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THE STRUCTURE OF $C_{20}H_{18}O_3$, A PRODUCT OF THE REACTION OF ACETOPHENONE WITH FORMALDEHYDE IN ACIDIC MEDIA[1, 2]

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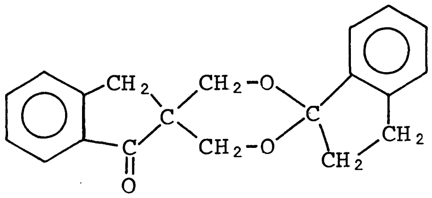
The chemical structure of $C_{20}H_{18}O_3$ (I) which is a crystalline product obtained from the acidic condensation of acetophenone with formaldehyde has been established as 1-benzoyl-4-methylene-5-phenyl-6,8-dioxacyclo[3,2,1]octane. This compound is identical with the product, $C_{20}H_{18}O_3$, isolated by Beets and Heeringa from the Prins reaction of phenylacetylene. The formation mechanism has also been proposed.

The acidic condensation of acetophenone with formaldehyde is complicated and therefore gives many intricate products. Only a few of them such as phenyl vinyl ketone, 5-benzoyl-1,3-dioxane and the titled compound (I), mp 91-91.5°C, were isolated by one of the present authors.[3]

Oximation of I in pyridine gave monooxime (II), mp 159-160°C. The physical constants of I and the oxime implied that the compound I must be identical with a product isolated by Beets and Heeringa from the Prins reaction of phenylacetylene in 1955.[4] They have proposed a hypothetical structure for it, that is,



[5]

III

Recently, our inspection of the IR data of I suggested that this compound might have one or two monosubstituted benzenes (two strong absorption bands at 752 and 703 cm^{-1}). The further MS and NMR data have confirmed the existence of benzoyl and phenyl groups in I (ten protons of aromatic by NMR, and benzoyl and phenyl ions by MS). The residual eight protons are roughly separated into two groups in the NMR (Fig. 1). The four among them are in the 7-8τ region (13.5 mol% in $CDCl_3$; He, f, g and h are roughly estimated from the low field side; all multiplets) and the other four in 5-6τ (Hd, b, c and a from the same side). While the analyses of the high field protons are very difficult because of their similar chemical shifts and complicated spin-spin interactions, all the low field protons are assigned respectively to two of a vinylidene group [Hc centered at 5.74

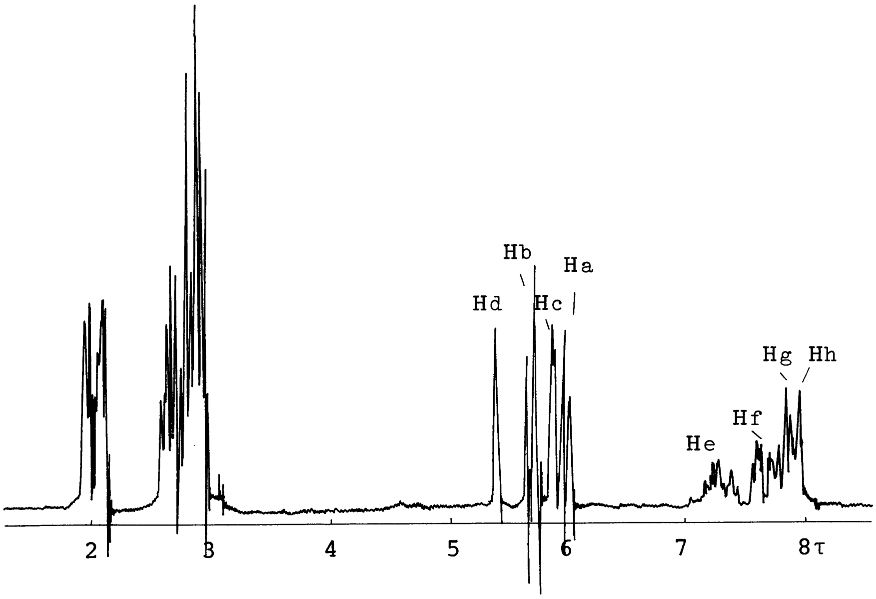
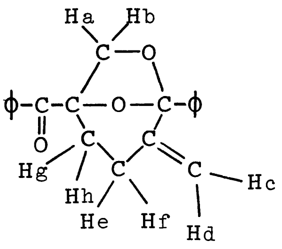


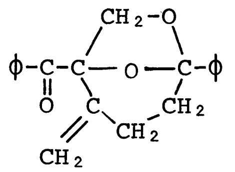
Fig. 1. 100MHz NMR spectrum of I (13.5 mol% in $CDCl_3$).

and Hd at 5.25τ, doublet of doublet; J_{cd}=1, and another J=1.5 Hz (long-range coupling)] and two of a methyleneoxy (AB; dd; Ha centered at 5.85, Hb at 5.56τ, J_{gem}=8 Hz). Since the further splits of the proton Ha (J=1.5 Hz) seem to be by a long-range coupling with one of the high field protons (maybe with Hg), this oxymethylene must link to two quaternary carbon atoms. The geminal coupling constant between these methylene protons (Ha and Hb) was 8 Hz, and this fact suggests that the size of the ring containing this methyleneoxy group may be rather a five-membered ring than a six-membered one.$^{6)}$

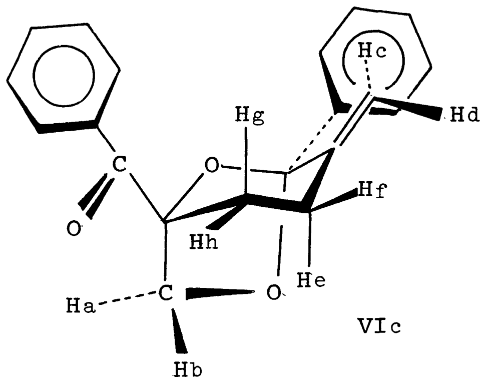
Sodium borohydride reduction of I in ethanol gave a mixture of isomeric secondary alcohols. One of the isomers, $C_{20}H_{20}O_3$ (IV), mp 139-141°C, was isolated after repeated recrystallizations from petroleum benzine, and this showed no other conjugation system than the original benzene rings in UV. Bromination of IV in acetic acid easily gave its dibromide (V), mp 177-178°C, which showed a 1,2-dibromoethylidene group in NMR ($BrCH_2CBr=$, AB; dd; J_{gem}=11 Hz). Here the original existence of a carbon-carbon double bond, a vinylidene group, in I was confirmed clearly, and therefore the number of rings which I contains must be two other than the two benzene rings. From the NMR split patterns of the hydroxyl proton (d, J=1.8 Hz, verifying a secondary alcohol) and benzylidene proton (d, J=1.8 Hz) of IV, the benzoyl group of I must link to a quaternary carbon atom. Also the last oxygen atom is adjacent to two quaternary carbons. An application of NMR double resonance technique operated at 100 MHz showed that only one proton, He, in the high field group couples with two protons of the vinylidene.$^{7)}$ Supposing a ketal structure in I by the Beets's oximation and hydrogenation results, we arrived at the two possible structures as VIa and VIb.



VIa



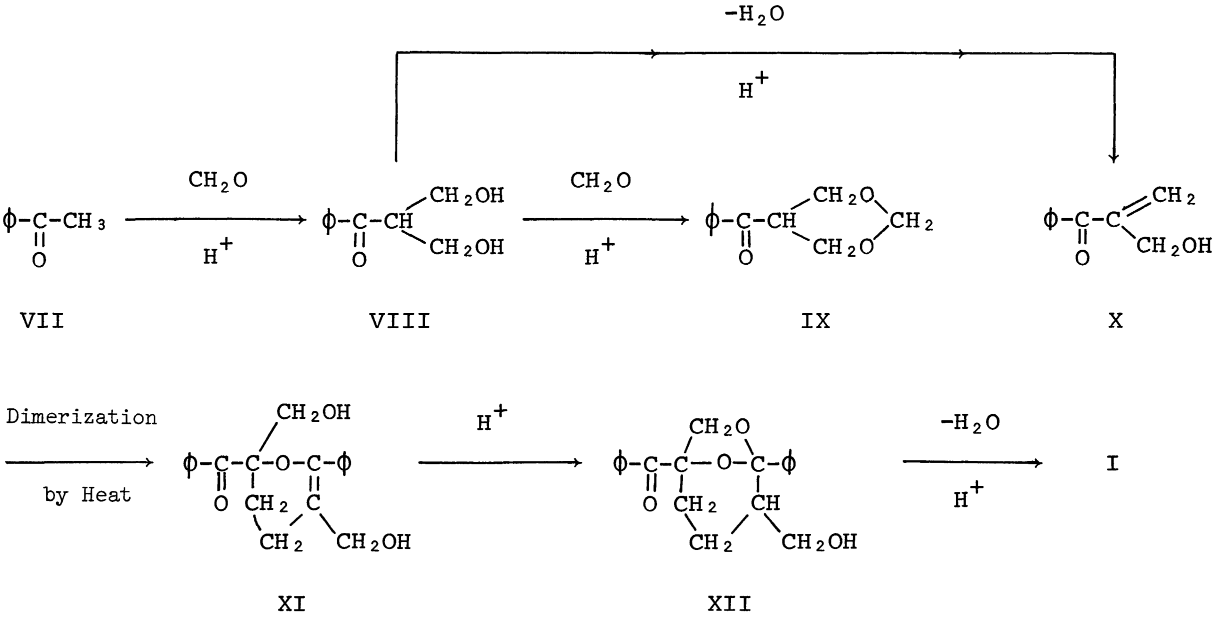
VIb



VIc

Here, comparing the NMR data of I and of the derivatives, we can say which formula is better. Changing the benzoyl group of I to the oxime (II) or to the secondary alcohol (IV) gave much more effects to the protons Ha, Hb, Hg and Hh (shifted to the higher field, the assumed centers of the multiplets of Hg and Hh being compared for convenience.) than to the Hc and Hd, while in the IV-dibromide (V) the He and Hf moved to the high field side more largely than the Hg and Hh, and the protons a and b remained unchanged. The chemical shift of Hc of I at elevated temperature moves to the lower field. That is, four protons, a, b, g and h are near to the benzoyl group, and the hydrogens c and d, especially c, are close to the phenyl, and the structure VIa is therefore the most probable. We image a steric formula like VIc7) at present. Construction of the molecular models of VIc is quite easy.

As to the formation mechanism of I, the following is possible.



VII VIII IX X

XI XII

The direction of this dimerization (X → XI) can be supported by many examples of the similar reactions of Diels-Alder type,$^{9)}$ and the subsequent cyclization of XI to XII also.$^{10)}$ In fact, we have just succeeded in an isolation of I besides formaldehyde on acid hydrolysis of 5-benzoyl-1,3-dioxane (IX) under heating.

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1) Paper presented by A. Terada at the Kumamoto meeting of the Chemical Society of Japan, and the Japan Society for Analytical Chemistry, Kumamoto, October 1971.

2) For preceding papers of this series, see A. Terada and A. Hassner, Bull. Chem. Soc. Japan, 42, 2666 (1969).

3) A. Terada, Nippon Kagaku Zasshi, 81, 612 (1960); The mp 89-91°C was previously reported.

4) M. G. J. Beets and L. G. Heeringa, Rec. trav. chim., 74, 1085 (1955).

5) They reported that their product, $C_{20}H_{18}O_3$, mp 91.4-91.7°C, showed the following results: (i) One mole of I absorbed 2 moles of hydrogen over Adams Pt catalyst at room temperature, and another mole of hydrogen gradually. The acetophenone-carbonyl of I disappeared in UV by this hydrogenation. (ii) One mole of hydroxylamine reacted with one mole of I rapidly and 1.5 moles of the reagent was consumed during two days. The mp of the monooxime was 158.2-159.2°C. (iii) No absorption of bromine in CCl_4. (iv) No formal structure. (v) The yields of I were 1/2% from phenylacetylene and 5% from phenylpropynol, respectively. From these results and a presumable formation of α-indanone in their preparation, they proposed the hypothetical structure (III) as illustrated above.

6) L. M. Jackman and S. Sternhell, "Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry" 2nd ed., Pergamon press, London (1969) p. 277.

7) No spin-spin coupling between protons f and c, f and d may show their coplanarities.$^{8)}$

8) Ref. 6, p. 316.

9) C. W. Smith, D. G. Norton, and S. A. Ballard, J. Am. Chem. Soc., 73, 5273 (1951).

10) For example, Y. Nishimura and T. Tanaka, Kogyo Kagaku Zasshi, 70, 466 (1967).

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