Crystal Structure of Thiolphthalide

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The crystal and molecular structure of thiolphthalide has been determined by X-ray crystallographic analysis. The crystals of this compound are orthorhombic (space group P $2_1 2_1 2_1$) with cell dimensions of a = 4.104 Å., b = 11.835 Å., and c = 14.602 Å. The structure was determined by Patterson and Fourier methods and refined by least squares to a final R value of 0.070. The two C—S bond lengths are 1.83 Å. and 1.77 Å., with the latter bond adjacent to the carbonyl group. The angle subtended by the C—S bonds is 94°.

THOUGH THE importance of thiolesters in biological systems has been well established (1), there appears to be a lack of structural data on such compounds in the literature. Significant structural variations have been observed between acetylcholine (2) and acetylthiolcholine (3), but the accuracy of these structures does not permit a detailed comparison of the valence states about the respective ester linkages. In an attempt to obtain more definitive information about the resonance in thiolesters the crystal structure of thiolphthalide has been completed.

EXPERIMENTAL

Elongated colorless prisms obtained by sublimation were used, and the unit cell dimensions for these crystals were measured on a General Electric XRD-6 diffractometer with Ni filtered Cu Kα radiation. They were found to be a = 4.104 ± 0.001 Å., b = 11.835 ± 0.003 Å., c = 14.602 ± 0.007 Å., and $\alpha = \beta = \gamma = 90.0°$. The systematic absences of the $h\,0\,0$ ($h = 2n + 1$), $0\,k\,0$ ($k = 2n + 1$), and $0\,0\,e$ ($e = 2n + 1$) reflections indicated the space group P $2_1 2_1 2_1$. The density calculated from the X-ray data is 1.42 Gm./cm.³ (assuming 4 molecules in the unit cell). Attempts were made to measure the density of the material in potassium iodide solutions, but an accurate value was not obtained.

The intensity data were collected by the stationary counter-stationary crystal technique with balanced Ni-Co filters. The mounted crystal had to be coated with petroleum jelly in order to retard its sublimation. Even though it was so covered, a 20% decrease in intensity was observed over the whole data collection period. A correction for this effect was applied to the intensities. Lorentz and polarization factors were applied to the data as well as an adjustment for the anisotropy of transmission about the ϕ axis. A correction for the α_1-α_2 splitting was also made using a correction similiar to that of Tulinsky et al. (4). In the 2θ range of the

data collection (0–120°), 640 reflections out of a total possible number of 660 had intensities significantly greater than their background counts.

The Patterson function revealed the sulfur position and from subsequent Fourier syntheses the locations of the other atoms were obtained. The positional and thermal parameters were refined by least squares using a block diagonal matrix approximation. A weighting of $1/f_c$, where f_c is the scattering factor for carbon, was utilized in the least squares analysis. This weighting is approximately equivalent to differential synthesis weighting. The 20 unobserved reflections were given zero weight. In the later stages of refinement the hydrogen atoms were located from an electron density difference Fourier synthesis (see Fig. 1)[1] and included in the final cycles of least squares. The final R value was 0.070 (including the 20 unobserved reflections which were given half the minimum observable intensity). The atomic form factors used in all the above calculations were those tabulated by Cromer and Waber (5).

The atomic positional and thermal parameters for the atoms together with their estimated standard deviations are given in Table I. A list of the observed and calculated structure factors amplitudes will be supplied upon request.

RESULTS AND DISCUSSION

The intramolecular bond distances and angles for the molecule are shown in Fig. 2. These values were not corrected for the thermal libration of the molecule. The mean standard deviation of the intramolecular bond lengths and angles for the nonhydrogen atoms are 0.01 Å. and 0.6°. The average error for the C—H bonds is 0.10 Å.

The two C—S bonds differ significantly in their bond lengths. The C(8)—S distance of 1.83 Å. agrees well with the "commonly" accepted C—S single bond length of 1.82 Å. (6), while the C(7)—S bond is significantly shorter than this value. The latter bond appears to have approximately 35% double bond character (estimated from the data presented in Reference 6). The C—O— bonds in various lactones (7–10) also show an analogous difference in their molecular structures. It is worthy to note that the bond length of the carbonyl group is quite similar to the average value found for the same group in the two γ-lactone moieties of anemonin (7), where the value is 1.19 Å. In comparing the thiol-lactone portion of this molecule to anemonin, a most striking difference is observed between the C—S—C and C—O—C angles, which 94.5 and 110° (mean value), respectively, this

TABLE I—ATOMIC POSITIONAL AND THERMAL PARAMETERS[a]

Atom	x/a	y/b	z/c	B_{11}/B_{iso}	B_{22}	B_{33}	B_{12}	B_{13}	B_{23}
C(1)	0.4191 (21)	0.0867 (5)	0.3776 (4)	0.0618 (53)	0.0047 (4)	0.0038 (3)	−0.0019 (30)	0.0015 (27)	0.0002 (6)
C(2)	0.3572 (22)	−0.0180 (5)	0.3390 (5)	0.0641 (51)	0.0051 (5)	0.0043 (3)	−0.0023 (33)	0.0056 (29)	−0.0004 (7)
C(3)	0.4543 (24)	−0.1145 (6)	0.3867 (6)	0.0926 (73)	0.0050 (5)	0.0061 (4)	−0.0058 (38)	0.0119 (33)	−0.0001 (8)
C(4)	0.6030 (29)	−0.1022 (7)	0.4696 (6)	0.0944 (73)	0.0088 (7)	0.0057 (4)	−0.0097 (56)	0.0097 (37)	−0.0053 (9)
C(5)	0.6678 (25)	0.0028 (9)	0.5068 (5)	0.0799 (71)	0.0123 (8)	0.0044 (4)	0.0075 (56)	0.0035 (33)	0.0012 (10)
C(6)	0.5692 (24)	0.0958 (6)	0.4619 (5)	0.0766 (66)	0.0075 (6)	0.0044 (3)	0.0093 (38)	−0.0022 (29)	0.0008 (8)
C(7)	0.2987 (22)	0.1834 (6)	0.3204 (5)	0.0761 (64)	0.0062 (5)	0.0045 (4)	−0.0029 (35)	−0.0023 (29)	0.0009 (8)
C(8)	0.1931 (24)	−0.0180 (6)	0.2479 (5)	0.0857 (70)	0.0062 (6)	0.0046 (4)	−0.0058 (35)	−0.0049 (30)	−0.0007 (8)
O	0.3192 (21)	0.2817 (4)	0.3384 (4)	0.1265 (66)	0.0042 (3)	0.0072 (4)	0.0066 (30)	−0.0005 (31)	−0.0001 (6)
S	0.1263 (6)	0.1302 (2)	0.2179 (1)	0.0744 (14)	0.0082 (1)	0.0047 (1)	0.0026 (11)	−0.0062 (8)	0.0017 (2)
C(3)H	0.454 (267)	−0.177 (76)	0.359 (62)	4.1					
C(4)H	0.712 (272)	−0.152 (85)	0.506 (66)	4.7					
C(5)H	0.780 (206)	0.012 (64)	0.552 (49)	1.4					
C(6)H	0.719 (217)	0.156 (67)	0.485 (53)	2.4					
C(8)H₁	−0.062 (312)	−0.056 (88)	0.244 (72)	6.5					
C(8)H₂	0.390 (278)	−0.078 (81)	0.207 (65)	4.7					

[a] The estimated standard deviations are given in parentheses × 10⁴ except those for the isotropic temperature factors of the hydrogens, which have an average error of ±2.0 Å². The anisotropic temperature factor is of the form: $T = \exp. - (B_{11}h^2 + B_{22}k^2 + B_{33}l^2 + B_{12}hk + B_{13}hl + B_{23}lk)$.

Fig. 1—Hydrogen atom electron density contours in a difference Fourier synthesis computed at the conclusion of the refinement. Contour levels at 0.1 e.Å.⁻³, starting at 0.1 eÅ.⁻³.

difference may be indicative of the ability of the sulfur atom to use its d orbitals in this bonding situation.

Within experimental error the other bond lengths and angles of the molecule agree favorably with their expected values.

The 10 nonhydrogen atoms comprising the molecule are essentially planar. The least squares equation of the plane through these atoms is:

$$-0.8897\,X - 0.0358\,Y + 0.4552\,Z = -0.9511 \text{ Å.}$$

where X, Y, and Z are the coordinates in Å. measured along a, b, and c, respectively. The root mean square deviation of the 10 atoms from this plane is 0.001 Å.

The packing arrangement of the molecules in the crystal lattice is shown in Fig. 3. The shortest intermolecular contacts are represented as dashed lines. With the exception of the C(8)—H2...O intermolecular contact, all the distances appear to be normal van der Waals contacts. Even though the estimated standard deviation for the C(8)H2...O distance is 0.12 Å., the contact is substantially smaller than the sum of the van der Waals radii between the respective atoms [1.2Å.(H) + 1.4 Å.(O)]. C—H...O hydrogen bonds have been found in a number of heterocyclic structures (11).

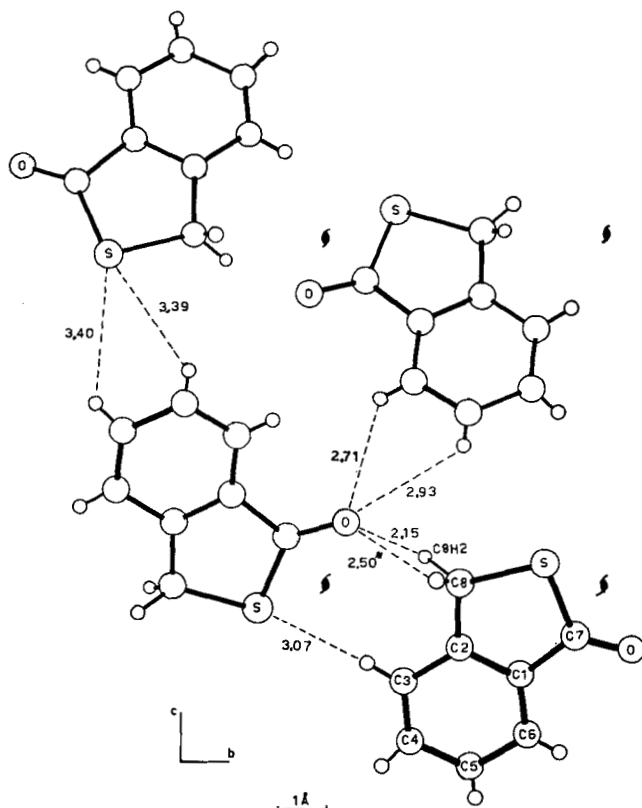*Fig. 2—The intramolecular bond distances and angles in thiolphthalide. The thermal ellipsoids are also shown.*

Fig. 3—The arrangement of the molecules as viewed down the a-axis. Dashed lines show shortest intermolecular contacts.

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 Keyphrases

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