

Photochemical Reactions of *NN*-Dialkyl- α -thioamides

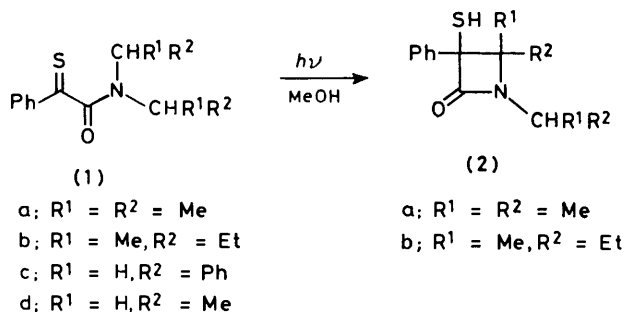
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NN-Di-isopropyl- and *NN*-di-*s*-butyl- α -phenylthioacetamide, (1a) and (1b), undergo γ -hydrogen abstraction on irradiation in methanol to give the corresponding β -lactams (2a) and (2b), respectively. Irradiation of *NN*-diethylthioamide (1d) yields the dimeric product, the disulphide (3d), while photolysis of (1d) in a viscous medium gave the thiazolidinone (6d) *via* γ -hydrogen abstraction. These reactions are presumed to proceed from the upper excited states. The selective γ -hydrogen abstraction is explicable in terms of an electron-transfer mechanism.

PHOTOCHEMICAL reactions of thiones have received much attention. They undergo intramolecular hydrogen abstraction¹ as well as cycloaddition with olefins.² Interestingly, thiones gives δ -hydrogen abstraction products specifically^{1c} in contrast to ketones which undergo γ -hydrogen abstraction (type II reaction) on irradiation.³ δ -Hydrogen abstraction of ketones takes place only when γ -hydrogens are absent or δ -hydrogens are activated by substituents.⁴ On the other hand, thiones undergo γ -hydrogen abstraction only when they possess no δ -hydrogens and γ -hydrogens are activated by heteroatoms.^{1c} Recently, we reported the photochemical reactions of α -oxoamides⁵ and $\alpha\beta$ -unsaturated amides.⁶ We now report those of α -thioamides which are iso-electronic with these amides.⁷ In this reaction, selective γ -hydrogen abstraction by thiocarbonyl groups took place in spite of the presence of δ -hydrogens.

RESULTS AND DISCUSSION

In general, photoreactions of *NN*-dialkyl- α -thioamides are not clean, and many unidentified by-products are formed in every case. When *NN*-di-isopropylthioamide (1a) in methanol was irradiated with a high-pressure mercury lamp through a Pyrex filter, the 3-mercaptoazetidinone (2a) was produced *via* γ -hydrogen abstraction in 38% yield.[†] The structure of (2a) was



determined by elemental analysis and spectral data, in particular the close similarity of the n.m.r. spectrum to that of the 3-hydroxy-compound.⁵ Irradiation of (1a) in benzene afforded a complex mixture, and the yield of (2a) was quite low (<10%). Photolysis of *NN*-di-*s*-butylthioamide (1b) also gave the corresponding type

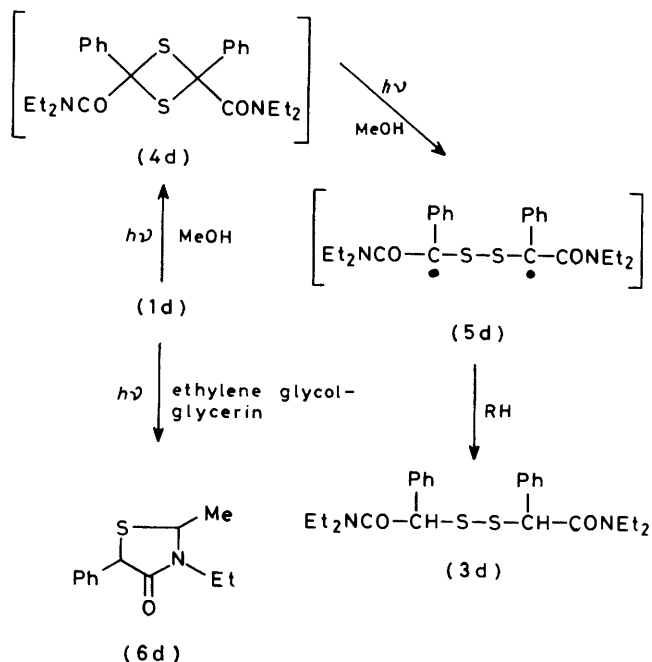
† All yields described in this paper are isolated yields.

II cyclisation product (2b) (25%). In these cases, no δ -hydrogen abstraction products (3-mercaptopyrrolidin-2-ones) were isolated. On the other hand, *NN*-dibenzylthioamide (1c) yielded only an intractable mixture on irradiation. The lactam (2a) was not detected when (1a) was irradiated in the $n-\pi^*$ region of the thiocarbonyl group (*ca.* 585 nm), although many unidentified products were produced. This suggests that the photocyclisation of the thioamides proceeds from the upper excited states, as in the case of thiones.

Irradiation of *NN*-diethylthioamide (1d) in methanol gave the disulphide (3d) in 48% yield. The structure of (3d) was confirmed by an independent synthesis from *NN*-diethyl-2-chlorophenylacetamide and Na₂S₂. The formation of (3d) is explicable in terms of dimerisation of (1d) and subsequent reductive decomposition of the resulting 1,3-dithietan (4d). Photochemical⁸ and thermal⁹ dimerisation of α -thioamides to dithietans and photochemical conversion of dithietans into disulphides¹⁰ have been reported. A possibility of the direct formation of the biradical (5d) from (1d) cannot be excluded. The efficient dimerisation of (1d) is attributable to the lack of bulky substituents on the nitrogen. The bulky secondary alkyl groups of (1a) and (1b) are presumed to inhibit the dimerisation and make inefficient γ -hydrogen abstraction possible. It is also conceivable that the difference in behaviour of (1a) and (1b) *versus* (1d) is due to the lower reactivity of the γ -CH₂ bonds in (1d), although it is known that thione hydrogen abstraction is relatively insensitive to bond strength.^{1a}

In order to avoid the bimolecular reaction of (1d), photolysis of (1d) in a highly viscous medium was carried out. When (1d) in ethylene glycol-glycerin (1 : 1) was irradiated as above, a monomeric product, the thiazolidin-4-one (6d), was obtained (41%) instead of (3d). The structure of (6d) was determined by elemental analysis, the i.r. spectrum, and the close similarity of the n.m.r. spectrum to that of the corresponding oxazolidin-4-one.^{5b} Although the precise mechanism for the formation of (6d) is still not clear as in the case of oxazolidin-4-ones produced in the photolysis of α -oxoamides, it seems certain that the primary process of the reaction is γ -hydrogen abstraction.^{5a}

These results indicate that α -thioamides undergo selective γ -hydrogen abstraction in spite of the presence of δ -hydrogens. The difference in reactivity of the



thioamides and thiones is quite interesting. It may be explained in terms of an electron-transfer mechanism; the reaction may involve sequential electron-proton transfer rather than one-step hydrogen transfer.¹¹⁻¹³

EXPERIMENTAL

Starting Materials.—The α -thioxoamides (1a), (1c), and (1d) were prepared according to previous described methods.⁹

NN-Di-*s*-butyl-2-phenyl-2-thioxoacetamide (1b) was also synthesised in a similar manner and had m.p. 84–86 °C; ν_{\max} (CHCl₃) 1 610 cm⁻¹; λ_{\max} (MeOH) 586 nm (log ϵ 1.56); δ (CDCl₃) 1.5–2.4 (4 \times Me + 2 \times CH₂), 2.9–3.8 (m, 2 H, methines), 7.25–7.7 (m, 3 H, Ar-H), and 8.0–8.3 (m, 2 H, Ar-H) (Found: C, 69.2; H, 8.4; N, 5.05. C₁₆H₂₃NOS requires C, 69.25; H, 8.35; N, 5.05%).

General Procedure for Photochemical Reactions of NN-Dialkyl α -Thioxoamides.—A solution of the amide (1) (200 mg) in a solvent (40 ml) was irradiated in a Pyrex tube under argon with a 450-W high-pressure mercury lamp till the blue solution turned pale yellow (2–10 h). After removal of the solvent, the residue was chromatographed on silica gel. A 300-W halogen lamp (Ushio JCV 100-300GS) was used for irradiation of (1a) in the long wavelength region.

1-Isopropyl-3-mercapto-4,4-dimethyl-3-phenylazetididin-2-one (2a) had m.p. 100.5–101 °C; ν_{\max} (CHCl₃) 2 630 and 1 730 cm⁻¹; δ (CDCl₃) 0.95 (s, 3 H, 4-Me), 1.35 (d, 6 H, J 7 Hz, CHMe₂), 1.59 (s, 3 H, 4-Me), 2.32 (s, 1 H, SH, D₂O exchangeable), 3.52 (sep, 1 H, J 7 Hz, CHMe₂), and 7.2 (m, 5 H, Ar-H) (Found: C, 67.35; H, 7.75; N, 5.55. C₁₄H₁₉NOS requires C, 67.45; H, 7.7; N, 5.65%).

4-Ethyl-3-mercapto-4-methyl-3-phenyl-1-*s*-butylazetididin-2-one (2b) was a mixture of stereoisomers and did not crystallise; ν_{\max} (CHCl₃) 1 730 cm⁻¹; δ (CDCl₃) 0.5–2.1 (4 \times Me + 2 \times CH₂), 2.35 and 2.48 (each s, total 1 H, SH, D₂O exchangeable), 3.3 (m, 1 H, CHMe₂), and 7.3 (m, 5 H, Ar-H) (Found: C, 68.75; H, 7.95; N, 5.0. C₁₆H₂₃NOS requires

C, 69.25; H, 8.35; N, 5.05%). The analysis is poor because the product did not crystallise.

NNN'N'-Tetraethyl-2,2'-dithiodiphenylacetamide (3d) had m.p. 147–148 °C; ν_{\max} (CHCl₃) 1 620 cm⁻¹; δ 1.00 (CDCl₃) 1.00 (t, 6 H, J 7 Hz, Me), 1.15 (t, 6 H, J 7 Hz, Me), 3.33 (m, 8 H, CH₂), 5.05 (s, 2 H, methine), and 7.4 (m, 10 H, Ar-H) (Found: C, 64.74; H, 7.15; N, 6.05. C₂₄H₃₂N₂O₂S₂ requires C, 64.85; H, 7.25; N, 6.3%).

3-Ethyl-2-methyl-5-phenylthiazolidin-4-one (6d) had b.p. 120–130 °C/0.1 Torr (bath temp.); ν_{\max} (CHCl₃) 1 660 cm⁻¹; δ (CDCl₃) 1.15 (t, 3 H, J 7 Hz, CH₂Me), 1.59 (d, 3 H, J 6 Hz, 2-Me), 3.4 (m, 2 H, CH₂), 4.77 (q, 1 H, J 6 Hz, 2-H), 4.89 (s, 1 H, 5-H), and 7.32 (s, 5 H, Ar-H) (Found: C, 64.85; H, 6.85; N, 6.5. C₁₂H₁₅NOS requires C, 65.1; H, 6.85; N, 6.3%).

Synthesis of (3d) from NN-Diethyl-2-chlorophenylacetamide and Na₂S₂.—A solution of Na₂S (1 g) and sulphur (120 mg) in water (3 ml) was refluxed for 30 min. After the solution had been cooled to room temperature, the chloroamide⁹ (170 mg) in ethanol (2 ml) was added, and the solution was heated to 60 °C for 2 h. After addition of water (20 ml), the product was extracted with ethyl acetate, treated as usual, and chromatographed on silica gel. The product (yield 5%) was identical with that obtained in the photolysis of (1d) in methanol (i.r., n.m.r., t.l.c., and mixed melting points).

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