Supramolecular Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713649759

Stereoselective Inclusion and Structure of Equatorial-*trans*-1,2-dichlorocyclohexane

Masako Kato[ab]; Koichi Tanaka[c]; Fumio Toda[d]
[a] Division of Material Science, Graduate School of Human Culture, Nara Women's University, Nara, Japan [b] PRESTO, JST, Kawaguchi, Japan [c] Department of Applied Chemistry, Faculty of Engineering, Ehime University, Matsuyama, Ehime, Japan [d] Department of Chemistry, Faculty of Science, Okayama University of Science, Okayama, Japan

To cite this Article Kato, Masako , Tanaka, Koichi and Toda, Fumio(2001) 'Stereoselective Inclusion and Structure of Equatorial-*trans*-1,2-dichlorocyclohexane', Supramolecular Chemistry, 13: 1, 175 — 180

To link to this Article: DOI: 10.1080/10610270108034892

URL: http://dx.doi.org/10.1080/10610270108034892

SUPRAMOLECULAR CHEMISTRY, Vol. 13, pp. 175-180
Reprints available directly from the publisher
Photocopying permitted by license only

Stereoselective Inclusion and Structure of Equatorial-*trans*-1,2-dichlorocyclohexane

MASAKO KATO[a,b,*], KOICHI TANAKA[c] and FUMIO TODA[d]

[a]*Division of Material Science, Graduate School of Human Culture, Nara Women's University, Nara 630-8506, Japan;* [b]*PRESTO, JST, Kawaguchi 332-0012, Japan;* [c]*Department of Applied Chemistry, Faculty of Engineering, Ehime University, Matsuyama, Ehime 790-8577, Japan;*
[d]*Department of Chemistry, Faculty of Science, Okayama University of Science, 1-1 Ridai-cho, Okayama, 700-0005, Japan*

Optically active (*R, R*)-(-)-*trans*-1,2-dichlorocyclohexane (DCC) was isolated as an inclusion crystal with the optically active host, (*R, R*)-(-)-*trans*-2,3-(hydroxydiphenylmethyl)-1,4-dioxaspiro[4.4]-nonane, and the structure of the 2:1 inclusion crystal has been determined by X-ray analysis. Crystal data: $C_{72}H_{74}O_8Cl_2$, orthorhombic, $P2_12_12$ (No. 18), $a = 17.465(6)$ Å, $b = 20.095(6)$ Å, $c = 8.664(5)$ Å, $V = 3040(2)$ Å^3, $Z = 2$, $D_c = 1.24\,\mathrm{g\,cm^{-3}}$, $D_m = 1.23\,\mathrm{g\,cm^{-3}}$, $T = 293$ K and final $R_1 = 0.050$ for 2766 observed data ($I > 2\sigma(I)$). The conformation of DCC in the inclusion crystal has been found to be equatorial and the absolute configuration was definitely determined to be (*R, R*) on the basis of the known configuration of the host.

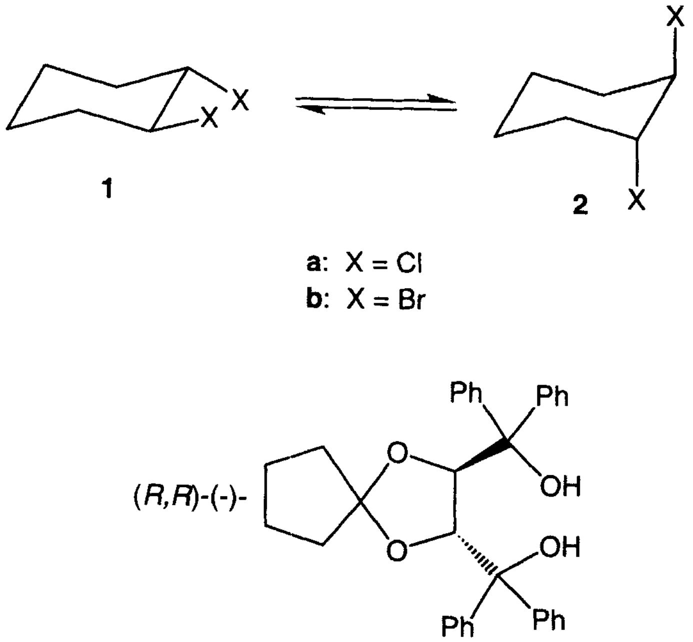
Keywords: Stereoselective inclusion; Dichlorocyclohexane; Conformation; X-ray structure; Inclusion crystal

INTRODUCTION

It has been studied whether *trans*-1,2-dichloro- and *trans*-1,2-dibromo-cyclohexane (DCC and DBC, respectively) exist as equatorial form (**1**) or axial form (**2**). On the basis of the infrared spectroscopy, it was established that DCC exists mostly as an equatorial form, whereas DBC exists as an axial form both in the liquid and crystalline states [1, 2]. Exceptionally, an axial form of DCC was reported in an inclusion complex with thiourea [3, 4]. It was suggested that the small cavity of the host derived the axial conformation of DCC. However, structural information was only from the spectroscopic measurements and direct structural determination by X-ray analysis has never been reported. We have isolated a new inclusion crystal which contains optically active isomer of DCC and a chiral host compound, (*R, R*)-(-)-*trans*-2, 3-bis(hydroxydiphenylmethyl)-1,4-dioxaspiro[4.4]nonane (**3**), and determined the conformation and the absolute configuration of DCC by X-ray analysis as well as the infrared spectroscopy. This is the first X-ray structural report that has confirmed the conformation of DCC directly.

---

*Corresponding author.



1 **2**

a: X = Cl
b: X = Br

3

SCHEME

RESULTS AND DISCUSSION

The isolation of optically active isomer of DCC, (-)-**1a** has been accomplished by repeating inclusion complexation of *rac*-DCC with **3** as described in detail in the experimental section. The resulting 2 : 1 complex of **3** and DCC shows the IR bands at 908 and 818 cm^{-1} suggesting an equatorial conformer of DCC [1].

In order to certify the conformation and the absolute configuration, X-ray structure analysis of the inclusion crystal was carried out. Figures 1 and 2 show the molecular structures of the host **3** and (-)-**1a**, respectively. Relevant bond lengths and angles are summarized in Table I. The chiral host molecule **3** has inter- and intra-molecular hydrogen bonds among the hydroxyl groups as those are seen for the neat crystal [5]. In the cavity surrounded by the host molecules, the guest molecule DCC is sitting in an equatorial conformer being in disorder as shown in Figure 2. Figure 3 shows the packing diagram of the inclusion complex. There is no intermolecular hydrogen bond between **3** and (-)-**1a**, although an intermolecular hydrogen bond between **3** and guest molecules often plays an important role to construct inclusion crystal lattice [6]. Figure 4 shows the packing diagram of the host molecule only with van der Waals sphere. The cavity surrounded by the host molecules seems to correspond to only an equatorial form of DCC ((-)-**1a**). In fact, the possibility of the axial conformation was completely excluded in the course of the X-ray analysis because the distance between the large Fourier peaks that was assignable to chlorine atoms was found to be around 3 Å. The distance only fits the equatorial conformer. The optimized molecular model by Chem3D suggests that the distance between two chlorine atoms of the axial conformer should be more than 4 Å, whereas that of the equatorial conformer should be around 3 Å.

It was reported that the thiourea molecules form a channel with the cross-sectional

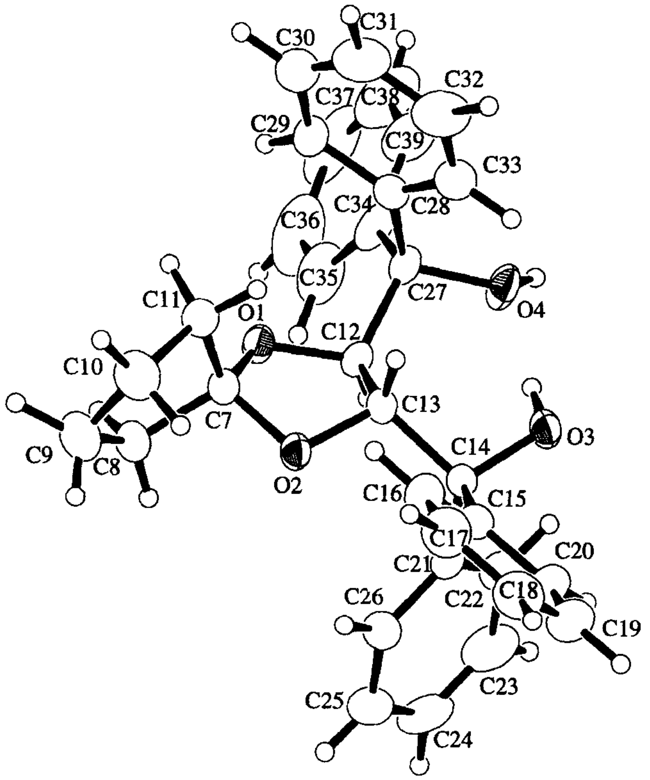


FIGURE 1 Molecular structure of the host **3**, showing the numbering scheme.

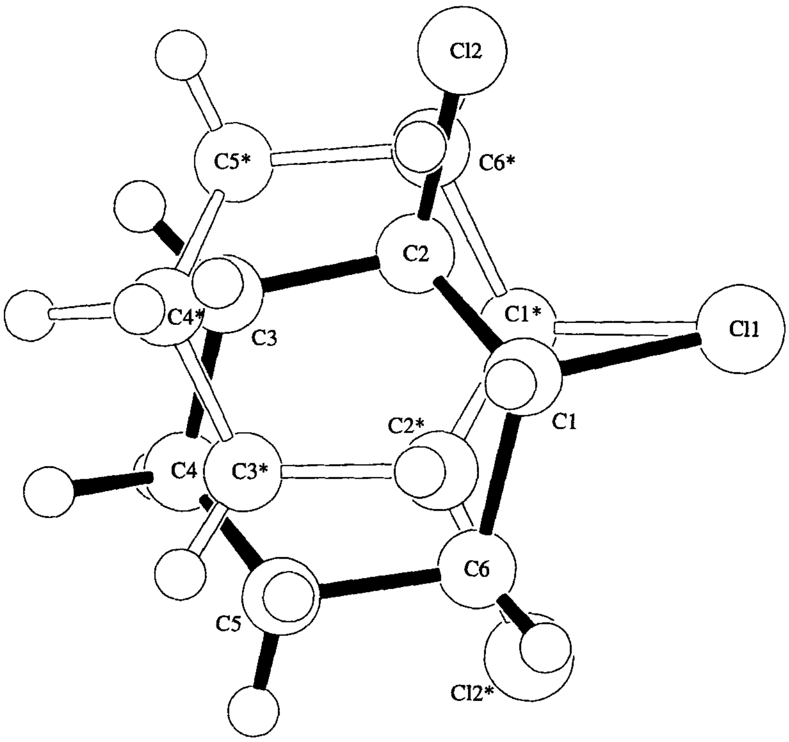


FIGURE 2 Molecular structure of the guest (-)-**1a**, showing the numbering scheme.

TABLE I Selected bond lengths (Å) and angles (°) of the inclusion crystal $(\mathbf{3})_2 \cdot (-)$-**1a**

Cl1—C1	1.80(1)	Cl2—C2	1.71(2)
C1—C2	1.43(2)	C1—C6	1.61(3)
C2—C3	1.55(3)	C3—C4	1.51(4)
C4—C5	1.44(3)	C5—C6	1.57(3)
Cl1—C1—C2	108(1)	Cl1—C1—C6	111(1)
C2—C1—C6	112(1)	Cl2—C2—C1	110(1)
Cl2—C2—C3	110(1)	C1—C2—C3	111(1)
C2—C3—C4	110(2)	C3—C4—C5	111(2)
C4—C5—C6	109(1)	C1—C6—C5	107(1)

Hydrogen-bonding geometry

D—H···A	D···A	D—H	H···A	D—H···A
O3—H21···O4	2.629(3)	0.891	1.756	166.1
O4—H32···O3^{i}	2.693(3)	0.910	1.892	145.7

Symmetry code: $^{i}-x, -y+1, z$.

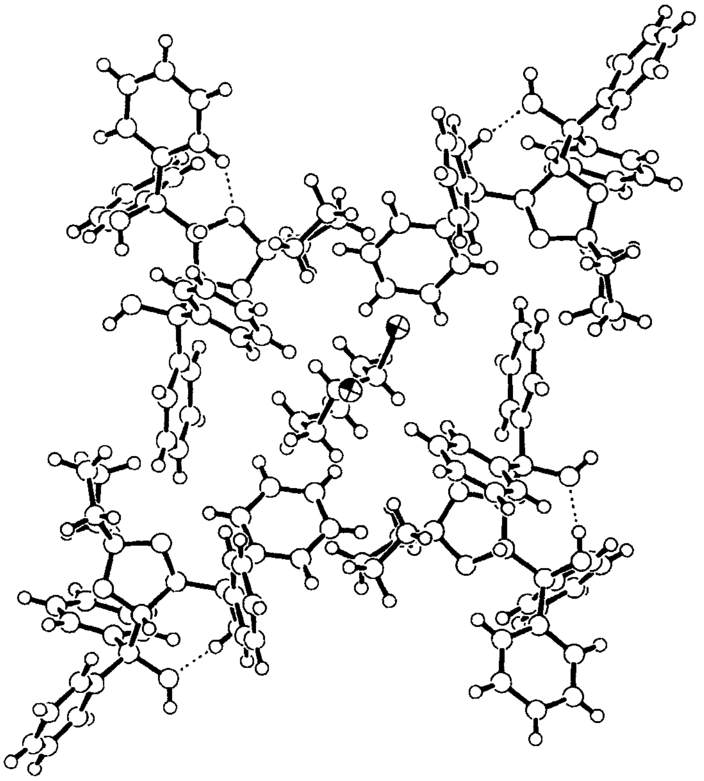


FIGURE 3 Packing diagram of the inclusion complex $(\mathbf{3})_2 \cdot (-)$-**1a** viewed down the c axis. The shaded octants denote Cl atoms.

dimension of ca. 5.8 – 6.8 Å in the crystalline state [7]. The reason the DCC took the axial conformation in the thiourea crystal was attributed to the particular crystal structure of the host [2]. In contrast to that, the inclusion crystal of **3** has a narrow cavity (Fig. 4). DCC, which prefers the

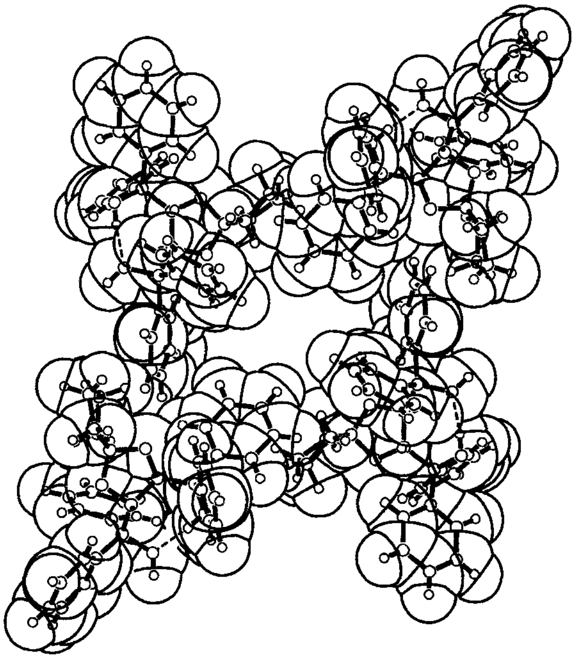


FIGURE 4 Packing diagram of the host molecule **3** with van der Waals sphere.

equatorial conformation essentially, can just fit to the cavity to give the inclusion crystal. In the case of DBC, however, the inclusion compound with **3** was never obtained. It would be reasonable taking the size and the shape of the cavity into account as well as the fact that the axial form is known to be the stable conformer for DBC with bulky bromine atoms [1]. A molecular model of DBC also suggests the steric tightness between two bromine atoms for the equatorial conformer.

Furthermore, as the host molecule **3** is chiral and thus the cavity formed is also chiral, only (-)-enantiomer of **1a** is successfully included stereoselectively. Absolute configuration of the guest (-)-**1a** was automatically determined to be (*R*, *R*) on the basis of the absolute configuration of the host (*R*, *R*).

In conclusion, equatorial-DCC has been isolated stereoselectively as a new inclusion crystal by using the chiral host **3**, and the equatorial conformation and the (*R*, *R*) absolute configuration have been confirmed by the X-ray structure analysis.

EXPERIMENTAL SECTION

Materials

The inclusion complex containing optically active guest, (*R*, *R*)-(-)-**1a** was isolated by repeating inclusion complexation of *rac*-DCC with **3** using the following procedures: When a solution of **3** (50 g, 0.1 mol) in *rac*-DCC (50 g, 0.33 mol) was kept at room temperature for 12 h, the 2 : 1 inclusion complex of **3** and (-)-**1a** was obtained as colorless prismatic crystals (45.8 g, 80% yield based on **3**, mp 108–110°C). Heating of the sample at 200°C/20 mmHg gave (-)-**1a** of 43% ee by distillation(6 g, 77% yield based on **3**, $[\alpha]_D$ $-22.3°$ (*c* 0.59, hexane)). The same treatment of the (-)-**1a** of 43% ee (6 g) with **3** (5 g) followed by distillation as above gave (-)-**1a** of 72% ee (0.7 g,

TABLE II Crystallographic data of the inclusion crystal **(3)**$_2$·(-)-**1a**

Formula: $C_{72}H_{74}O_8Cl_2$	$fw = 1138.28$
Cryst system: orthorhombic	space group: $P2_12_12$ (No. 18)
$a = 17.465(6)$ Å	$D_c = 1.24\,\mathrm{g\,cm^{-3}}$, $D_m = 1.23\,\mathrm{g\,cm^{-3}}$
$b = 20.095(6)$ Å	$\mu(\mathrm{MoK}\alpha) = 0.164\,\mathrm{mm^{-1}}$
$c = 8.664(5)$ Å	no. observed $(I > 2\sigma(I)) = 2766$
$V = 3040(2)$ Å^3	no. variables = 373
$Z = 2$	$R_1{}^a = 0.050$ for observed data
$T = 293$ K	$wR_2{}^b = 0.192$ for all data
$\lambda = 0.71073$ Å	$S = 0.96$

[a] $R_1 = \Sigma||F_o| - |F_c||/\Sigma|F_o|$.

[b] $wR_2 = [\Sigma w(F_o^2 - F_c^2)^2/\Sigma w(F_o^2)^2]^{1/2}$, $w = [\sigma_c^2(F_o^2) + (0.094P)^2 + 0.8079P]^{-1}$, where $P = (F_o^2 + 2F_c^2)/3$.

90% yield based on **3**, $[\alpha]_D$ −41.0° (*c* 0.97, hexane)). When the (-)-**1a** of 72% ee (0.6 g) was treated again with **3** (0.7 g) as described above, it finally gave (-)-**1a** of 90% ee as colorless oil (0.06 g, 55% yield, $[\alpha]_D$ −51.3° (*c* 0.91, hexane)). The optical purity of (-)-**1a** was determined by gas chromatography on a chiral packing, Chirasil-DEX CB which is available from Chrompak, Middleburg, The Netherlands.

X-ray Crystallography

A colorless prismatic crystal of the optically active 2:1 inclusion complex, **(3)**$_2$·(-)-**1a** having approximate dimensions of 0.60 × 0.48 × 0.34 mm was mounted on a glass fiber. The diffraction data were collected on a Rigaku AFC-7R four-circle diffractometer with graphite monochromated MoKα radiation ($\lambda = 0.71073$ Å) to $2\theta = 55°$. Crystallographic data are summarized in Table II. The structure was solved by direct methods [8] and expanded using Fourier techniques [9]. Non-hydrogen atoms except for the cyclohexane ring were refined anisotropically. DCC was found to be disordered except for Cl1 which was located on the 2-fold axis and thus at the beginning of the refinement, the cyclohexane ring was treated as a rigid group, which resulted in the determination of the molecular structure of DCC with normal C–Cl bond lengths. Finally, all the non-hydrogen atoms of the cyclohexane ring were refined independently with isotropic temperature factors. Hydrogen atoms were included but not refined. The final cycle of full-matrix least-squares refinement was based on 2766 observed reflections ($I > 2\sigma(I)$) and 373 parameters and converged with $R_1 = 0.050$. Crystallographic data, experimental details, positional and thermal parameters, complete bond lengths and angles, and structure factors are included in Supplementary Material. All calculations were performed using the teXsan crystallographic software package [10].

References

[1] Klaeboe, P. (1971). *Acta Chem. Scand.*, **25**, 695 and references cited therein.

[2] Gustavsen, J. E., Klaeboe, P. and Kvila, H. (1978). *Acta Chem. Scand.*, **32**, 25 and references cited therein.

[3] Nishikawa, M. (1963). *Chem. Pharm. Bull.*, **11**, 977.

[4] Toda, F. and Tanaka, K. (1988). *Tetrahedron Lett.*, **29**, 551.

[5] Toda, F., Tanaka, K., Miyamoto, H., Koshima, H., Miyahara, I. and Hirotsu, K. (1997). *J. Chem. Soc. Perkin Trans.*, **2**, 1877.

[6] Toda, F., Miyamoto, H., Koshima, H. and Urbanczyk-Lipkowska, Z. (1997). *J. Org. Chem.*, **62**, 9261.

[7] Schiessler, R. W. and Flitter, D. (1952). *J. Am. Chem. Soc.*, **74**, 1720.

[8] Debaerdemaeker, T., Germain, G., Main, P., Refaat, L. S., Tate, C. and Woolfson, M. M. (1988). *MULTAN88*. University of York, UK.

[9] Sheldrick, G. M. (1993). *SHELXL-93*, University of Göttingen, Germany.

[10] *teXsan*, 1985 and 1992, Crystal Structure Analysis Package, Molecular Structure Corporation.