Crystal Structure of a Host-guest Complex of 4,4'-Ethylidenebisphenol and 5-Chloro-2-methyl-4-isothiazoline-3-one

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A microbicide, 5-chloro-2-methyl-4-isothiazoline-3-one (**1**), makes a host-guest complex with a host molecule of 4,4'-ethylidenebisphenol (**2**). The crystal structure, analyzed by X-rays, revealed that one of the two OH groups of **2** make a strong hydrogen bond with the carbonyl group of **1**. The O...O distance is 2.627(3) Å. The other OH group of **2** makes an intermolecular hydrogen bond to the OH group of the adjacent **2** forming a linear chain along the *c* axis. The O...O distance is 2.765(3) Å.

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The compound 5-chloro-2-methyl-4-isothiazoline-3-one (**1**) has been used as a microbicide for various industrial water systems such as cooling-water systems, and paper making process systems.¹⁻³ A microbicide is, in general, very toxic, and thus dangerous to handle. We intended to make host-guest complex crystals using **1** as a guest to make the handling easier. Host-guest complex formation has been widely applied to control the reactivity of the guest molecule.⁴ The design of hydrogen-bonded host-guest complexes has been extensively studied. When a microbicide compound is included as a guest in a host-guest complex, the guest molecule is slowly released from the complex due to the hydrogen bond. This means that the microbicide in the host-guest complex would be milder than the microbicide itself; furthermore, it may be active for a longer time than that of the pure form. When a compound of 4,4'-ethylidenebisphenol (**2**) was used as a host, good crystals suitable for X-ray work were obtained. The present paper describes the crystal structure of the host-guest complex shown in Fig. 1. Although **1** was previously used as a guest molecule,⁵ this is the first report on the structure of a host-guest complex using **2** as a host.

Both molecules are commercially available. The specimen crystal was obtained from the recrystallization of a 1:1 mixture of **1** and **2** from a methanol solution.

The structure was solved by a direct method and refined by full-matrix least-squares method. The ethylidene moiety is disordered. The occupancy factors of the major and minor components are 0.834(8) and 0.166(8), respectively. Although

the corresponding disordered structure of phenol groups should be observed, it was unresolved in the present analysis, because the disordered parts are severely overlapped. Thus, structural parameters related to the phenol groups are an average of the disordered structures. Although most of the hydrogen atoms were located on a difference Fourier map, some of them were located geometrically. Anisotropic and isotropic temperature factors were applied to non-hydrogen and hydrogen atoms, respectively. Hydrogen atoms were included in a least-squares using a riding-atom model. The crystal data and the experimental details are listed in Table 1, the atomic coordinates in Table 2, and selected bond lengths and angles in Table 3.

The molecular structure and the crystal structure viewed along the *b*-axis are shown in Figs. 2 and 3, respectively. **1** is a planar molecule, and the maximum deviation from the least-squares plane formed by eight atoms is -0.019(4) Å for C(17). The molecular structure is quite similar to that observed in the host-

Fig. 1 Chemical structure.

Table 1 Crystal and experimental data

Formula: C ₁₈ H ₁₈ ClNO ₃ S	
Formula weight = 363.84	
Crystal system: monoclinic	
Space group: <i>P</i> 2 ₁ / <i>a</i>	<i>Z</i> = 4
<i>a</i> = 16.152(6) Å	
<i>b</i> = 10.127(5) Å	<i>β</i> = 105.48(3)°
<i>c</i> = 11.450(5) Å	<i>T</i> = 296(2) K
<i>V</i> = 1805.0(13) Å ³	
<i>D_x</i> = 1.339 g/cm ³	
No. of reflections used: 4144 (<i>R</i> _{int} = 0.0361)	
2 θ _{max} (Mo K α) = 55°	
<i>R</i> (<i>F</i>) = 0.0520, <i>wR</i> (<i>F</i> ²) = 0.1251 (2436 refs, <i>I</i> > 2 σ (<i>I</i>))	
Goodness-of-fit = 1.028	
(Δ / σ) _{max} = < 0.001	
($\Delta\rho$) _{max,min} = 0.305, -0.401 e/Å ³	
Measurements: Rigaku AFC-5R	
Program system: SHELXL-97	
Structure determination: direct methods (SHELXS97)	
Refinement: full-matrix least-squares (SHELXL-97)	

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Table 2 Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$). $U(\text{eq})$ is defined as one third of the trace of the orthogonalized U_{ij} tensor.

Atom	x	y	z	$U(\text{eq})$
C1(1)	-66(1)	-3088(1)	3600(1)	100(1)
S(1)	1070(1)	-1480(1)	5524(1)	63(1)
O(1)	2151(1)	576(2)	13012(2)	55(1)
O(2)	2974(1)	-759(2)	5107(2)	52(1)
O(3)	-480(1)	-823(3)	7388(2)	77(1)
N(1)	700(1)	-874(2)	6661(2)	55(1)
C(1)	3422(2)	1568(3)	8211(2)	49(1)
C(2)	3021(2)	2079(3)	7098(2)	51(1)
C(3)	2854(2)	1329(2)	6058(2)	44(1)
C(4)	3105(2)	26(2)	6117(2)	40(1)
C(5)	3497(2)	-532(3)	7229(2)	52(1)
C(6)	3657(2)	242(3)	8262(2)	57(1)
C(8)	3262(2)	1898(3)	10328(2)	52(1)
C(9)	3742(2)	1298(3)	11374(3)	61(1)
C(10)	3365(2)	849(3)	12261(2)	56(1)
C(11)	2500(2)	999(2)	12105(2)	42(1)
C(12)	2005(2)	1589(3)	11057(2)	51(1)
C(13)	2393(2)	2027(3)	10195(2)	59(1)
C(14)	91(2)	-2208(3)	4914(3)	60(1)
C(15)	-474(2)	-1998(3)	5555(3)	63(1)
C(16)	-129(2)	-1195(3)	6610(3)	56(1)
C(17)	1263(2)	-109(4)	7643(3)	72(1)
C(7)	3603(3)	2495(4)	9306(3)	50(1) ¹
C(18)	4571(3)	2767(6)	9717(3)	76(2) ¹
C(7B)	3890(4)	2007(18)	9518(5)	54(6) ²
C(18B)	4087(15)	3474(17)	9526(18)	68(6) ²

*1: occupancy 0.834(8), 2: occupancy 0.166(8).

Table 3 Selected bond lengths [$\text{\AA}$] and angles [$^\circ$]

C1(1)-C(14)	1.708(3)
S(1)-N(1)	1.687(2)
S(1)-C(14)	1.716(3)
O(3)-C(16)	1.236(3)
N(1)-C(16)	1.363(3)
N(1)-C(17)	1.465(4)
C(14)-C(15)	1.333(4)
C(15)-C(16)	1.438(4)
N(1)-S(1)-C(14)	89.58(13)
C(16)-N(1)-C(17)	124.2(2)
C(16)-N(1)-S(1)	115.2(2)
C(17)-N(1)-S(1)	120.61(18)
C(15)-C(14)-C(1)	127.4(2)
C(15)-C(14)-S(1)	113.5(3)
C(1)-C(14)-S(1)	119.11(17)
C(14)-C(15)-C(16)	112.6(3)
O(3)-C(16)-N(1)	122.0(3)
O(3)-C(16)-C(15)	128.8(3)
N(1)-C(16)-C(15)	109.2(2)

guest crystal. Because the crystal structure of **1** has not yet been reported, it is difficult to estimate the packing effect to **1** in this environment. One of the two OH groups of **2** make a hydrogen bond of O-H...O with the oxygen atom of another OH group of the neighboring host molecule (**2**) to form a linear chain along the *c* axis. The O(2)...O(1)ⁱ, O(2)...H(20), H(20)...O(1)ⁱ distances, and angle of O(2)...H(20)...O(1)ⁱ are 2.765(3), 0.82, 1.95 $\text{\AA}$, 175 $^\circ$, respectively (symmetry operation: *i*: [x, y, -1+z]). Another OH group of **2** donates an O-H...O type hydrogen bond to the carbonyl group of **1**. The O(1)...O(3)ⁱⁱ, O(1)...H(10),

Fig. 2 Molecular structure. The central ethylidene moiety is disordered. The major part is drawn with a filled bond (occupancy 0.834(8)) and the minor part with an open bond (0.166(8)). The thermal ellipsoids are drawn at the 50% probability level. Hydrogen atoms are omitted for clarity.

Fig. 3 Crystal structure viewed along the *b*-axis. The hydrogen bonds are shown with dotted lines. The disordered structure is omitted for clarity.

H(10)...O(3)ⁱⁱ distances, and the angle of O(1)...H(10)...O(3)ⁱⁱ are 2.627(3), 0.82, 1.82 $\text{\AA}$, 168 $^\circ$, respectively (symmetry operation: *ii*: [-x, -y, 2-z]). Other intermolecular contacts are not significantly short. The linear hydrogen-bonding chain structure, composed of the host molecules, probably stabilizes the formation of the host-guest complex.

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