NS_2\cdot C_6H_2O_7N_3$. It is certain from the foregoing reactions that the atom group, $C_5H_8NS_2$, in I to IV is present as a cation. From these facts and from considerations of NMR, infrared and Raman spectra to be discussed below, the structure of 1, 6-dithia-3a-azonia-2, 3, 4, 5-tetrahydropentalene can be given to this cation.



$$\begin{matrix}ClCH_2CH_2\\ClCH_2CH_2\end{matrix}\!\!>\!NH\cdot HCl + CS_2 \rightarrow C_5H_8NS_2Cl\cdot 2H_2O$$

I



I ; X=Cl$^-$·2H$_2$O
II ; X=Br$^-$·2H$_2$O
III ; X=I$^-$
IV ; X=Picrate anion

The NMR spectrum of I in heavy water shows only one signal at 5.82τ, excluding that due to water, and only one signal at 5.70τ, in that of the iodide III. These facts indicate that the protons of the two methylene groups on either side of nitrogen atom are in an equivalent shielding state.

For this cation (A), a structure with all eight skeletal atoms in one plane, or a structure similar to it, is suggested. If all the skeletal atoms were included in one plane, this cation should have two symmetrical planes at right angles to each other. Consequently, its vibrational spectrum can be handled as the vibration of the C_{2v} symmetrical group, and the freedom of 42 vibrations can be classified into the following four species:

A_1	A_2	B_1	B_2	(Total)
13	8	12	9	42

Of these, the eight vibrations belonging to the A_2 species are infrared inactive, and the Raman lines due to the 13 vibrations belonging to A_1 species should show polarizability.

Under such assumptions, the infrared and Raman spectra of the chloride I were measured and their spectra were analyzed. The Raman spectrum was measured in an aqueous solution (ca. 32%), and the infrared spectrum, as a potassium bromide disk[*1]. The results of these measurements are shown in Table I, together with the infrared absorption frequencies of the bromide II and the iodide III.

The data in Table I show the following points:

a) The number of Raman lines of I was not as great as had been expected, but the majority of these Raman lines corresponded to the infrared absorption bands. The infrared spectra of the three compounds show that the absorptions due to the water of crystallization (3405~3220 and 1665~1618 cm^{-1}) are not present in the spectrum of III and that the majority of absorption bands, excluding specially weak ones, appear in all the three compounds, with only a slight difference in frequency and in a similar intensity. This will appear natural if it is assumed that the observed vibrations are virtually all due to the vibration of the cation (A).

b) The Raman line at 1566 cm^{-1}, assigned to the C=N stretching vibration shows an especially small depolarization factor (ρ); this fact, signifying that C=N stretching is a vibration belonging to the A_1 species which does not change the symmetry of a molecule,

---

[*1] The same results were obtained by measurement in Nujol.

TABLE I. OBSERVED FREQUENCIES OF 1,6-DITHIA-3a-AZONIA-2,3,4,5-TETRAHYDROPENTALENE HALIDES

Chloride·$2H_2O$ (I)				Bromide·$2H_2O$ (II)	Iodide (III)
Raman[*1]			IR[*2]	IR[*2]	IR[*2]
cm^{-1}	Int.	ρ	cm^{-1}	cm^{-1}	cm^{-1}
			3470 sh		
3445	10.5		3405 vs	3335 vs	
3393			3340 vs		
3300				3230 s	
3120	6.8		3220 sh		
3023	4.2	0.78	3010 w	2990 vw	3000 vw
2976	10.0	0.47	2965 w		2965 vw
				2930 vw	
2908	2.3	0.41			2910 vw
2873	2.2	0.48			2840 vw
			2110 w	2140 w	
			1643 s	1655 sh	
			1618 m	1639 s	
1566	8.2	0.33	1571 vs	1571 vs	1574 vs
1486	w			1478 vw	
			1469 w		
1455	6.7	0.60		1449 sh	1451 w
1435	3.8	0.9	1433 m	1435 w	1440 w
					1425 m
				1380 vw	1376 vw
			1375 vw		
				1365 vw	1358 vw
			1334 w	1329 w	1320 w
					1308 m
1310	5.0	0.49	1304 m	1302 m	
					1302 m
1259	4.5	0.46	1260 m	1259 m	1253 m
				1231 w	1216 m
1201	1.0		1201 s	1205 s	1201 vs
1170	1.2	1.0	1186 s	1190 s	1171 s
			1154 w	1150 w	1163 sh
					1134 m
			1072 s	1071 s	1063 s
1070	1.0	0.9			
			1058 s	1057 s	1048 s
1020	w		1021 vw	1021 w	999 s
			997 vw	996 w	
967	1.5	0.8	975 w	970 w	961 m
910	1.2				910 vw
					846 w
827	1.1		825 wb		
					814 m
758	0.7				
674	2.2	0.5	661 sb	707 sb	677 m
649	vw		635 sh		649 vw
			613 sb	598 sh	600 w
605	9.7	0.36			
			592 sb	585 sh	582 m
			492 sb	538 sb	547 m
470	1.9				
			458 sh	458 m	456 w
453	5.8	1			
			425 sh		

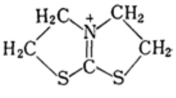
[*1] Raman spectrum was measured as the aqueous solution; the relative intensities were given taking the peak intensity of the intense line at 2976 cm^{-1} as the standard.

ρ: Depolarization factor

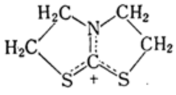
[*2] Infrared spectra were measured as the potassium bromide disk.
vs: very strong, s: strong, m: medium, w: weak, vw: very weak, sh: shoulder, b: broad

also indirectly endorses the correctness of the structure of I. Besides the above, the lines at 2976 and 2908 cm^{-1} (CH_2 stretching), 1310 and 1259 cm^{-1} (skeletal stretching or CH_2 wagging), and 674 and 599 cm^{-1} (skeletal stretching ?) all have small depolarization factors; these can all be assigned to vibrations of the A_1 species.

c) The observed C=N stretching frequencies (1574~1566 cm^{-1}) are rather lower than those of 2-methylthiazolidine (1635 cm^{-1}; hydrochloride, 1630 cm^{-1})[1] and 2-phenylthiazolidine (1605 cm^{-1})[2]. This is thought to be due to the great contribution of the A′ structure, and it is also considered to be responsible for the appearance of eight signals as a singlet in the proton NMR spectrum of I.



A



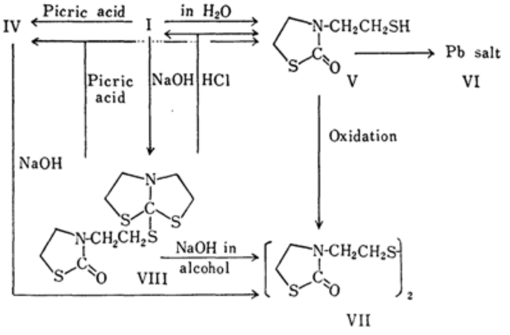
A′

d) The frequencies in the 1486~1439 cm^{-1} region are assigned to the scissor vibrations of CH_2 groups. The bands in the 1205~1170 and 1072~1048 cm^{-1} regions which are strong in the infrared spectra, may probably be assigned to the CH_2 twisting and skeletal stretching vibrations, respectively.

When the aqueous solution of I is allowed to stand for a long period of time, a liquid (V) sparingly soluble in water separates out. V shows infrared absorptions at 2550 and 1667 cm^{-1}, due to –SH and C=O respectively, and lacks the absorption at 1571 cm^{-1} seen in I. V forms a lead salt (VI) of yellow needles (m. p., 143°C), $(C_5H_8ONS_2)_2Pb$. This lead compound shows an absorption for carbonyl at 1661 cm^{-1}, but it does not show the infrared absorption characteristic of the SH group. From these facts, a structure of *N*-(2′-mercaptoethyl)-2-thiazolidinone can be given to V and its lead sulfide to VI. I changes into V even when its solution is heated on a water bath.

When the mercapto compound V is treated with hydrogen peroxide in ethanol, β-(2-thiazolidinon-3-yl)ethyl disulfide (VII) is obtained as colorless plates (m. p. 94°C). VII is also obtained on treating the picrate IV with dilute alkali. The oxidation of V to VII occurs easily, as is usually the case with mercapto compounds. Therefore, in the case of the preparation of V, the disulfide VII is obtained at times as the crystalline part insoluble in ether.

The drop-by-drop addition of a sodium hydroxide solution into the aqueous solution of I affords colorless crystals (VIII) of m. p., 114°C. The molecular weight of VIII is over 300; its infrared spectrum does not show absorptions characteristic of the C=N and SH groups, but it does show absorption bands in the finger-print region considered to be that due to the thiazolidinone group. The treatment of VIII with 2 N sodium hydroxide in ethanol gives the disulfide VII, and its passage through an alumina column gives a mixture of V and VII. The treatment of VIII with picric acid in ethanol results in the formation of approximately equivalent amounts of the picrate IV of the cation and the mercapto compound V. Similarly, the treatment of VIII with hydrochloric acid gives the chloride I and mercapto compound V. From the foregoing experimental results, the structure of 1a-[β-(2-thiazolidinon-3-yl)ethylthio]-1, 6-dithia-3a-aza-2, 3, 4, 5-tetrahydropentalene can be given to VIII.



Experimental[*2]

1,6-Dithia-3a-azonia-2, 3, 4, 5-tetrahydropentalene Chloride (I).—To a solution of 7.14 g. of bis(2-chloroethyl)amine hydrochloride dissolved in 4 ml. of water, with 10 ml. of pyridine added, 2.4 ml. of carbon disulfide was added drop by drop during about a 1 hr. period, during which time the solution was stirred while being cooled with ice. The white turbid solution so formed was stirred at room temperature for 45 min., warmed at 40°C for 20 min., and chilled in ice, after which process colorless crystals precipitated out. By filtration, 7.95 g. of crystals (yield, 91.4%) were obtained; these were then dissolved in a minimum amount of water and recrystallized by the addition of ethanol to colorless needles (I) (m. p., 95°C).

UV λ_{max}^{MeOH} 257 mμ (log ε 4.01).

Found: C, 27.54; H, 5.37; N, 6.30; S, 29.15;

---

[1] R. B. Martin, S. Lowey, E. L. Elson and J. T. Edsall, *J. Am. Chem. Soc.*, **81**, 5089 (1959).

[2] M. G. Ettlinger, ibid., **72**, 4699 (1950).

[*2] All melting points are uncorrected. Elemental analyses for carbon, hydrogen and nitrogen were carried out by Miss Yoko Endo and Miss Yukiko Endo of this Institute, while that for sulfur was carried out by the Takamine Research Laboratory, Sankyo Co., Ltd., to all of whom the authors thanks are due.

Cl, 16.34. Calcd. for $C_5H_8NS_2Cl\cdot 2H_2O$: C, 27.56; H, 5.56; N, 6.44; S, 29.46; Cl, 16.29%.

The drying of I over phosphorus pentoxide in a vacuum desiccator results in the loss of a part of the water of crystallization, and it effloresces to a white powder (m. p., 115~131°C).

Found: C, 30.28; H, 5.38; N, 7.43. Calcd. for $C_5H_8NS_2Cl\cdot H_2O$: C, 30.07; H, 5.05; N, 7.01%.

1,6-Dithia-3a-azonia-2,3,4,5-tetrahydropentalene Bromide (II), Iodide (III) and Picrate (IV).—A solution of 2.5 g. of potassium bromide dissolved in 3 ml. of water was added to a solution of 1.6 g. of I dissolved in 3 ml. of water; the mixture was then allowed to stand under ice cooling, by which process 0.8 g. of the bromide (II) was obtained as colorless crystals (m. p. 95°C).

Found: C, 22.98; H, 4.99; N, 5.51. Calcd. for $C_5H_8NS_2Br\cdot 2H_2O$: C, 22.89; H, 4.62; N, 5.34%.

A solution of 3 g. of potassium iodide dissolved in 3 ml. of water was added to the solution of 1.6 g. of I dissolved in 3 ml. of water; the mixture was then allowed to stand. The crystals that separated out were collected by filtration (1.7 g. of colorless cubic crystals (III); m. p., 220°C (decomp.). Recrystallization from ethanol containing a small amount of water gave colorless rhombs of the same melting point.

UV $\lambda_{\max}^{\text{MeOH}}$ 258 mμ (log ε 4.03).

Found: C, 21.87; H, 2.73; N, 5.15; S, 21.90; I, 46.00. Calcd. for $C_5H_8NS_2I$: C, 21.97; H, 2.95; N, 5.13; S, 23.48; I, 46.47%.

To 114 mg. of I suspended in 3 ml. of ethanol, 2 ml. of a 6% ethanolic solution of picric acid was added; the mixture was then warmed on a water bath until the whole dissolved. When this solution was allowed to stand at room temperature, 194 mg. of yellow needles (IV) (m. p., 154°C) was obtained.

UV $\lambda_{\max}^{\text{MeOH}}$ mμ (log ε): 250 (4.29), 355 (4.21).

Found: C, 35.44; H, 2.67; N, 14.93. Calcd. for $C_{11}H_{10}O_7N_4S_2$: C, 35.29; H, 2.69; N, 14.97%.

The picrate IV was also obtained by the treatment of III with picric acid.

***N*-(2′-Mercaptoethyl)-2-thiazolidinone (V) and its Lead Salt (VI).**—A solution of 660 mg. of I dissolved in 3 ml. of water was heated in a sealed tube. After the solution had been heated for 3 hr., a liquid layer separated out; the tube was then heated for a further 15 hr. The separated aqueous layer was evaporated in vacuo to dryness at room temperature, and 5 ml. of benzene was added to its residue. From the insoluble crystals, 70 mg. of I were recovered, while from the benzene soluble part, 85 mg. of liquid mercapto compound V were obtained. The remaining liquid layer was washed with water and dried in a vacuum desiccator to 360 mg. of liquid V which is easily soluble in ether, benzene and alcohols and which vaporizes gradually at 120~140°C/0.1 mmHg.

This mercapto compound V was also obtained when an aqueous solution of I was allowed to stand in a sealed tube at room temperature for 4 months.

IR strong bands (liquid): 2925, 2865, 2550, 1667 (1690 in CCl_4), 1479, 1447, 1412, 1360, 1328, 1293, 1234, 1199, 1147, 935, 698 and 662 cm^{-1}.

The addition of a solution of 530 mg. of basic lead acetate dissolved in 5 ml. of water to a solution of 160 mg. of V dissolved in 5 ml. of ethanol resulted in the precipitation of yellow crystals. The crystals were collected by filtration and washed with water to 330 mg. of the lead salt (VI) as yellow needles (m. p., 143°C). VI is sparingly soluble in water and in organic solvents.

Found: C, 22.23; H, 3.08; N, 4.93; Pb, 39.27. Calcd. for $C_{10}H_{16}O_2N_2S_4Pb$: C, 22.59; H, 3.03; N, 5.27; Pb, 38.97%.

β-(2-Thiazolidinon-3-yl)ethyl Disulfide (VII).—a) A mixture of 100 mg. of V dissolved in 1.5 ml. of ethanol and 1.5 ml. of 10% hydrogen peroxide solution was allowed to stand overnight at room temperature. By the evaporation of the solvent, 90 mg. of crystals (m. p., 93.5~94°C) were obtained. Recrystallization from ethyl acetate gave colorless plates (VII) (m. p., 94°C).

IR strong bands (KBr disk): 1660, 1441, 1411, 1291, 1237, 1201, 923, 815 and 696 cm^{-1}.

Found: C, 37.31; H, 4.99; N, 8.72%; mol. wt. (Rast), 335. Calcd. for $C_{10}H_{16}O_2N_2S_4$: C, 37.01; H, 4.97; N, 8.63%; mol. wt., 324.5.

b) To a solution of 80 mg. of V in 2 ml. of ethanol, 3 drops of ammonia water were added; air was then blown on the mixture for 3 hr. With the evaporation of the solvents, 73 mg. of rhombic crystals (m. p. 91.5~93°C) were obtained. Those crystals showed no depression of the melting point on admixture with the VII obtained by afore-mentioned method a).

The Treatment of IV with Alkali. — To 40 mg. of the picrate IV suspended in 3 ml. of water, 2.2 ml. of 0.05 N sodium hydroxide were added; the mixture was then warmed on a water bath until in solution. This yellow solution was adjusted to pH 8 and allowed to stand; 15 mg. of VII were thereby obtained as colorless plates (m. p., 91~93°C).

1a-[β-(2′-Thiazolidinon-3′-yl)ethylthio]-1,6-dithia-3a-aza-2,3,4,5-tetrahydropentalene (VIII). — Into a solution of 2.18 g. of I dissolved in 20 ml. of water, about 6 ml. of a 2 N sodium hydroxide solution were stirred drop by drop over a 1 hr. period; crystals were thereby precipitated out. The mixture was adjusted to pH 8.0, allowed to stand in an ice box overnight, and filtered to collect 1.40 g. of crystals (m. p., 108~110°C).

The filtrate with a pH value of 4.5 was adjusted to pH 8.0 by the addition of a 2 N sodium hydroxide solution and again allowed to stand in an ice box; 0.13 g. of crystals (m. p., 107~110°C) was thereby obtained.

The two crops of crystals were combined (quantitative yield) and recrystallized from benzene as rhombic crystals with an m. p. of 108.5°C. Further recrystallization from methanol gave colorless needles (VIII) (m. p., 114°C).

UV $\lambda_{\max}^{\text{MeOH}}$ 258 mμ (log ε 3.91).

IR strong bands (KBr disk): 1668, 1451, 1447, 1410, 1286, 1229, 1203, 1073, 930, 744, 735, 695 and 689 cm^{-1}.

Found: C, 39.26; H, 5.17; N, 9.15; S, 41.18%; mol. wt., 311. Calcd. for $C_{10}H_{16}ON_2S_4$: C, 38.93; H, 5.23; N, 9.08; S, 41.57%; mol. wt., 308.5.

The Treatment of VIII with Alkali in Ethanol.—A suspension of 50 mg. of VIII in 2.5 ml. of ethanol was stirred, and 0.5 ml. of 2 N sodium hydroxide solution was added. The mixture was stirred at room temperature for one hour until the whole dissolved and then allowed to stand overnight; the ethanol was then evaporated. The residue was acidified with hydrochloric acid and extracted with benzene. The extract was dried over anhydride. sodium sulfate, and the benzene was evaporated, leaving a liquid. A part of this liquid crystallized. A small amount of ether was added to this residue and filtered to collect 20 mg. of colorless crystals (m. p., 87~89°C), which showed the same infrared spectrum as that of VII.

The Reaction of VIII and Picric Acid.—A solution of 69 mg. of picric acid dissolved in 2 ml. of ethanol was added to a solution of 95 mg. of VIII dissolved in 6 ml. of ethanol while being warmed. The crystals that precipitated out were allowed to dissolve by warming, the solution was allowed to stand, and the crystals that precipitated out were collected by filtration (115 mg. of yellow needles; m. p., 154°C). This substance showed no depression of the melting point on admixture with the picrate IV obtained by the afore-mentioned method.

The filtrate was passed through an alumina column to remove the picric acid, and the ethanolic effluent was evaporated to remove the solvent, leaving 50 mg. of a colorless liquid. The infrared spectrum of this liquid agreed completely with that of the mercapto compound V.

The Reaction of VIII and Hydrochloric Acid.—Into a suspension of 120 mg. of VIII in 5 ml. of ethanol, 0.5 ml. of 2 N hydrochloric acid was added under stirring at room temperature, and the solution thus obtained was allowed to stand in an ice box overnight. After the evaporation of the solvent, a small amount of benzene was added to the residue, and it was filtered to collect 80 mg. of colorless crystals which were identified as cation chloride I. The solvent evaporated from the filtrate to 70 mg. of a liquid which showed the same infrared spectrum as the mercapto compound V.

Spectral Measurements.—The NMR spectra were measured in heavy water with a Varian V-4300 spectrometer (60 Mc.). The ultraviolet spectra were taken with a Hitachi model EPS-2 spectrophotometer, and the infrared spectra, with a Perkin-Elmer model 21 infrared spectrophotometer (sodium chloride and potassium bromide prisms) and a Hitachi model EPI-S2 infrared spectrophotometer (sodium chloride prism).

The Raman spectrum of I was measured with a Shimadzu automatic-grating Raman spectrometer, Type GRS-750, using the Hg-e line (4358 Å) from a Toronto-type mercury lamp as the exciting line.

The authors are indebted to Mr. Kensuke Takahashi for the measurement of the NMR spectra, to Mr. Tetsuo Hata for co-operation in the measurement of the Raman spectrum, and to Mr. Humio Sato for that of the ultraviolet spectra. The authors are also grateful to the Sankyo Co., Ltd., for its financial assistance in the present research.

The Chemical Research Institute of
Non-Aqueous Solutions
Tohoku University
Katahira-cho, Sendai