

Catalytic promotion of piperonyl alcohol to trimethylenedioxyorthocyclophane by bentonitic earth, or by hydrochloric acid

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Abstract

The cyclooligomerization of piperonyl alcohol (**1**) afforded trimethylenedioxyorthocyclophane (**2**), a novel product, which was promoted by the catalytic action of a commercial bentonitic earth, Tonsil Actisil FF, as well as by hydrochloric acid in 1, 4-dioxane. The structure of **2** was established by ¹H, ¹³C NMR and HMQC experiments (DMSO-d₆ and in the solid state), and by the corresponding mass spectrometric data (EI, CID and HR). © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

The strong driving force to self-condensation of benzylic alcohols bearing electron-donating groups via electrophilic aromatic substitution, provides a common route to obtain cyclotriveratrilene CVT and analogues [1]; thus, several reports have been performed in order to inform about the synthesis of tri, tetra, penta and hexaorthocyclophanes [2–8].

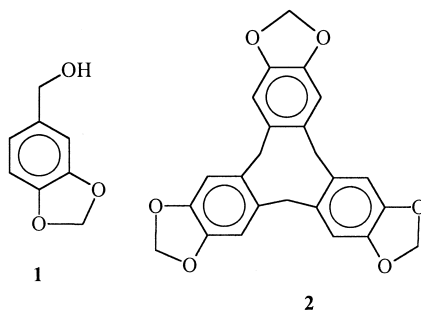
In our research programme [9–11], a commercial bentonitic clay ¹ has played an interesting role as an active catalytic agent, moreover and of particular interest for this work, we have previously

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¹ Tonsil Actisil FF (TAFF), commercial mexican bentonitic clay available from Tonsil Mexicana S.A. de C.V., Mexico City, Mexico at US\$ 0.95/kg. Examined with X-ray fluorescence, this clay proved to have the following composition (in %): SiO₂, 74.5; Al₂O₃, 9.3; MgO, 0.4; Fe₂O₃, 1.3; CaO, 4.0; K₂O, 0.4; TiO₂O, 9.7 (110°C). The clay showed a specific surface area of 190 m²/g; an interlayer distance typical of a montmorillonite 15 Å (2θ = 7) was obtained. When X-ray thermodiffractograms were run, the laminar structure was found to be unstable above 150°C. Quartz and cristobalite are also important components in the clay composition.

described the cyclic and linear oligomerization of 3, 4, 5-trimethoxybenzyl alcohol to the corresponding cyclotrimertrilene analogue [12]. It could be stated that these class of compounds are interesting structures since they furnish cavities for the inclusion of suitable guest species [13].

In this work, we studied the behavior of **1** under the influence of the named clay and also by means of strong acid conditions (HCl/1,4-dioxane) in order to promote the formation of trimethylenedioxy-orthocyclophane (cyclotripiperotrilene, CPT) **2**. At the end point of the named experiments the target molecule was isolated, even quantitatively when HCl was employed.



It is convenient to mention that, Collet, in a review of cyclooveratrilenes and cryptophanes [1], as well as in a previous paper by Lindsey [14], included the structure of **2** as synthesized by an Italian group [15,16]. However, after an exhaustive search in the literature as well as by the study of the original articles mentioned by various authors [7,8,13,14,17–21], we concluded that the structure assigned was a result of a misinterpretation of the reported data. Thus, the aim of this paper is to offer two catalytic procedures for the one pot synthesis of the CPT, as well as its full characterization by physical and spectroscopical means. Moreover, it is appropriate to establish that previous attempts to obtain **2** under various conditions proved futile [8] leading in one case only to the formation of compound **7** by condensation of 6 moles of **1**, in addition to the diarylmethane **6** [15,16].

2. Results and discussion

Various and similar experiments performed with the bentonite and piperonyl alcohol lead up to the following results: When **1** was treated with the clay in 1:1 w/w ratio employing methylene chloride or tetrahydrofuran as solvents at room temperature during 4 h, only the compounds **3–5** were isolated in 19, 16, and 6% yield, respectively. However, when the relation was modified 1:4 w/w ratio using the same solvents in addition to **3–5** (27%) and **6** (4%), the novel molecule **2** was also isolated in 5% yield. Thus, as expected under the employment of the clay to promote the cyclooligomerization of **1** to cyclotripiperotrilene, the precursor is **3** as it was previously reported [7,8]. At this point, an interesting fact was observed when **1** was treated with a mixture of HCl/1, 4-dioxane 3:1 v/v ratio at room temperature, the starting material was totally consumed (6 h) as detected by thin layer chromatography, under these conditions, **2** was isolated in 92.5% yield. It is worth-mentioning that in a set of similar experiments the substrate was treated with HCl/1, 4-dioxane at different ratios producing the expected molecule at lower yields (Fig. 1). Furthermore, analogous experiments performed under lower reactions times (1–5 h) proved to be futile in order to obtain the target

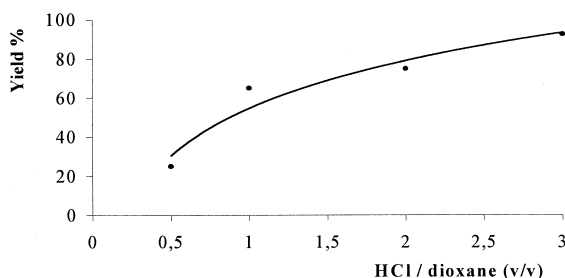
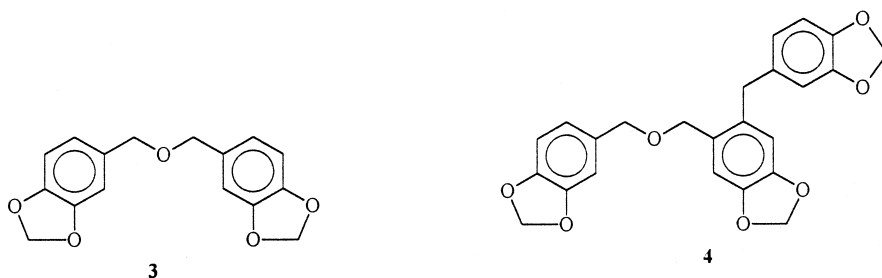


Fig. 1. Promotion of CPT using various ratios of HCl/1,4-dioxane (v/v): 456 mg (1 mmol) of **1**; 5, 10, 20, and 30 ml of HCl and 10 ml 1,4-dioxane; 6 h. Each point is the average of three events.

molecule. After all these results, we envisaged that the optimum conditions corresponds to the 3:1 ratio of HCl/1, 4-dioxane (v/v) during 6 h at room temperature.



Consequently, the oligomerization of piperonyl alcohol as reported by Cruz-Almanza et al. [8], must proceed through the ether intermediate **3** under the use of the bentonitic clay, and when the mineral acid HCl in 1,4-dioxane is used, the driving force to produce **2** should be a carbenium intermediate, followed by a successive electrophilic aromatic substitution leading to the target compound.

In other words, it seems that when the clay is used the reaction goes through an interlamellar pathway which promotes the formation of open oligomers (steric hindrance), this last and the high initial concentration of piperonyl alcohol must give mainly the precursor **3**. On the other hand, under the presence of a strong proton media, the formation of this species is avoided, and without “cavity restrictions” the reaction should proceed by a carbocation providing **2**.

For the structural attribution of the target molecule, we envisaged that the high resolution data of the main fragments originated by EIMS as well as the CID-daughter peaks [22] for such ions (Table 1), were in agreement with the orthocyclophane moiety; in addition, an interesting fact was that the molecular radical ion **a** led directly to the fragments **b–d**.

Table 1
Daughter ions of the main fragments generated by linked-scans and high resolution data from molecule **2**

Fragment	Assignment	Composition	m/z observed (% ra)	Daughter ions (m/z) ^a
a	$M + \cdot$	$C_{24}H_{18}O_6$	402.1093 (98.5)	387, 372, 267
b	$[M-CH_3]^+$	$C_{23}H_{15}O_6$	387.0836 (33.5)	357, 329, 299, 267
c	$[M-CH_2O]^+$	$C_{23}H_{16}O_5$	372.0978 (32.7)	355, 344, 313, 202
d	$[M-C_8H_7O_2]^+$	$C_{16}H_{11}O_4$	267.0646 (100)	332, 215

^aAcquired by CID (Linked-scans at constant B/E).

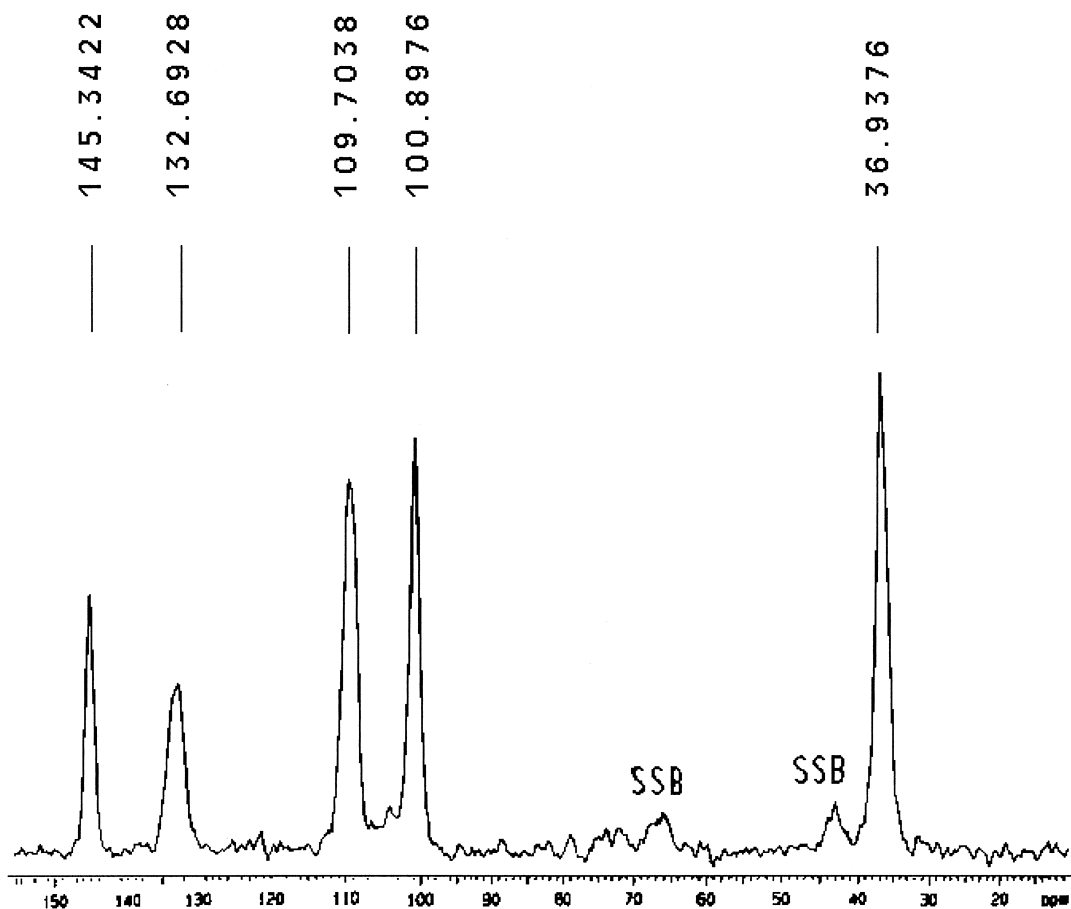


Fig. 2. CP-MAS, ^{13}C NMR (solid state) of CPT.

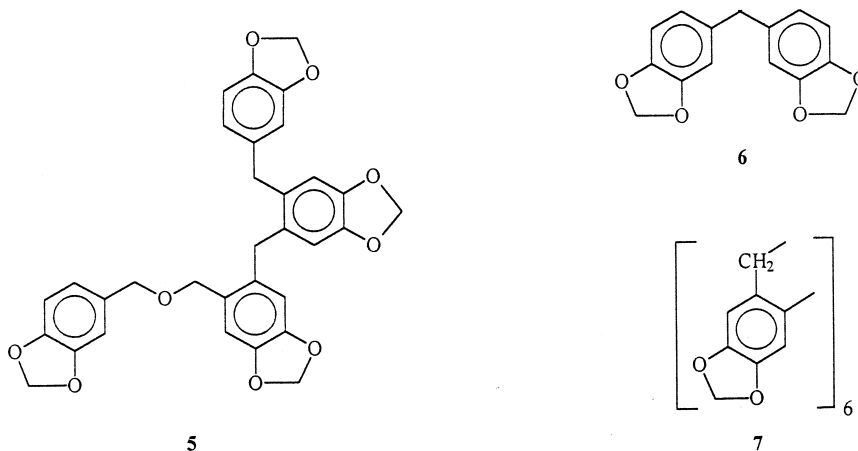
As expected, the CPT a C_3 trimer in connection to its congeners, must have a rigid crown conformation, as it was established to its analogues by X-ray crystallography [23], and by ^1H NMR spectra showing a characteristic AB system of the methylene bridges [24]. This information is in agreement with **2**, since its ^1H NMR spectrum displays two typical doublet signals of an AB system at δ_{A} 4.723 ($J = 13.7$ Hz) and δ_{B} 3.451 ($J = 13.7$ Hz), both signals corresponding to the diastereotopic

Table 2
HMQC data of CPT

Assignments ^a	$^1\text{H}/^{13}\text{C}$ Correlation δ (ppm)
C-4,4'	AB 4.723 and 3.451/36.937
C-5	AB 5.895 and 5.77
C-2,2'	7.001/109.703
C-3,3'	–
C-1,1'	–

^aSee Fig. 3 for assignments.

Treatment of **1** with TAFF 1:1 w/w ratio, only ether **3** (19%), oligomers **4** (16%) and **5** (6%) were obtained. This alcohol with 1:4 clay w/w ratio: ether **3** (8%), oligomers **4** (13%), **5** (6%), biphenylmethane **6** (4%) and **2** (5%) were isolated.



5. Formation of trimethylenedioxyorthocyclophane (**2**) with HCl/1,4-dioxane

5.1. General procedure

A total of 456 mg of **1** was vigorously stirred at room temperature in the presence of 30 ml of concentrated HCl and 10 ml of 1,4-dioxane. The advancement of the reaction was determined by *tlc* until the disappearance of the substrate during 6 h and the appearance of a white powder. The resulting mixture was filtered in hot, the solid obtained was washed with *n*-hexane, CHCl₃ and EtOH, then it was dried under vacuum. Finally, **2** was isolated 372 mg (92.5%) as white amorphous powder; mp, decompose over 300°C; highly insoluble in common solvents; slightly soluble (hot) in DMSO.

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