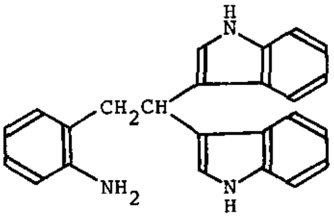
HETEROCYCLES, Vol 12, No.4, 1979

# A NOVEL INDOLE TRIMER; DIINDOLO[2,3-a: 2',3'-c]CARBAZOLE[1]

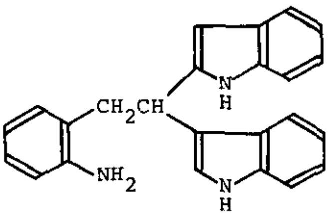
Takao Kaneko and Mitsuyoshi Matsuo*
Tokyo Metropolitan Institute of Gerontology, 35-2 Sakaecho,
Itabashiku, Tokyo 173, Japan
Yoichi Iitaka
Faculty of Pharmaceutical Sciences, University of Tokyo,
Bunkyoku, Tokyo 113, Japan

Abstract —— The reaction of indole with a mixture of $TiCl_3$ and $H_2O_2$ gives a novel indole trimer, diindolo[2,3-a: 2',3'-c]-carbazole (3), whose structure has been determined spectrometrically and confirmed from the structure determination of its acetyl derivative (4a) by X-ray crystallography.

Indole is easily polymerized under acidic conditions to give a dimer and a trimer.[2] The structure of the trimer is formulated as (1).[3] Recently, another trimer (2) has been obtained by Ishii et al.[4] We now wish to report the formation of diindolo[2,3-a: 2',3'-c]carbazole (3), a novel heterocyclic system which is derived from an asymmetric fusion of three indole molecules.

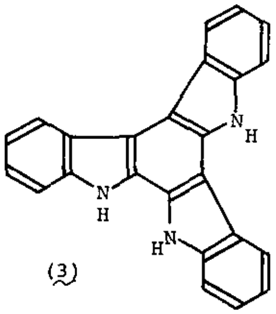


(1)

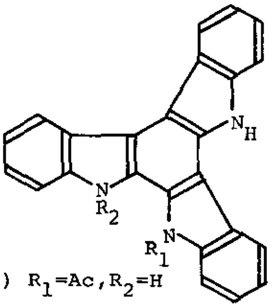


(2)

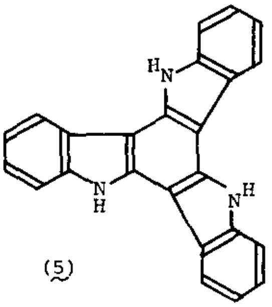
When indole was treated with a hydroxyl-radical-generating $TiCl_3$-$H_2O_2$ system[5] for 15 min at pH 1.0 below 20 °C under a nitrogen atmosphere, a light-labile product (3), besides oxindole and 2,3'-diindolyl, was isolated [(3), 8.1 % yield, $C_{24}H_{15}N_3$, mp 302 - 304 °C (decomp.) from hexane - THF; $\nu_{max}$ (KBr) 3390 $cm^{-1}$ (NH); $\lambda_{max}$ (EtOH) 215.5, 253.5, 271.5sh, 298, 305, 317sh, 333, 346.5, and 373 nm (log $\varepsilon$ 4.62, 4.91, 4.23, 4.74, 4.81, 4.39, 4.45, 4.62, and 4.24, respectively); m/e 345 ($M^+$, 100 %) and 172.5 ($M^{2+}$, 25 %)].[6] Its $^1$H nmr spectrum showed signals for NH groups at δ 11.68 (3H, br.s) and for aromatic protons at 7.49, 7.87, and 8.91 (6H, 3H, and 3H, each m, respectively), and its $^{13}$C nmr spectrum showed the presence of only aromatic carbon atoms absorbing in the range from 105.9 to 138.9 ppm. On the basis of elemental analysis and spectroscopic data, this product is suggested to correspond to three indole molecules losing six hydrogen atoms.



(3)



(4a) $R_1$=Ac,$R_2$=H
(4b) $R_1$=H,$R_2$=Ac



(5)

Acetylation of this compound (3) with acetic anhydride in the presence of sodium acetate gave two kinds of the mono-N-acetyl derivatives (84.3 % yield), which contained (4a) and (4b) in a ratio of 4 : 1 as estimated by gas chromatography. This result excludes the idea that (3) is the symmetric trimer (5), since (5) must give only a kind of the mono-N-acetyl derivative. When the solution containing (4a) and (4b) were made basic with a solution of sodium hydroxide, their uv spectra were immediately changed into that of (3). Although the minor acetate (4b) has not been isolated, the spectral data of the mixture of (4a) and (4b) suggest its structure is isomeric with that of (4a) in regard to a nitrogen atom attaching to an acetyl group.[7] The nmr spectrum of one (4a) of the acetates [(4a), mp 304 - 306 °C (decomp.) from hexane - THF; $\nu_{max}$ (KBr) 3390 cm$^{-1}$ (NH) and 1655 ($\underline{C}OCH_3$); m/e 387 ($M^+$, 95 %)] purified by fractional crystallization exhibited signals for NH groups at δ 11.14 (1H, br.s) and 11.91 (1H, br.s), for an acetyl group at 3.08 (3H, s), and for aromatic protons at 7.41, 7.90, 8.17, and 8.90 (6H, 2H, 1H, and 3H, each m, respectively). The nmr spectrum of a nearly equimolar mixture of (4a) and (4b) showed signals for NH groups at δ 11.16 (1H, br.s) and 12.12 (1H, br.s), and for an acetyl group at 3.06 (3H, s) in addition of the signals assigned to (4a). Furthermore, these results support that the indole trimer obtained is fully aromatized like (3). In order to confirm the structure of (3) being light-labile in the air, the structure of (4a) has been determined by single-crystal X-ray diffraction analysis.

Crystal data: Very thin platy crystals of (**4a**) with approximate dimensions of 0.3 X 0.3 X 0.01 mm were grown in hexane - THF solutions. Space group $P2_1/a$, a = 16.851(15), b = 8.562(8), c = 13.046(13) Å, $\beta$= 102.13(8)°, U = 1840.2 $Å^3$, $D_x$ = 1.40 g $cm^{-3}$, Z = 4. The intensities of 884 independent reflexions with $2\theta$ angles less than 130° were measured on Philips PW 1100 four-circle diffractometer using Cu-$K_\alpha$ radiation monochromated by a graphite plate. The crystal was rather strong against X-ray irradiation and the intensities of three standard reflexions were reduced only 2.3 % during the intensity measurement. The structure was solved by the direct method and refined by the block-diagonal method to an R value of 0.104 without hydrogen atom.

An ORTEP drawing of the molecular structure is shown in the Figure 1.[8] The central benzene ring and three indole rings substantially are coplanar, the average value of the deviations of atoms in each ring being 0.02 - 0.04 Å, so that all the carbon atoms in this system are expected to be conjugated with each other.

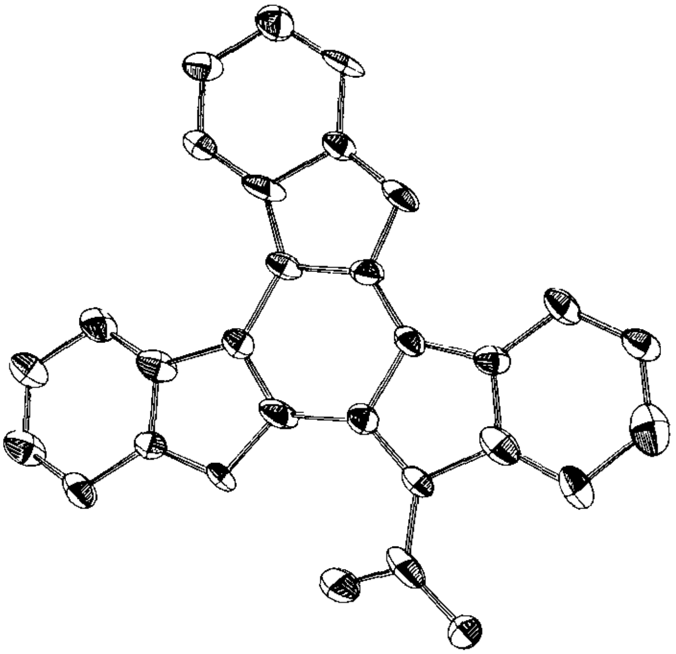
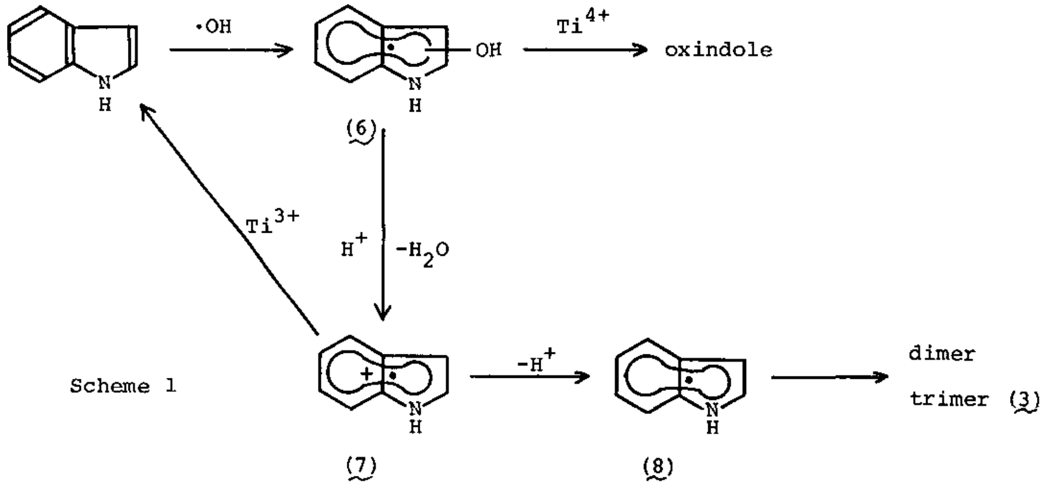


Figure 1. ORTEP drawing of the structure of (**4a**).

From a consideration of the proposed reaction mechanism of the oxidation of aromatic compounds with Fenton's reagent,[9,10] radicals (**6**), (**7**), and (**8**) are presumed to be the intermediates of the reaction products. It is likely that radical (**6**) initially formed is either oxidized to oxindole or converted to radical cation (**7**). (**7**) may be either reduced with $Ti^{3+}$ to give the starting material or polymerized to give diindolyl and diindolocarbazole (**3**). A possible pathway for the formation of the products under acidic conditions is shown in Scheme 1. This is quite interesting as compared with the fact that protonation of indole leads to the formation of (**1**) and (**2**).[3,4]



Scheme 1

References

1. TMIG-I No.19
2. G. F. Smith, 'Advances in Heterocyclic Chemistry,' Vol. 2, ed. A. R. Katritzky, Academic Press, New York, 1963, p. 300.
3. G. F. Smith, Chem. & Ind. (London), 1954, 1451.
4. H. Ishii, K. Murakami, Y. Murakami, and K. Hosoya, Chem. Pharm. Bull. (Tokyo), 1977, **25**, 3122.
5. H. Taniguchi and H. Hatano, Kagaku No Ryoiki, 1974, **27**, 785, and references cited therein [e.g., C.R.E. Jefcoate and R.O.C. Norman, J. Chem. Soc.(B), 1968, 48].
6. Analysis calcd. for $C_{24}H_{15}N_3$: C, 83.46; H, 4.38; N, 12.17. Found: C, 83.26; H, 4.38; N, 12.08. The starting material was recovered in the range from 10 to 45 %, and significant amounts of highly polar materials were formed.
7. The mass spectrum of (**4b**), contaminated by small amounts of the isomer (**4a**), were superimposable with that of (**4a**).
8. C. K. Johnson, ORTEP Report ORNL-3794, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1965.
9. R. O. C. Norman and R. J. Prichett, J. Chem. Soc. (B), 1967, 926.
10. C. Walling and R. A. Johnson, J. Am. Chem. Soc., 1975, **97**, 363.

Received, 21st December, 1978