Complexation of Some Phenol Hosts with Quinoline *N*-Oxide and the Structural Studies of Their Complexes by X-ray Crystallography

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The 1:1 inclusion complexes of phenol hosts, 4,4′-isopropylidenebisphenol, 4,4′-cyclohexylidenebisphenol, and 4-(1,1,3,3-tetramethylbutyl)phenol, with quinoline *N*-oxide were obtained in good yields. Single-crystal X-ray structural analyses revealed the molecular arrangement of the inclusion complexes.

Heteroaromatic *N*-oxides are unique compounds since the N–O group, which is formed by the overlap of the lone-pair of the N atom with an empty orbital of the O atom, can exhibit both electron-donor and electron-acceptor properties based on the molecular structure and conditions.[1] In organic synthesis, *N*-oxides are frequently employed as not only synthetic precursors, but also ligands and catalysts. Furthermore, *N*-oxides show a significant variety of biological activities and are used as drugs.[2] The study of the molecular interaction of *N*-oxides with organic compounds remains an attractive research area in the field of biological chemistry and supramolecular chemistry as well as organic chemistry.[3,4] In our previous reports, we showed that the simple hosts bearing a bis- or di-phenol unit efficiently included quinoline guests.[5] The hosts create a hydrogen-bonding network and the guests are accommodated through a strong hydrogen bond with the hydroxy group of the phenol unit. During the course of our study on the host–guest inclusion complex, we found that some phenols readily include quinoline *N*-oxide (**1**) (Chart 1) and form 1:1 crystalline complexes. Furthermore, we studied the structures of the inclusion complexes with **1** using single-crystal X-ray analyses.

A typical procedure is as follows: quinoline *N*-oxide (**1**) (1.0 mmol)[6] and phenol **2–7** (Chart 1) (1.0 mmol) were dissolved in toluene (4 mL) at 110 °C. After storage at room temperature, the inclusion complex of good quality suitable for the X-ray analysis was collected by filtration. The results are summarized in Table 1.[7]

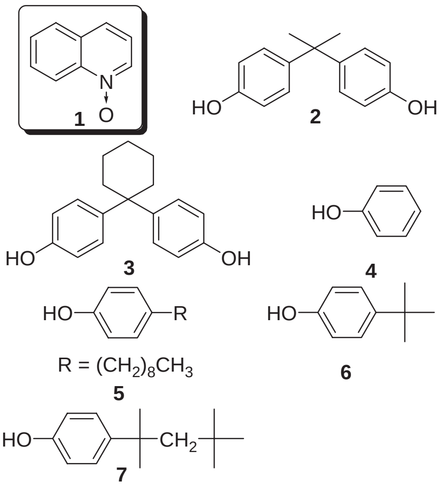

Chart 1.

When **1** and alkylphenols bearing a bis-phenol unit such as 4,4′-isopropylidenebisphenol (**2**)[8] and 4,4′-cyclohexylidenebisphenol (**3**)[9] were dissolved in toluene, a 1:1 inclusion complex was readily obtained in 97 and 91% yields, respectively. On the other hand, the formation of an inclusion complex of alkylphenols bearing a mono-phenol unit (**4–7**) proceeded with selectivity; the complexes of phenol (**4**), 4-nonylphenol (**5**), and 4-*t*-butylphenol (**6**) were not observed at all, whereas 4-(1,1,3,3-tetramethylbutyl)phenol (**7**) gave the unexpected 1:1 inclusion complex with **1** in 90% yield. This unexpected 1:1 ratio of **1** to **7** can also be achieved in $CHCl_3$, AcOEt, THF, acetone, and EtOH (48, 84, 70, 78, and 69%, respectively).

In order to clarify the details of the different interactions between the phenol hosts **2**, **3**, and **7** and guest **1**, the resulting complexes were subjected to single-crystal X-ray structural analyses (Figure 1). The structure of **1** included into **2** corresponds to the molecular arrangement characterized by hosts bearing a bis-phenol unit: two independent hydrogen bonds between the OH hydrogen of host **2** and *N*-oxide of guest **1** are observed, and a two-dimensional hydrogen-bonded network is formed between **1** and **2** as shown in Figure 1a.[10,11] The guest molecules join together these chains via the O1···O2 and O1···O3 bonds (2.668, and 2.689 Å, respectively). On the other hand, a different molecular arrangement is observed in the inclusion complex of **1** with **3** as shown in Figure 1b. It is noteworthy that a cyclic dimer is formed between guests and hosts. The guest **1** is accommodated through two independent hydrogen bonds, and the hydrogen-bond lengths are 2.624 (O1···O2) and 2.673 Å (O1···O3), respectively.[12] In the inclusion complex of a host bearing a bis-phenol unit, cyclic dimer formation is very unique, and it is considered that these different arrangements

Table 1. Inclusion complex of some phenols with **1** in toluene

Phenol	Inclusion ratio (phenol:**1**)[a]	Yield/%	mp/°C
2	1:1	97	150.9–152.4 pale yellow prism
3	1:1	91	170.1–172.7 pale yellow prism
7	1:1	90	137.0–140.0 clear prism

[a]Determined by ^1H NMR.

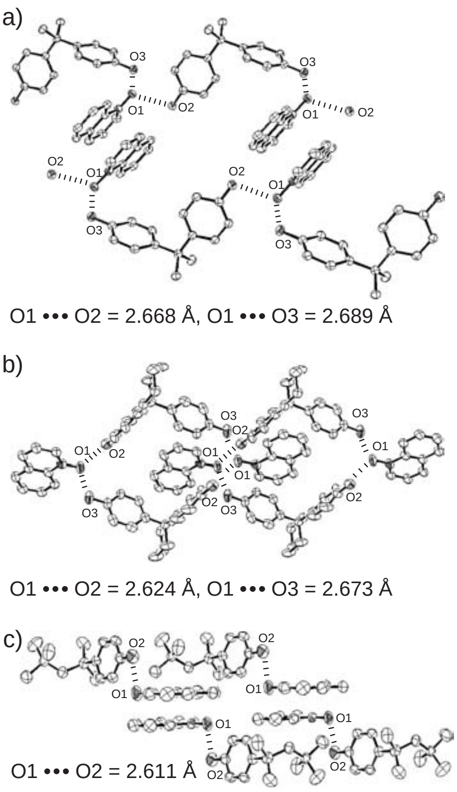

Figure 1. X-ray structure of inclusion complex of hosts **2**, **3**, and **7** with **1**. (a) inclusion complex of **2** with **1**, (b) inclusion complex of **3** with **1**, (c) inclusion complex of **7** with **1**.

depend upon the substrate of the bis-phenol hosts. As shown in Figure 1c, a very different arrangement is observed in the inclusion complex of **7** with **1**; molecule **1** is accommodated only by a hydrogen bond between the OH hydrogen of **7** and *N*-oxide of **1** (O1···O2 2.611 Å), and two **1** molecules are accommodated at a relatively close position (ca. 3.69 Å).[13] It is considered that these factors would play an important role, and molecule **1** is adequately stabilized in the inclusion complex of **7** with **1**.

In conclusion, we have shown that quinoline *N*-oxide (**1**) is readily included into 4,4′-isopropylidenebisphenol (**2**), 4,4′-cyclohexylidenebisphenol (**3**), and 4-(1,1,3,3-tetramethylbutyl)-phenol (**7**). Single-crystal X-ray structural analyses revealed the molecular arrangement of the inclusion complexes. Further detailed applications using the inclusion complex are now in progress.

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References and Notes

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10 A two-dimensional hydrogen-bonded network is generally observed using the hosts bearing the bis-phenol unit, see, Refs. 8 and 9.

11 Crystal data: $C_{15}H_{16}O_2 \cdot C_9H_7NO$ $M_r = 373.43$, triclinic, space group $P\bar{1}$, $a = 9.1679(5)$, $b = 9.9262(7)$, $c = 12.4270(8)$ Å, $\alpha = 93.706(2)$, $\beta = 90.7958(17)$, $\gamma = 119.2115(16)^\circ$, $V = 983.66(11)$ Å^3, $Z = 2$, $D_{\mathrm{calcd}} = 1.261$ g cm^{-3}, $R = 0.0558$, $R_w = 0.1471$, Temperature: 108 K, CCDC deposition number: 650757.

12 Crystal data: $C_{18}H_{20}O_2 \cdot C_9H_7NO$ $M_r = 413.50$, monoclinic, space group $P2_1/c$, $a = 10.027(2)$, $b = 18.751(4)$, $c = 13.911(2)$ Å, $\beta = 124.174(10)^\circ$, $V = 2163.9(7)$ Å^3, $Z = 4$, $D_{\mathrm{calcd}} = 1.269$ g cm^{-3}, $R = 0.1351$, $R_w = 0.3485$, Temperature: 108 K, CCDC deposition number: 650756.

13 Crystal data: $C_{14}H_{22}O \cdot C_9H_7NO$ $M_r = 350.48$, triclinic, space group $P\bar{1}$, $a = 8.3731(7)$, $b = 9.641(1)$, $c = 13.283(2)$ Å, $\alpha = 71.783(6)$, $\beta = 79.461(8)$, $\gamma = 83.485(7)^\circ$, $V = 999.5(2)$ Å^3, $Z = 2$, $D_{\mathrm{calcd}} = 1.164$ g cm^{-3}, $R = 0.076$, $R_w = 0.094$, Temperature: 300 K, CCDC deposition number: 646164.