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PHOTOREACTIONS OF THIOBARBITURATES WITH OLEFINS; THIETANE FORMATION BY INTERMOLECULAR PHOTOCYCLOADDITION[1)]

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Upon irradiation of thiobarbiturates (**1a-c**) in the presence of olefins (**4a-d**), [2+2]cycloaddition occurred to give thietanes (**5**, **7**, and **8**) and its related compounds (**6** and **9**).

KEYWORDS thiobarbiturate; thietane; photoreaction; intermolecular photocycloaddition; Paterno-Büchi reaction; thiouracil

Our studies of the photochemistry of imide systems[2)] have been extended to the nitrogen-thiocarbonyl systems, i.e., thioamide[3)] and thioimide.[4)] During the course of our systematic studies of the photochemistry of the thioimide systems, we found that there are some distinct differences in the photochemical behavior of the imide-carbonyls and the thioimide-carbonyls. For example, the cyclic thioimides are inert, in principle, to the Norrish type I and type II reactions, which are representative photoreactions in the imide systems.[4)] The major photochemical processes of the cyclic thioimides have been limited to [2+2]photocycloaddition (Paterno-Büchi type reaction) with olefins, although certain thioimides having a benzylic hydrogen in the N-alkyl side chain undergo the Norrish type II reaction to give cyclized products.[1a,5)]

As a logical extension of the thioimide photochemistry, our findings led us to investigate the photoreaction of thiobarbiturates, whose skeletons consist of a combination of a thioimide and an amide or a thioamide (two-imides system). Although the photochemistry of barbiturates (oxygen analogues)[6)] has been studied, little is known about that of the thiobarbiturates (sulfur analogues). In the present communication, we report efficient thietane formation by intermolecular photocycloaddition of thiobarbiturates with olefins.

Photolyses of thiobarbiturates (**1-3**) and olefins (**4a-d**) (1 : 20 molar ratio) were carried out in acetonitrile (10 mM) with a 1 kW high-pressure mercury lamp through a Pyrex filter under a nitrogen atmosphere at room temperature. The progress of photoreaction was monitored by thin layer chromatography until the barbiturates used disappeared. The results are collected in Table I and Chart 1.

Upon irradiation of 2-thiobarbiturate (**1**) with 2,3-dimethyl-2-butene (**4a**) for 5 h, 2-thietane (**5a**) and a 2-isopropylidene compound (**6a**) were obtained in 51% and 47% yields, respectively. Probably the desulfurized product **6a** arises from the initially formed thietane **5a** through photochemical fission (cycloreversion) of the thietane ring.[4)] In the case of ethyl vinyl ether (**4b**) having an electron donative group, 2-thietane (**5b**) and 2-ethoxylmethylene compound (**6b**) were obtained in moderate yields after short irradiation. Also in irradiation[7)] of α-methylstyrene (**4c**) and **1**, an alkylidene compound (**6c**) was obtained in good yield together with 2-thietane (**5c**, 7%). Similarly in a case of acrylonitrile (**4d**) having an electron withdrawing group, only the alkylidene compound (**6d**) was obtained in 63% yield. Further, photoreactions of 2,4-dithiobarbiturate (**2**) and 2,4,6-trithiobarbiturate (**3**) with olefin **4a** were examined. In the case of 2,4-dithiobarbiturate (**2**) having two thiocarbonyls, only 4-thietane (**7a**) was obtained, in 91% yield, even after short photolysis for 30 min. Interestingly, with 2,4,6-trithiobarbiturate (**3**), 4-monothietane (**8**) was obtained in 51% yield together with a dithiouracil derivative (**9**, 24%).

The structures of the products[8)] were determined on the basis of the spectral and analytical data, and chemical experiments. For both **5a** and **6a**, a symmetrical structure was suggested on the basis of their ^{1}H-NMR and ^{13}C-NMR spectra, indicative of the thietane formation between an olefin and a thiocarbonyl at the 2-position. In contrast with **5a** and **6a**, the ^{1}H-NMR and ^{13}C-NMR spectra of **7a** and **8a** rejected their symmetrical structures, because their N-methyl peaks were not identical. To confirm the position of thietane formation, 4-thietane **7a** was treated with Lawesson's reagent. The resulting product was identified as **8a** derived from **3** and **1a** by NMR spectroscopy, while the **8a** was not identical with the thionation product **10** which is derived from 2-thietane **5a** and Lawesson's reagent.

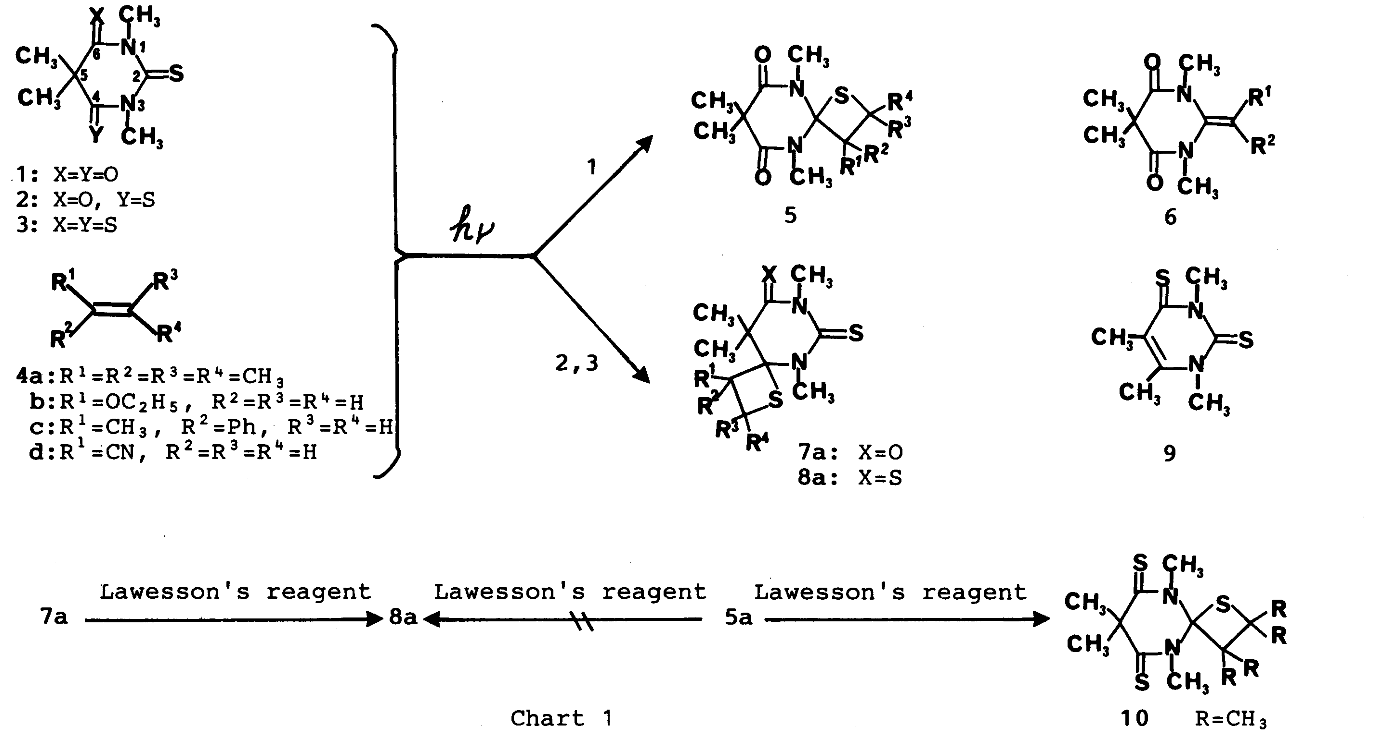

Chart 1

Table I. Photoreactions of **1**–**3** with **4**

Substrate	Olefin	Time (h)	Product thietane	Yield (%)	mp °C	Product alkylidene	Yield (%)	mp °C
1	**4a**	5	**5a**	51	96-98	**6a**	47	97-99
	4b	2	**5b**	17	77-78	**6b**	40	94-96
	4c	12	**5c**	7	92.5-94	**6c**	88	186-186.5
	4d	6				**6d**[a]	63	98-99
2	**4a**	0.5	**7a**	91	113-115			
3	**4a**	1	**8a**	51	130-132	**9**	24	125-127

a) Starting material **1** was recovered in 6% yield.

Thiobarbiturates (**1**–**3**) are alicyclic thioimide-amide systems in which a thiocarbonyl is flanked with two amides (**1**), an amide and a thioamide (**2**), and two thioamides (**3**), respectively. In conclusion, these thiobarbiturates undergo efficient [2+2]photocycloaddition with olefins to give thietanes and/or its fission-products as well as the simple cyclic thioimide systems.[4] When the substrate has multiple thiocarbonyls (at 2-, 4- and/or 6-positions) in its molecular framework as in **2** and **3**, the photocycloaddition occurred at the 4-thiocarbonyl in preference to the 2-thiocarbonyl. This preference seems to be due to more intensive absorption of the chromophoric system involving the 4-thiocarbonyl group (**2**,**3**) at longer wave-lengths than in the 2-thiocarbonyl system, under the irradiation conditions, resulting in more effective excitation of the terminal thiocarbonyl. In addition, in analogy with oxetane chemistry,[9] the initially formed thietanes easily underwent photochemical cycloreversion (thiocarbonyl-olefin metathesis). Introduction of various alkylidene groups at the thiocarbonyl carbon instead of the sulfur atom will be possible by selecting appropriate olefins. Therefore, this thietane formation followed by cycloreversion may be of some synthetic utility. Although the pathway for the formation of dithiouracil **9** is not yet clear, the thiouracil **9** was obtained on irradiation of **3** even in the absence of olefins. 5,5-Diethyl-2,4,6-trithiobarbiturate, an analogue of **3**, also showed similar photochemical behavior. Further investigation of this interesting photorearrangement in the nitrogen-thiocarbonyl systems is underway.

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7) In the case of **4c**, ten moles equivalent was used for **1**.

8) All compounds showed reasonable spectral data (IR, Mass, and NMR) and analytical data. Selected data: **5a**: MS: m/z 284 (M^+); ^{1}H-NMR ($CDCl_3$) δ: 1.16 (6H, s, CH_3x2), 1.46 (3H, s, CH_3), 1.48 (3H, s, CH_3), 1.55 (6H, s, CH_3x2), 3.63 (6H, s, N-CH_3x2); ^{13}C-NMR ($CDCl_3$) δ: 23.4 (q), 25.5 (q), 26.5 (q), 28.1 (q), 37.4 (q), 45.2 (s), 45.4 (s), 64.5 (s), 87.9 (s), 173.5 (s). **6a**: MS: m/z 210 (M^+); ^{1}H-NMR ($CDCl_3$) δ: 1.35 (6H, s, CH_3x2), 1.86 (6H, s, CH_3x2), 3.18 (6H, s, N-CH_3x2); ^{13}C-NMR ($CDCl_3$) δ: 20.1 (q), 20.5 (q), 36.5 (q), 48.8 (s), 118.7 (s), 132.6 (s), 172.5 (s). **7a**: MS: m/z 300 (M^+); ^{1}H-NMR ($CDCl_3$) δ: 0.93 (3H, s, CH_3), 1.07 (3H, s, CH_3), 1.16 (3H, s, CH_3), 1.44 (3H, s, CH_3), 1.48 (3H, s, CH_3), 1.80 (3H, s, CH_3), 3.47 (3H, s, N-CH_3), 3.83 (3H, s, N-CH_3); ^{13}C-NMR ($CDCl_3$) δ: 23.1 (q), 23.3 (q), 23.5 (q), 25.8 (q), 27.9 (q), 28.6 (q), 34.3 (q), 43.3 (q), 46.0 (s), 47.1 (s), 57.7 (s), 79.8 (s), 172.4 (s), 180.2 (s). **8a**: MS: m/z 316 (M^+); ^{1}H-NMR ($CDCl_3$) δ: 0.91 (3H, s, CH_3), 1.05 (3H, s, CH_3), 1.13 (3H, s, CH_3), 1.45 (3H, s, CH_3), 1.48 (3H, s, CH_3), 2.03 (3H, s, CH_3), 3.87 (6H, s, N-CH_3x2); ^{13}C-NMR ($CDCl_3$) δ: 23.7 (q), 25.9 (q), 26.3 (q), 27.9 (q), 28.7 (q), 29.2 (q), 43.6 (q), 43.9 (q), 46.1 (s), 53.9 (s), 57.5 (s), 80.0 (s), 177.1 (s), 208.1 (s). **9**: MS: m/z 200 (M^+); ^{1}H-NMR ($CDCl_3$) δ: 2.30 (3H, s, CH_3), 2.58 (3H, d, J=0.9 Hz, CH_3), 3.67 (3H, s, N-CH_3), 3.80 (3H, s, N-CH_3); ^{13}C-NMR ($CDCl_3$) δ: 25.6 (q), 25.9 (q), 33.5 (q), 37.8 (q), 137.0 (s), 137.3 (s), 178.1 (s), 184.3 (s). **10**: mp 152-153.5 °C; MS: m/z 316 (M^+); ^{1}H-NMR ($CDCl_3$) δ: 1.17 (6H, s, CH_3x2), 1.58 (6H, s, CH_3x2), 1.92 (3H, s, CH_3), 2.09 (3H, s, CH_3), 4.22 (6H, s, N-CH_3x2); ^{13}C-NMR ($CDCl_3$) δ: 23.4 (q), 28.0 (q), 34.2 (q), 41.1 (q), 45.8 (s), 47.8 (q), 57.4 (s), 67.5 (s), 92.2 (s), 208.4 (s).

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