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New [4 + 4] photodimerization of 5-chloro-2-pyridone to the *meso-cis-syn* dimer as an inclusion complex with 1,2,4,5-benzenetetracarboxylic acid

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As the first example of the [4 + 4] *cis-syn* dimer of 2-pyridone, the *meso-cis-syn* dimer of 5-chloro-2-pyridone was prepared by photoirradiation of a 1:4 inclusion complex of a 1,2,4,5-benzenetetracarboxylic acid host and 5-chloro-2-pyridone in the solid state, and the steric course of the reaction was studied by X-ray analysis.

In relation to damage to DNA by photodimerization of its basic components in nucleotide, photodimerization reactions of 2-pyridone derivatives are very important. However, the photodimerization of 2-pyridones **1** has not been successful, since **1** exists as an equilibrium mixture with corresponding enol forms **2**. For example, the photoirradiation of an equilibrium mixture of **1a** and **2a** in solution for 72 h gave *trans-anti* dimer **3a** in 40% yield.[1] In the crystal, only keto form **1a** exists,[2] but its photoirradiation in the solid state does not give any photodimer. In the case of 5-chloro-2-pyridone **1b**, photoirradiation

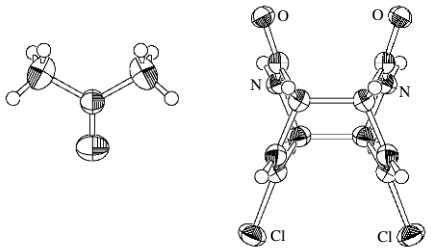
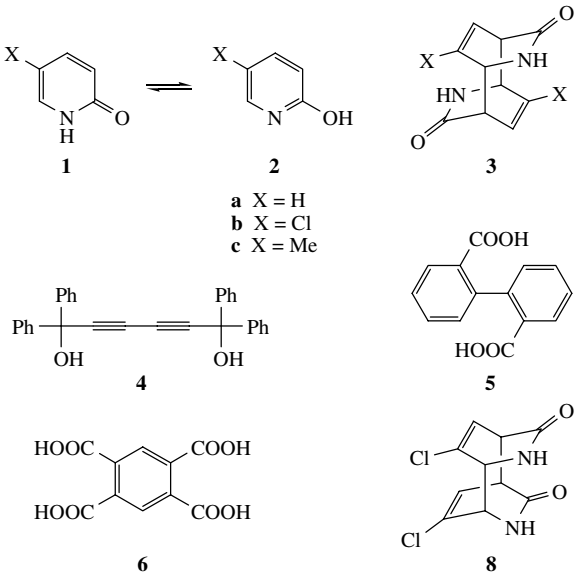


Figure 1 X-ray structure of **9**.

of powdered **1b** for 30 h gave **3b** in 73% yield, although the photoreaction in MeOH for 20 h gave **3b** only in 42% yield.[3] The data suggest that the photoreaction of 2-pyridone in its single crystal is effective. Nevertheless, 5-methyl-2-pyridone **1c** is inert to photoirradiation in the solid state. Finally, it was found that much more efficient photodimerization of **1** proceeds as an inclusion complex with an appropriate host compound. For example, the photoirradiation of a powdered 1:2 inclusion complex of 1,1,6,6-tetraphenylhexa-2,4-diyne-1,6-diol **4** and **1a** for 6 h gave **3a** in 76% yield.[4] By the same method using **4** as a host compound, photodimerizations of various 2-pyridone derivatives to the corresponding *trans-anti* dimers have also been accomplished.[5] A simple host compound such as 1,1′-biphenyl-2,2′-dicarboxylic acid **5** was also found to be useful for the photodimerization of **1a**. Photoirradiation of a 1:2 inclusion complex of **5** and **1a** in the solid state for 20 h gave **3a** in 92% yield.[6] It has been clarified by X-ray analysis that two molecules of **1a** molecules are located in the inclusion complex with **5** at the positions so as to give **3a** by dimerization.[6]



1 **2** **3**

a X = H
b X = Cl
c X = Me

4 **5**

6 **8**

In all of the above cases, however, only *trans-anti* dimer **3** was produced but not the *cis-syn* dimer. As we are aware, no *cis-syn* dimer has been reported thus far. We succeeded in preparing *meso-cis-syn* dimer **8** of **1b** by photoirradiation of 1:4 inclusion complex **7** of 1,2,4,5-benzenetetracarboxylic acid host **6** and **1b**. Recrystallization of **6** (99 mg) and **1b** (101 mg) from MeOH (2 ml) gave 1:4 inclusion complex **7** of **6** and **1b** as colourless crystals (103 mg, 34% yield, mp 202–209 °C). Photoirradiation of powdered **7** (180 mg) in the solid state using a 400 W high-pressure Hg lamp for 100 h gave a crude reaction mixture. The mixture was washed with MeOH (10 ml) to give a solid. ^{1}H NMR analysis showed that the solid consisted of **8** (51% yield) and an unidentified dimer (18% yield). A single crystal of **8** for X-ray analysis was prepared by recrystallization of the mixture containing **8** from acetone (1:1 inclusion complex **9** with acetone). Although **8** is unstable in the mixture with the unidentified dimer, **8** in **9** is stable enough for X-ray analysis.†

The *meso-cis-syn* dimer structure of **8** was elucidated by X-ray analysis of **9** (Figure 1).‡ In order to clarify the steric course of

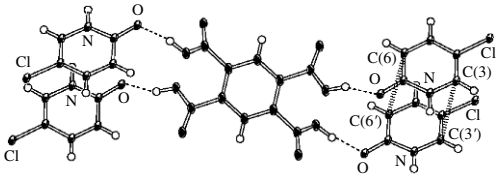


Figure 2 X-ray structure of **7**.

the photodimerization of **1b** to **8** in **7**, the X-ray crystal structure of **7** was also studied.† As shown in Figures 2 and 3, four **1b** molecules bind to one **6** host molecule through hydrogen bond formation. The two relevant hydrogen bonds, COOH···O=C between the host and the guest molecules and NH···O=C between the guest molecules, are shown schematically in Figure 3. In **7**, two **1b** molecules are spatially arranged at very close positions [distances between C(6)–C(6′) and C(3)–C(3′) are 3.59 and 3.85 Å, respectively] as mirror images and their [4 + 4] dimerization should give *meso-cis-syn* dimer **8**. Since a 1:2 inclusion complex of **6** and **1c**, which had been prepared by recrystallization of **6** and **1c** from MeOH as colourless crystals (54% yield,

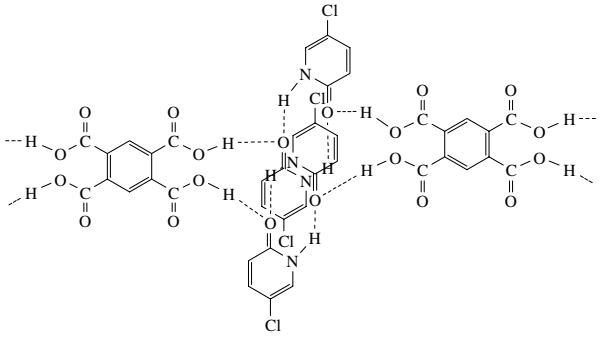


Figure 3 Molecular structure of **7**.

† When a solution of **6** (99 mg, 0.390 mmol) and **1b** (101 mg, 0.782 mmol) in MeOH (2 ml) was kept at room temperature for 12 h, a 1:4 inclusion complex (**7**) of **6** and **1b** was obtained as colourless crystals (103 mg, 34% yield, mp 202–209 °C). The crude product obtained by photoirradiation of powdered **7** (180 mg, 0.233 mmol) in the solid state using a 400 W high-pressure Hg lamp for 100 h was washed with MeOH (15 ml) to give the reaction product as a white solid [mp 183–312 °C (decomp.)]. ^{1}H NMR analysis showed that the solid contains **8** (51% yield) and an unidentified dimer (18% yield).

For **8**: ^{1}H NMR (500 MHz, CF_3COOD) δ: 3.78 (dd, 2H, J 2.4 and 4.6 Hz), 4.47 (br. m, 2H), 5.94 (br. m, 2H). ^{13}C NMR (125 MHz, CF_3COOD) δ: 49.63, 64.72, 126.43, 143.08, 183.61.

When **8** was recrystallised from acetone, a 1:1 inclusion complex **9** of **8** and acetone was obtained as colourless prisms (80% yield, mp was not clear). Photoirradiation of **9** in the solid state for 100 h gave recovered **9** unchanged.

When a solution of **6** (103 mg, 0.404 mmol) and **1c** (85.6 mg, 0.784 mmol) in MeOH (2 ml) was kept at room temperature for 24 h, a 1:2 inclusion complex of **6** and **1c** was obtained as colourless crystals (100 mg, 54% yield, mp 195–199 °C).

‡ *Crystallographic data for* **7**: $C_{10}H_6O_6 \cdot 4(C_5H_4NCl)$, M = 772.34, monoclinic, space group $C2/c$ (no. 15); a = 22.1471(6), b = 10.2111(3) and c = 14.3422(3) Å, β = 90.265(1)°, V = 3243.4(1) Å^3, Z = 4, d_{calc} = = 1.582 g cm^{-3}, T = 173 K, 3089 unique reflections, R_{int} = 0.044 up to a 2θ = 55°, number of parameters = 1151, R_1 = 0.0347, wR = 0.1069, GOF = 0.0997 for 3560 reflections.

Crystallographic data for **9**: $C_{10}H_8N_2O_2Cl_2 \cdot C_3H_6O$, M = 317.17, orthorhombic, space group *Pnma* (no. 62), a = 7.4908(2), b = 11.9813(4) and c = 15.8317(5) Å, V = 1420.89(8) Å^3, Z = 4, d_{calc} = 1.498 g cm^{-3}, T = 173 K, 1573 unique reflections, R_{int} = 0.038 up to a 2θ = 55°, number of parameters = 1439, R_1 = 0.0691, wR = 0.2378, GOF = 1.498 for 1573 reflections.

Atomic coordinates, bond lengths, bond angles and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre (CCDC). These data can be obtained free of charge *via* www.ccdc.cam.uk/conts/retrieving.html (or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336 033; or deposit@ccdc.cam.ac.uk). Any request to the CCDC for data should quote the full literature citation and CCDC reference numbers 257431 and 257432. For details, see 'Notice to Authors', *Mendeleev Commun.*, Issue 1, 2004.

mp 195–199 °C), was inert to photoirradiation, the chlorine atom of **1b** would play an important role in the molecular arrangement, as shown in Figures 2 and 3, and efficient photodimerization in the inclusion complex.

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