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2-AZABICYCLO[3.2.0]HEPTANE-3,4-DIONES (2): STEREOCHEMISTRY OF THE PHOTO-CYCLOADDUCTS OF 3-ETHOXYCARBONYL-2-PHENYL-Δ^2-PYRROLINE-4,5-DIONE WITH SUBSTITUTED OLEFINS.[1]

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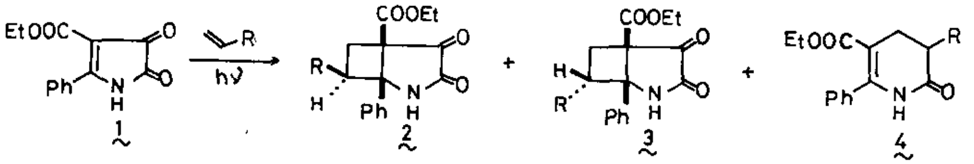
The stereochemistries of photo-cycloadducts of 3-ethoxycarbonyl-2-phenyl-Δ^2-pyrroline-4,5-dione with substituted olefins were established by chemical and spectroscopic means. Styrene- and butadiene-major adducts were 7-*exo* -isomers, while ethyl vinyl ether- and vinyl acetate-major adducts were 7-*endo*-isomers. The 7,7-disubstituted derivative, the isopropenyl acetate-adduct, was also established as an O-*endo*-isomer.

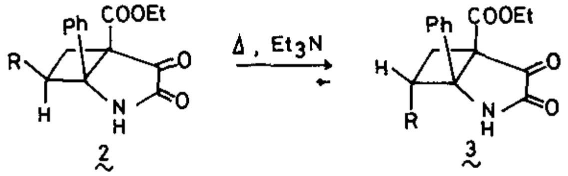
Photo-cycloaddition of 3-ethoxycarbonyl-2-phenyl-Δ^2-pyrroline-4,5-dione (1) with a substituted olefin gives a 7-substituted 2-azabicyclo[3.2.0]heptane-3,4-dione (2 or 3) with high regio- and stereo-selectivity[2], usually accompanied by a small amount of its isomer (3 or 2)[2] and a dihydropyridone (4)[3]. For the stereochemistry of the major product, the configurations of 7-substituent of styrene- and butadiene-adduct were elucidated as *exo* (2a and 2b)[2] on the basis of X-ray analyses of the corresponding N-4′-bromophenyl derivatives, respectively.[4,5] The others, however, are speculated only on reaction analogy with 2a and 2b, hence requiring rigid proofs.



a: R=Ph, b: R=-CH=CH$_2$, c: R=OEt , d: R=OAc

Recently, we found that a 7-substituted-2-azabicyclo[3,2,0]heptane-3,4-dione epimerizes at C_7 on mild base treatment giving rise to a thermodynamically more stable isomer predominantly.[6]

Thus, 7-*exo*-phenyl derivative (2a)(the major styrene-adduct) epimerizes to the more stable 7-*endo*-phenyl isomer (3a)(the minor styrene-adduct), indicating that the *endo*-isomer is thermodynamically more stable than the *exo*-isomer. This finding provided a method to determine the stereochemistry of 7-substituted-2-azabicyclo[3.2.0]heptane-3,4-diones. Examination of all above photo-cycloadducts by this method revealed some unexpected results.



When the photo-cycloadduct of ethyl vinyl ether[2] was heated with 10%NEt_3-benzene at 80°, it smoothly gave an equilibrium mixture of the original compound (3c) and a new isomer in ratio of 6.5:1 as measured by the NMR *spectrum of the* product. Isolation of the new isomer (2c), mp.148-150°, and treatment of this with NEt_3 again gave the same equilibrium mixture of 3c and 2c. The above results indicate, contrary to expectation, that the ethyl vinyl ether-major adduct is the *endo*-isomer (3c), since it is thermodynamically more stable.

The photo-cycloadduct of vinyl acetate[2], on the same base treatment, also gave an equilibrium mixture of the original compound (3d) and a new isomer (2d) in ratio of 8:1. Although the isolation of the minor isomer (2d) in a pure form was failed, the result again suggested that the vinyl acetate-major adduct is the *endo*-isomer (3d).

As suggested already for 7-phenyl derivatives[2], the NMR spectra of the pair of epimers revealed that C_7-H of an *exo*-isomer always resonates at higher field by 0.6-1.1 ppm than that of an *endo*-isomer (Table 1). The difference of the chemical shift between 2c and 3c (or 2d and 3d) supported the assigned stereochemistry. Thus, the exo/endo ratio of the all photo-cycloadducts of 1 with olefins were reexamined by NMR and the results are given in Table 2. In all cases the both epimers more or less existed in the products. The *endo*-isomer (3b) in the butadiene-adduct was newly isolated as colorless needles, mp.146-148° as a minor product.

The stereochemistry of the major photo-adduct of isopropenyl acetate[2] was elucidated as 5 from the following reasons. On base treatment, it epimerized into a 3:5 mixture of 5 and the epimer (6)[6]. Since the stereochemical bulkiness of Me and OAc are supposed as Me>OAc, 6 must be the more stable Me-*endo* isomer.

Table 1. Physical and Spectral Data of Photo-cycloadducts. (NMR, δ ppm in $CDCl_3$).

Cycloadduct	mp.	C_7-H	Δδ(exo-endo)	C_7-OAc	C_7-Me
styrene	2a: 212-214°	4.17(t, J=10 Hz)			
	3a: 180-183°	4.83(t, J=10 Hz)	0.66		
butadiene	2b: 170-172°	3.32[b]			
	3b: 146-148°	4.13(dd, J=9, 8 Hz)	0.81		
ethyl vinyl ether	2c: 148-150°	4.12(t, J=8 Hz)			
	3c: 149-152°	4.77(dd, J=8, 6 Hz)	0.65		
vinyl acetate	2d: a)	5.01(t, J=10 Hz)		1.76	
	3d: gum	5.88(dd, J=9, 7 Hz)	0.87	2.10	
isopropenyl acetate	5 : 164-166°			2.05	1.50
	6 : 181-184°			1.73	1.50

a) not isolated in pure form. b) overlaped with C_6-H.

Table 2. Photo-cycloaddition of 1 with Olefins.[a]

	Yield(%)			Ratios of exo/endo	
Olefins	exo(2)	endo(3)	(4)	photoaddition	equilibrium
styrene	40	8	7	5/1[b]	<1/100
butadiene	47.5	20	1	2.3/1[c]	d)
ethyl vinyl ether	1.6	53	4	1/30[c]	1/6.5
vinyl acetate	6.3	36	-	1/5.7[b]	1/8
isopropenyl acetate	O-*exo* (6) 6	O-*endo* (5) 36	4.5[f]	1/6.0[b][e]	1.5/1[e]

a) Irradiated with 300w Hg-lamp using pyrex filter in dimethoxyethane at 0°C for 45 min.

b) Calculated from NMR spectrum of the crude mixture.

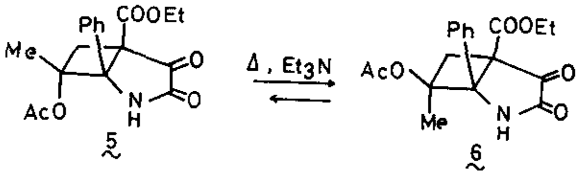
c) Calculated from isolated yield.

d) Base treatment of 2 gave a different product which will be reported in a separate paper.

e) O-exo(Me-endo)/O-endo(Me-exo) ratio.

f) gum. IR: 1750, 1720, 1700(sh), 1650 cm^{-1}. UV λ_{max}^{EtOH} : 283 nm(ε 7,600).
NMR: δ 3.95(2H, q, J=7 Hz), 3.58(1H, d, J=16 Hz), 2.77(1H, d, J=16 Hz) 2.08(3H, s), 1.6(3H, s), 0.90(3H, t, J=7 Hz).

Exo- and *endo*-OAc signals of vinyl acetate-adducts appeared at δ 1.76 and 2.10, respectively, separating by 0.34 ppm. The OAc signals of 5 and 6 were at δ 2.05 and 1.73, corresponding the former signal to OAc-*endo* (Me-*exo*) isomer and the latter to OAc-*exo* (Me-*endo*) isomer, respectively.



The possibility of photo-epimerization of C_7-substituent was excluded, since on irradiation (1 hr.) the adducts 2, 3 and 5, did not give the isomers, 3, 2 and 6, though 50∼70% of the compounds were deteriorated.

Summarizing the above results, on photo-cycloaddition of 1 with olefins the stereochemistry of the product, 7-substituted 2-azabicyclo[3.2.0]heptane-3,4-dione, changes depending on the nature of the substituent of the olefins used, which is an *exo* isomer from styrene or butadiene and an O-*endo* isomer from the olefins carrying oxygen function.

Although we could not give definite reasoning why this reversion of stereochemistry took place, a possible explanation is as follows. In the transition state of the photo-cycloaddition, olefins with O-function will be disposed as to close the oxygen atom and the dioxopyrroline ring by electrostatic attraction of unshaired electron on the oxygen and the electron deficient dioxopyrroline ring, while olefins carrying π-electron substituent such as styrene and butadiene are oriented as to gain π-π overlap of substituent and the phenyl group at C_1. Thus the former array gives an *endo* and the latter gives an *exo* isomer, respectively.

References and Note

1. Dioxopyrrolines XVI. Part XV: T. Sano, Y. Horiguchi, and Y. Tsuda, Heterocycles, preceding paper.
2. T. Sano and Y. Tsuda, Heterocycles, 1976, 4, 1229.
3. T. Sano, Y. Horiguchi, Y. Tsuda, and Y. Itatani, Heterocycles, 1978, 9, 161.
4. T. Sano, Y. Tsuda, H. Ogura, K. Furuhata, and Y. Iitada, Heterocycles, 1976, 4, 1233.
5. T. Sano, Y. Tsuda, H. Ogura, K. Furuhata, and Y. Iitada, Heterocycles, 1976, 4, 1367.
6. see Part XV.

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