Photochemical Reactions of Non-enolizable α-Keto-esters Derived from Dehydroginkgolide A

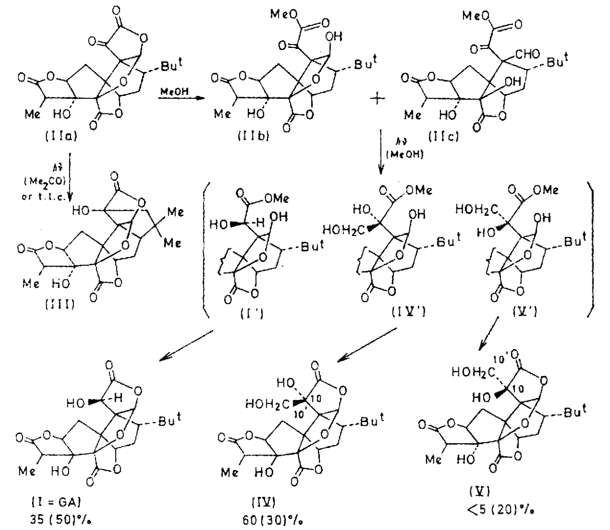
By Y. NAKADAIRA, Y. HIROTA, and K. NAKANISHI*†
(*Department of Chemistry, Tohoku University, Sendai, Japan*)

Summary Photoirradiation of the non-enolizable α-keto-ester (VI) in perdeuteriomethanol has shown that an intramolecular hydrogen abstraction gives the reduction product (VII), whereas an intermolecular hydrogen abstraction gives the adduct (VIII).

THE oxidation product of ginkgolide A (I) (GA),[1a–g] dehydro-GA (IIa), undergoes an extremely easy photocyclization in acetone to yield the rigid cage molecule photodehydro-GA (III).[1d,f] Since dehydro-GA (IIa) exists as a *ca.* 4 : 1 mixture of (IIb) and (IIc) in methanol,[2] it was expected that the reaction course would differ.

Irradiation of the equilibrium mixture of (IIb) [λ_{max} (MeOH) 333 nm., ϵ 35] and (IIc) [λ_{max} (MeOH) 265 nm., $\epsilon_{calc.}$ 4400] in methanol with a high-pressure Hg lamp for 1 hr. and separation of the products by silica gel chromatography indeed gave, in a 60% yield, GA (I)‡ and stereoisomers (IV) and (V), indicating that the primary products were presumably the stereospecifically reduced (I′) and the two methanol adducts (IV′) and (V′): compound (IV), m.p. 240°, $C_{21}H_{26}O_{10}$ (M^+, *m/e* 438); i.r. (KBr) 3520, 3450, 1792, and 1777 cm^{-1}; n.m.r. [$(CD_3)_2CO$] 3·80 (dd, *J* 4·6 and 12·5, 10′-H), 4·05 (dd, *J* 7·3 and 12·5, 10′-H), 4·48 (dd, *J* 4·6 and 7·3, 10′-OH), 5·12 p.p.m. (s, 10-OH); compound (V), m.p. 242—245°; i.r. (KBr) 3450, 1782 cm^{-1}; n.m.r. [$(CD_3)_2CO$] 3·71 (dd, *J* 2·5 and 6·7, 10′-OH), 3·87 (dd, *J* 6·7 and 11·0, 10′-H), 4·75 (dd, *J* 2·5 and 11·0, 10′-H), 5·50 p.p.m. (s, 10-OH). Isomers (IV) and (V) were differentiated by the observation of a *ca.* 25% NOE at 10-OH upon irradiation of the Bu^t group in the former compound. The other n.m.r. signals of (IV) and (V) are very similar to those of dehydro-GA (IIa): hence their structures are established. No photodehydro-GA (III) could be detected in the reaction mixture.

Similar irradiation of the ester acetal (VI),[2] having a chromophore closely related to (IIb), gave the reduction product (VII, R = H)‡ in 55% yield and the methanol adduct (VIII, R = H), 30%, m.p. 214—216°; i.r. (KBr) 3480, 1780, 1745 cm^{-1}; n.m.r. [$(CD_3)_2CO$] 3·77 (dd, *J* 7·8 and 10·8, 10′-H), 3·88 (dd, *J* 5·1 and 10·8, 10′-H), 4·14 (dd, *J* 5·1 and 7·8, 10′-OH), 4·68 p.p.m. (s, 10-OH). The configuration at C-10 (VIII; R = H) is as yet undetermined but as only one adduct was formed the methanol addition proceeds stereospecifically.



Numerals outside and inside parentheses represent, respectively, relative yields of photoproducts upon irradiation with high- and low-pressure Hg lamps.

Although such methanol additions have been reported for nonenolizable α-diketones,[3] there appears to be no recorded case for α-keto-esters, which usually undergo photoreduction and photodimerization in alcoholic solvents.[4] On irradiation of the ester acetal (VI) in perdeuteriomethanol, compounds (VII; R = D) and (VIII; R = D) were obtained.§ These results show two concurrent mechanisms: (i) an intramolecular hydrogen abstraction

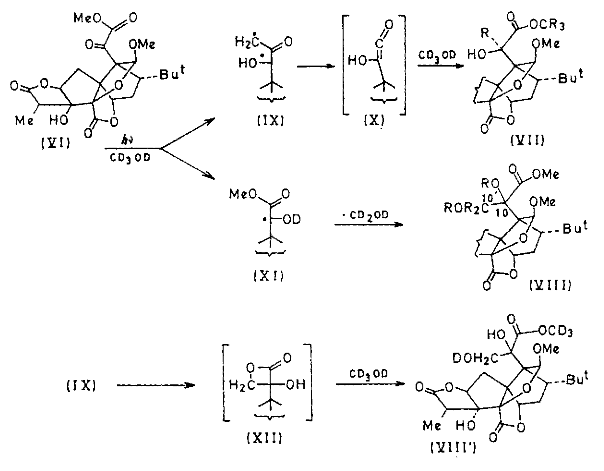
---

† Present address: Department of Chemistry, Columbia University, New York.

‡ Identifications by comparison of spectroscopic properties with those of authentic samples.

§ Positions of D atoms are based on n.m.r. spectra. The assignment of two methoxyl signals rests on small couplings of the acetal proton to the methoxyl group. The hydroxylic D atoms in (VIII) are exchanged with H atoms during isolation.

gives the biradical (IX) which is converted into the photoreduction product (VII) *via* the hydroxy-keten (X); this course is in agreement with that suggested by Neckers and co-workers;[4a,4d] (ii) an intermolecular hydrogen abstraction from the solvent gives the radical (XI) which subsequently adds CH_2OH to give (VIII). This adduct is not formed *via* the β-lactone (XII)[5] in the present case, because if this were the case the deuterium would be distributed as in (VIII′).



The stereospecificity in the formation of (VII) and (VIII) is probably due to steric hindrance by the Bu^t group. Each component of the mixture of (IIb) and (IIc) would likewise be expected to afford stereospecific adducts. Thus only one photoreduction product GA (I) is formed; the fact that both of the C-10 epimers (IV′) and (V′) are produced implies that the conformations of the keto-ester chains in (IIb) and (IIc) are different. In fact, irradiation with a low-pressure Hg lamp for 1 hr., which would increase the light absorbed by the aldehyde keto-ester (IIc), greatly enhanced the yield of stereoisomer (V), (overall yield 60%).

This research was supported by the National Institutes of Health and by a Grant-in-Aid from the Ministry of Education.

(*Received, August 8th,* 1969; *Com.* 1225.)

---

[1] (a) M. Maruyama, A. Terahara, Y. Itagaki, and K. Nakanishi, *Tetrahedron Letters*, 1967, 299; (b) *ibid.*, p. 303; (c) M. Maruyama, A Terahara, Y. Nakadaira, M. C. Woods, and K. Nakanishi, *ibid.*, p. 309; (d) M. Maruyama, A. Terahara, Y. Nakadaira, M. C. Woods, Y. Takagi, and K. Nakanishi, *ibid.*, p. 315; (e) M. C. Woods, I. Miura, Y. Nakadaira, A. Terahara, M. Maruyama, and K. Nakanishi, *ibid.*, p. 321; (f) K. Nakanishi, *Pure Appl. Chem.*, 1967, **14**, 89; see also (g) N. Sakabe, S. Takada, and K. Okabe, *Chem. Comm.*, 1967, 259.

[2] Y. Nakadaira, Y. Hirota, and K. Nakanishi, preceding communication.

[3] (a) G. E. Gream, J. C. Price, and C. C. R. Ramsey, *Austal. J. Chem.*, 1967, **20**, 1671; (b) B. M. Monroe and S. A. Weiner, *J. Amer. Chem. Soc.*, 1969, **91**, 450, see also, M. B. Rubin and R. G. La Barge, *J. Org. Chem.*, 1966, **31**, 3283.

[4] (a) E. S. Huyser and D. C. Neckers, *J. Org. Chem.*, 1964, **29**, 276; (b) N. C. Yang and A. Morduchowitz, *ibid.*, p. 1654; (c) D. S. Kendall and P. A. Leermarker, *J. Amer. Chem. Soc.*, 1966, **88**, 2766; (d) D. C. Neckers, "Mechanistic Organic Photochemistry," Reinhold, New York, 1967, p. 180.

[5] (a) P. Yates and A. G. Szabo, *Tetrahedron Letters*, 1965, 485; (b) W. H. Urry and D. J. Trecker, *J. Amer. Chem. Soc.*, 1962, **84**, 118; W. H. Urry, K. J. Trecker, and D. A. Winey, *Tetrahedron Letters*, 1962, 609.