azeotropically. After no more methanol was present, the water was removed azeotropically away with the chloroform. The remaining chloroform was distilled away from the reaction mixture, 32.0 g of methyl alcohol (1.0 mol) was added, and the solution was brought to reflux for another 24 hr. The above procedure was then repeated and the resultant product mixture was distilled through the Nester–Faust spinning-band column to give 1,1,2,2-tetrakis(methoxy)ethane, bp 85–90° (25 mm), 6.6 g (4% yield), 2-dimethoxymethyl-4,5-dimethoxy-1,3-dioxolane (**1**), bp 95–98° (5 mm), 16.0 g (15% yield), and 2,2′-bis(4,5-dimethoxy-1,3-dioxolane) (**2**), bp 105–108° (5 mm), mp 109–110°, 17.9 g (20% yield).

Anal. Calcd for $C_{10}H_{18}O_8$: C, 45.11; H, 6.77; mol wt, 266. Found: C, 45.11; H, 6.81; mol wt, 263.

The infrared spectra of both compounds **1** and **2** showed no carbonyl or hydroxyl bonds, but had strong absorption in that region expected for ethers or acetals.

Registry No.—**1**, 33834-89-8; **2**, 33834-90-1.

The Photochemistry of S-Methyl Diazothioacetate[1]

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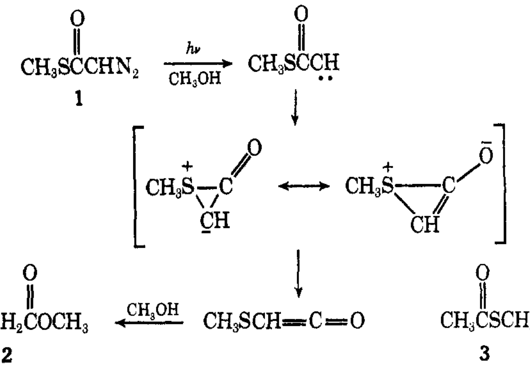
The photochemistry of α-diazo esters has received much attention recently both from chemists interested in the nature and mechanisms of the reactions undergone by these species[2a-e] and from others interested in using them as labeling reagents for active sites of enzymes.[3a-f] However, Wolff rearrangement of the carbenes produced upon irradiation of the diazo esters has diminished the utility of these compounds as labeling reagents, particularly in the case of diazoacetylglyceraldehyde-3-phosphate dehydrogenase[4] (only Wolff rearrangement observed) but also in diazoacetylchymotrypsin[3a,b] (15–20% rearrangement). In the former case, to date the only investigation of an α-diazothio ester, the per cent Wolff rearrangement was not determined since other products arising from, for example, solvent insertion would have gone undetected.

Since we are interested in enzyme labeling with diazo esters and because many enzymes contain the –SH group of a cysteine moiety at their active sites, we wished to examine the extent of Wolff rearrangement of an excited diazothio ester relative to oxygen (ester) and nitrogen (amide) analogs, and the effect of excited state multiplicity on the rearrangement. For these purposes the photochemistry of *S*-methyl diazothioacetate (**1**) has been studied.

Ester **1** was prepared in 25% yield from diazomethane and methyl chlorothiolformate. Direct photolysis of **1** in methanol with 310–380 nm light afforded in 86% yield only one detectable volatile product with a gc retention time identical with that of known methyl methylthioacetate (**2**). A dark control showed no reaction. The identity of the product was firmly established by distilling the final solution carefully to remove the methanol; the infrared spectrum of the remaining oil was identical with that of known **2**.

The sensitized decomposition was carried out using xanthone as sensitizer and light of wavelengths 310–355 nm. Gas chromatographic analysis of the reaction mixture present when 95% of **1** had disappeared revealed only a small amount of one product with a retention time identical with that of known *S*-methyl thioacetate (**3**) corresponding in area to a 7% yield from **1**.[5] Benzophenone sensitization gave similar results. As expected, xanthone-sensitized decomposition of **1** in isopropyl alcohol, a better hydrogen atom donor than methanol, gave an increased yield (23%) of this product. Once again dark controls showed no loss of **1**.



Assuming that the direct photolysis of **1** generates a singlet carbene, our results show that this carbene undergoes a very rapid Wolff rearrangement. No products arising from insertion into the solvent –OH bond or from hydrogen abstraction were detected by our methods of analysis. This is in contrast to the case with α-diazo esters and amides, which show a lower (20–60%) per cent rearrangement and give a significant amount of the other products.[2d] This enhanced migratory aptitude of a sulfur atom to a carbene center has also been found in carbenes generated from *p*-tosylhydrazone decomposition.[6,7]

The results of the sensitized decomposition demonstrate that multiplicity has a profound effect on the Wolff rearrangement in that the latter is eliminated entirely and only a moderate amount of what is probably the reduction product **3**, presumably formed *via* stepwise hydrogen abstraction by a triplet carbene, is

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(1) This work was supported by a grant (GB 27644) from the National Science Foundation and by a Faculty Research Grant from the Research Council of the University of Massachusetts, Amherst, Mass.

(2) Good leading references are (a) T. Dominh and O. P. Strausz, *J. Amer. Chem. Soc.*, **92**, 1766 (1970); (b) D. E. Thornton, R. K. Gosavi, and O. P. Strausz, *ibid.*, **92**, 1768 (1970); (c) W. Ando, *et al.*, *J. Org. Chem.*, **36**, 1732 (1971); (d) H. Chaimovich, R. J. Vaughan, and F. H. Westheimer, *J. Amer. Chem. Soc.*, **90**, 4088 (1968); (e) G. O. Schenck and A. Ritter, *Tetrahedron Lett.*, 3189 (1968).

(3) (a) A. Singh, E. R. Thornton, and F. H. Westheimer, *J. Biol. Chem.*, **237**, 3006 (1962); (b) J. Schafer, P. Baronowsky, R. Laursen, F. Finn, and F. H. Westheimer, *ibid.*, **241**, 421 (1966); (c) R. J. Vaughan and F. H. Westheimer, *J. Amer. Chem. Soc.*, **91**, 217 (1969); (d) D. T. Browne, S. S. Hixson, and F. H. Westheimer, *J. Biol. Chem.*, **246**, 4477 (1971). (e) C. Hexter and F. H. Westheimer, *ibid.*, **246**, 3928, 3934 (1971); (f) see also R. R. Rando, *J. Amer. Chem. Soc.*, **92**, 6706 (1970).

(4) J. H. Scott, unpublished results, Harvard University, 1965. Part of this work is cited in ref 2d.

(5) Due to the high absorption of **1** and the low solubility of sensitizer, it was necessary to use a dilute solution containing a relatively large amount of sensitizer in the presence of a very small amount of **1** in order to ensure complete absorption of light by the sensitizer. This precluded an extensive search for unknown products.

(6) J. H. Robson and H. Schechter, *J. Amer. Chem. Soc.*, **89**, 7112 (1967).

(7) Wolff rearrangement *via* an oxirene formation–hydrogen shift sequence, a minor process in diazo ester photolysis (vapor phase),[2b] seems unlikely in the present case, but it cannot be ruled out.

found.[8a] Most likely nonvolatile materials or products of very short retention time (see Experimental Section) formed *via* radical reactions account for the balance of the products. Triplet carbenes might be expected to show radical-like behavior; we have found that even when a very good migrating group is present they do not undergo the Wolff rearrangement.[8a,b]

Perhaps most importantly these results suggest that the sensitized decomposition of diazoacyl enzymes may prove to be a fruitful method for labeling active sites. We are actively investigating this area.

Experimental Section

Photolyses were carried out in a Rayonet photochemical reactor (Southern N. E. Ultraviolet Co.) equipped with RPR-3500 Å lamps. The reaction vessel was immersed in the well of a Pyrex cooling chamber around which water at 23-27° was pumped. The well was filled with water for the direct photolysis and with filter solution for the sensitized photolysis.

Gas chromatography was carried out on a Perkin-Elmer Model 990 gas chromatograph using a 7 ft × $^1/_8$ in. Poropak Q, 80/100 mesh column. Column temperature was 200°, injector and manifold temperatures 250°, and He flow rate 50 cc/min.

The ir spectra were determined on a Beckman IR-10 spectrophotometer, and nmr spectra on a Varian A-60 spectrometer using TMS as internal standard. The uv spectra were run on a Cary 14 spectrophotometer.

Microanalyses were performed by Mr. Charles Meade of the University of Massachusetts Microanalytical Laboratory.

***S*-Methyl Diazothioacetate** (1).—To 500 ml of a stirred solution of diazomethane in ether [prepared[9] from 27 g of bis(*N*-methyl-*N*-nitroso)terephthalamide] cooled in an ice bath was added dropwise a solution of 5.0 ml (56.9 mmol) of methyl chlorothiolformate in 100 ml of anhydrous ether over 15 min. The reaction flask was kept stoppered overnight at room temperature in the dark. The ether and excess diazomethane were blown off with a stream of dry nitrogen. An additional 50-ml aliquot of anhydrous ether was added and blown off to give 7.97 g of a deep yellow oil which was then stored in the refrigerator and protected from light. Portions of the crude oil were chromatographed before use, and the pure product was either used immediately or stored up to several months in the freezer before use.

In a typical purification 1.40 g of the crude oil was chromatographed on a silical gel column packed and eluted with 1:20 anhydrous ether-Skelly F (v/v). Fractions showing only material with R_f 0.42 on silica gel tlc in 1:5 ether-Skelly F were combined, and the solvent was removed with a nitrogen stream to give a thin yellow oil, *S*-methyl diazothioacetate (1, 0.292 g, 25%): ir (neat) 2095 (diazo), 1620 (C=O), 1335, 1133, 1028, and 856 cm^{-1}; nmr (CDCl$_3$) δ 2.56 (s, 3, CH$_3$) and 5.70 (s, 1, CH); uv max (MeOH) 278 nm (ϵ 13,300) and 241 (9120).

Anal. Calcd for $C_3H_4SON_2$: C, 31.04; H, 3.47; N, 24.14; S, 27.56. Found: C, 31.00; H, 3.50; N, 24.10; S, 27.50.

Carbon Disulfide Extractions.—In order to eliminate the big methanol peak on the gc traces, samples in methanol were routinely extracted into CS$_2$. CS$_2$ (1 ml), 2 ml of saturated sodium chloride solution, 0.25 ml of water, and 1 ml of the methanol solution to be analyzed were shaken together, and the CS$_2$ layer was then separated and examined by gc. In extractions with known samples of methyl methylthioacetate[10] (2) and *S*-methyl thioacetate[11] (3) at least 70 and 80%, respectively, of the amounts of these compounds originally in the methanol layer could be brought into the CS$_2$ layer. Similar products in the photolysis mixtures, then, can be expected to appear in the CS$_2$ layer.

CS$_2$ extractions were carried out as above only with pure methanol. Gc of the CS$_2$ layers reproducibly gave a certain pattern of peaks in the 0-4-min range which are referred to below as the "background peaks;" because of these peaks, products of retention times less than 4 min would go undetected.

Direct Photolysis of *S*-Methyl Diazothioacetate (1).—A solution of 0.0795 g (0.685 mmol) of 1 in 20 ml of anhydrous methanol in a Pyrex tube stoppered with a serum cap was purged with nitrogen for 20 min. The solution was photolyzed for 5.5 hr. After this time less than 1% of the original absorption at 278 nm remained. A similar solution kept at room temperature in the dark for 14 hr showed no decrease in the absorption at 278 nm.

Gc of the final solution revealed, in addition to the methanol peak, only a peak of retention time 17.3 min, identical with the retention time of known methyl methylthioacetate (2) on the same column. The peak area corresponded to an 86% yield of 2 from 1. In addition, a 0.5-ml aliquot of the final photolysis solution was diluted with 0.5 ml of methanol and carried through a CS$_2$ extraction. Gc of the CS$_2$ layer showed only the background peaks and the peak at 17.3 min. When 0.5 ml of the original reaction solution, before photolysis, was treated similarly only background peaks were seen.

A portion of the final reaction solution was distilled at atmospheric pressure until no further methanol distilled, 10 ml of anhydrous ether was added to the liquid remaining, and the ether solution was treated with MgSO$_4$, filtered, and blown down under nitrogen. An ir spectrum (neat) of the thin oil remaining was identical with that of known 2.

Sensitized Photolysis of *S*-Methyl Diazothioacetate (1).—A solution of 0.0150 g (0.129 mmol) of 1 and 0.2503 g (1.23 mmol) of xanthone (Aldrich Chemical Co., recrystallized twice from ethanol) in 50 ml of anhydrous methanol in a Pyrex vessel stoppered with a serum cap was purged with nitrogen for 20 min. The reaction solution was surrounded by a filter solution (270 g of NiSO$_4\cdot$6H$_2$O and 169 g of CoSO$_4\cdot$7H$_2$O diluted to 870 ml) which cut off light of wavelengths greater than 355 nm (2.4-cm path length).

The solution was photolyzed for 8 hr. Throughout the photolysis aliquots of the reaction solution were taken and the change in absorption at 284 nm after 1 drop of concentrated HCl was added was noted. The original reaction solution showed a 20% loss in absorption at 284 nm after treatment with acid. After 8 hr of photolysis a 1% decrease was noted. A similar solution kept in the dark for 14 hr at room temperature still showed a 20% decrease on acid treatment.

Gc of the original reaction solution gave, in addition to the methanol peak, a peak at 16.3 min. The final solution gave only a methanol peak. (In preliminary tests, gc of methanol solutions of 1 were found to give a peak of retention time 16-17 min, whereas gc of CS$_2$ solutions of 1 gave no peaks other than background peaks. Xanthone was retained on the column.)

When 1 ml of the final reaction solution was carried through a standard CS$_2$ extraction, the CS$_2$ layer on gc showed the background peaks and a peak at 4.3 min, identical with the retention time of known 3 on the same column, and corresponding in area to a 7% yield of 3 from 1. When 1 ml of the original reaction solution, before photolysis, was carried through the same procedure, only background peaks were seen.

Registry No.—1, 33821-93-1.

Acknowledgment.—We thank Professor Peter C. Uden for helpful suggestions concerning the gas chromatography.

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[8] (a) We assume by analogy to other cases[8b] that triplet sensitization, presumably a diffusion-controlled process, leading to a triplet carbene has occurred. (b) Triplet carboethoxycarbene derived from the benzophenone sensitization of ethyl diazoacetate apparently also does not undergo the Wolff rearrangement but rather gives products expected of a diradical-like species; see ref 2a, footnote 3. Similar results are found with α-diazo ketones: M. Jones, Jr., and W. Ando, *J. Amer. Chem. Soc.*, **90**, 2200 (1968); A. Padwa and R. Layton, *Tetrahedron Lett.*, 2167 (1965).

[9] J. A. Moore and D. E. Reed, *Org. Syn.*, **41**, 16 (1961).

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[11] F. W. Wenzel, Jr., and E. E. Reid, *J. Amer. Chem. Soc.*, **59**, 1089 (1937), method C.