Photochemical Cycloadditions of 1,3-Dipolar Systems. I. Additions of *N*,*C*-Diphenylsydnone and 2,5-Diphenyltetrazole

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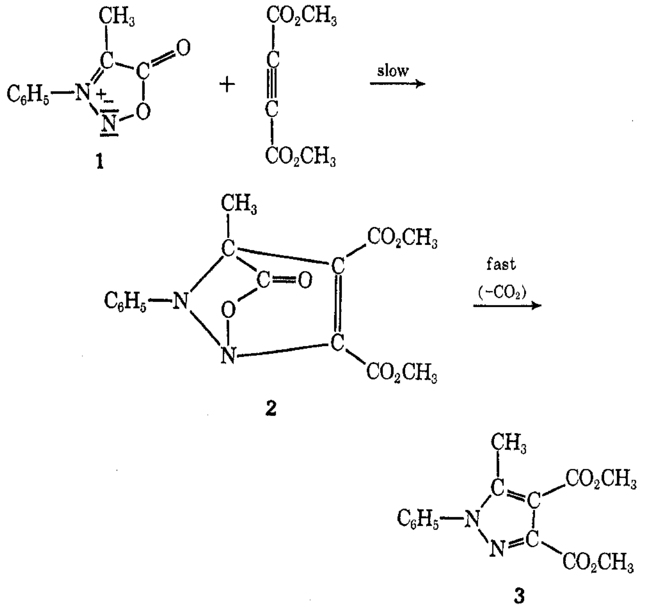
Photochemical cycloaddition of *N*,*C*-diphenylsydnone to dimethyl acetylenedicarboxylate gives rise to dimethyl 1,3-diphenylpyrazole-4,5-dicarboxylate, different from the thermal addition product. Similarly, the photoaddition of *N*,*C*-diphenylsydnone to dimethyl fumarate and dimethyl maleate gives rise to a mixture of dimethyl 1,3-diphenylpyrazoline-*trans*-4,5-dicarboxylate and dimethyl 1,3-diphenylpyrazole-4,5-dicarboxylate in each case. The photochemical transformation of *N*,*C*-diphenylsydnone, in the absence of any dipolarophile, leads to a mixture of benzil osazone, 2,4,5-triphenyl-1,2,3-triazole, and benzanilide. It has been suggested that the photoreactions of *N*,*C*-diphenylsydnone proceed through the intermediate formation of *N*,*C*-diphenylnitrileimine which then adds to the external dipolarophiles giving rise to the observed products. *N*,*C*-Diphenylnitrileimine has also been postulated as the intermediate in the photochemical cycloadditions of 2,5-diphenyltetrazole. Photolysis of 2,5-diphenyltetrazole in the absence of any added dipolarophile gives rise to a mixture of 2,4,5-triphenyl-1,2,3-triazole and benzil osazone.

Sydnones form a class of mesoionic compounds which contain the azomethineimine system as part of an aromatic ring.[2] In spite of their aromaticity, sydnones behave as potential 1,3-dipolar systems, undergoing addition reactions with different dipolarophiles.[3] These reactions, in general, are thermally induced, concerted processes which are allowed on the basis of orbital symmetry considerations.[4,5] In the reaction of *C*-methyl-*N*-phenylsydnone (**1**) with dimethyl acetylenedicarboxylate, for example, a nearly quantitative yield of dimethyl 5-methyl-1-phenylpyrazole-3,4-dicarboxylate (**3**) is formed. It has been suggested,[3g] on the basis of kinetic studies, that this reaction proceeds through the initial formation of an intermediate **2**, in a slow, rate-determining step, followed by a rapid loss of carbon dioxide from **2** to give the pyrazole **3** (Scheme I). The object of the present work was to study the photochemical cycloadditions of a cyclic azomethineimine, such as *N*,*C*-diphenylsydnone, with a view to examining the nature of the products formed in these reactions.

SCHEME I



Irradiation of a mixture of *N*,*C*-diphenylsydnone (**4**) and dimethyl acetylenedicarboxylate in benzene solution for 2 hr gave a 67% yield of dimethyl 1,3-diphenylpyrazole-4,5-dicarboxylate (**9**). The identity of this product was confirmed through an independent synthesis by a reported procedure.[6] It is pertinent to observe that the pyrazoles formed from the reaction of **4** with dimethyl acetylenedicarboxylate in thermal and photochemical reactions are not identical; the photoreaction leads to the formation of the pyrazole **9**, whereas dimethyl 1,5-diphenylpyrazole-3,4-dicarboxylate (**11**) is formed under thermal conditions. The possibility of photoisomerization of the pyrazole **11** to **9** under our reaction conditions was ruled out by showing, in a separate experiment, that **11** does not undergo photochemical isomerization when irradiated in benzene solution for a longer period (6 hr) than the time employed for the photochemical cycloaddition of **4** with dimethyl acetylenedicarboxylate.

A plausible route to the formation of **9** in the photoaddition of **4** is shown in Scheme II. In this scheme we assume that the first step in the reaction is the photochemical transformation of the starting sydnone **4** to an intermediate **5** (corresponding to the earlier structure suggested by Earl and Mackney for sydnone).[7] The intermediate **5** can then lose carbon dioxide to give the diazirine derivative **6**, which in turn would lead to *N*,*C*-diphenylnitrileimine (**7**), through a ring-opening process. Alternatively, the sydnone **4** can directly lose carbon dioxide under photolytic conditions to give the carbenonitrene intermediate **8**, which can then rearrange to *N*,*C*-diphenylnitrileimine. The nitrileimine **7** can subsequently react with dimethyl acetylenecarboxylate either through a thermal or a photochemical pathway to give the pyrazole **9**. In this connection, it might be mentioned that *N*-phenylnitrileimine has also been suggested as an intermediate

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[1] To whom all inquiries should be addressed.

[2] For comprehensive reviews on sydnones, see (a) W. Baker and W. D. Ollis, *Quart. Rev.* (*London*), **11**, 15 (1957); (b) F. H. C. Stewart, *Chem. Rev.*, **64**, 129 (1964).

[3] For some of these additions, see (a) H. Gotthardt, Ph.D. Thesis, München, 1964; (b) R. Huisgen, R. Grashey, H. Gotthardt, and R. Schmidt, *Angew. Chem. Int. Ed. Engl.*, **1**, 48 (1962); (c) R. Huisgen, H. Gotthardt, and R. Grashey, *ibid.*, **1**, 49 (1962); (d) H. Gotthardt and R. Huisgen, *Chem. Ber.*, **101**, 839 (1968); (f) H. Gotthardt, R. Huisgen, and R. Knorr, *ibid.*, **101**, 1056 (1968); (g) R. Huisgen and H. Gotthardt, *ibid.*, **101**, 1059 (1968).

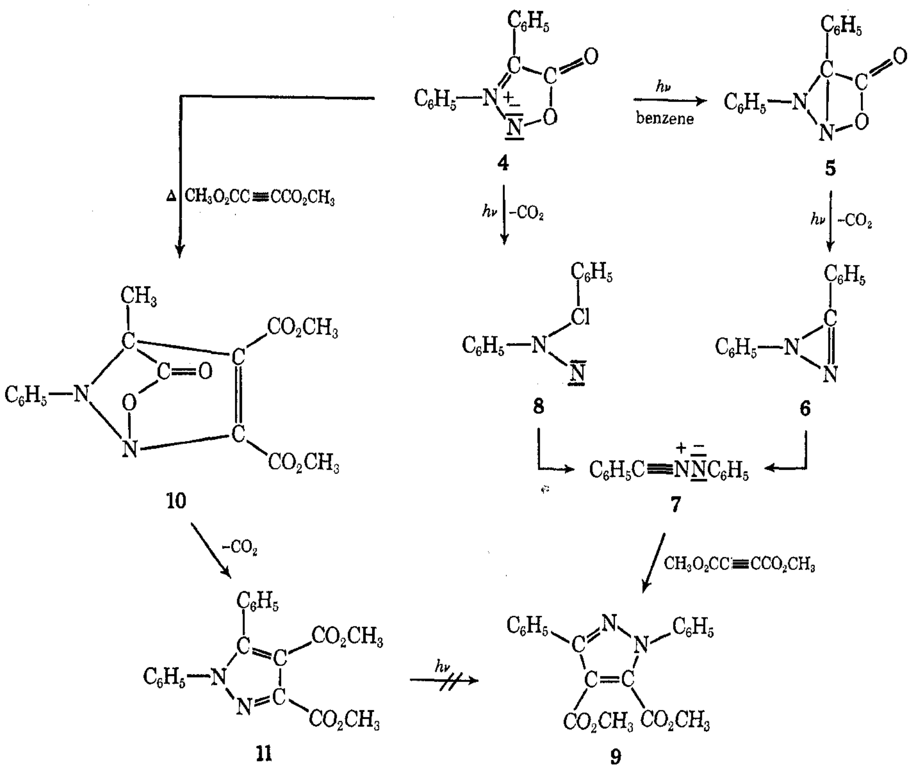
[4] (a) R. Hoffmann and R. B. Woodward, *Accounts Chem. Res.*, **1**, 17 (1968); (b) R. Hoffmann, *J. Amer. Chem. Soc.*, **90**, 1475 (1968); (c) R. B. Woodward and R. Hoffmann, *Angew. Chem. Int. Ed. Engl.*, **8**, 781 (1969).

[5] R. Huisgen, *ibid.*, **2**, 633 (1963).

[6] R. Huisgen, M. Seidel, G. Wallbilich, and H. Knupfer, *Tetrahedron*, **17**, 3 (1962).

[7] J. C. Earl and A. W. Mackney, *J. Chem. Soc.*, 899 (1935).

SCHEME II

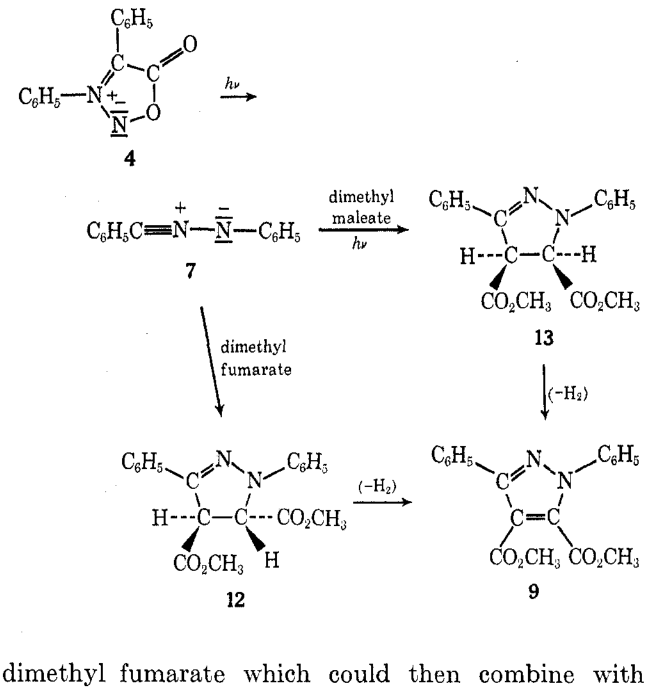


in the photochemical transformation of *N*-phenylsydnone to 3-phenyloxa-3,4-diazolinone-2.[8] We therefore felt it necessary to examine in detail some of the photochemical additions of **4** and related systems with a view to studying the nature of the products formed in these reactions.

Irradiation of a 1:1 mixture of **4** and dimethyl fumarate in benzene for 2 hr gave a 28% yield of dimethyl 1,3-diphenylpyrazoline-*trans*-4,5-dicarboxylate (**12**) together with a small quantity (6%) or the dimethyl 1,3-diphenylpyrazole-4,5-dicarboxylate (**9**). An increased yield of the pyrazoline **12** (52%) was obtained when the photoaddition was carried out using a 1:2 mixture of **4** and dimethyl fumarate. The formation of small amounts of pyrazole **9** can be rationalized in terms of a possible dehydrogenation of **12** by dimethyl fumarate, under the reaction conditions. The actual occurrence of such a dehydrogenation reaction has been verified by irradiating a mixture of the pyrazoline **12** and dimethyl fumarate in benzene solution, when a 24% yield of the pyrazole **9** was obtained.

Similarly, the photoreaction of a 1:1 mixture of **4** and dimethyl maleate gave a 20% yield of the *trans*-pyrazoline **12** and a 27% yield of the pyrazole **9**. A probable route to the formation of **9** is through the dehydrogenation of the pyrazoline **12** or dimethyl 1,3-diphenylpyrazoline-*cis*-4,5-dicarboxylate (**13**), the expected product of the stereospecific addition of **7** to dimethyl maleate (Scheme III). The formation of the *trans*-pyrazoline **12** from the reaction of **4** with dimethyl maleate, however, may be explained in terms of the photoisomerization of dimethyl maleate[9] to dimethyl fumarate which could then combine with the nitrileimine **7**.

SCHEME III



If *N,C*-diphenylnitrileimine (**7**) is involved as an intermediate in the photochemical addition of **4**, as shown in Scheme II, then it would be reasonable to assume that the photolysis of **4** in the absence of any dipolarophile should give rise to products which are essentially those derived from **7**. Irradiation of a benzene solution of **4** for 2 hr led to the formation of a mixture of products consisting of benzil osazone (**16**, 3%), 2,4,5-triphenyl-1,2,3-triazole (**18**, 14%), and benzanilide (**21**, 3%). A probable route to the formation of these products is shown in Scheme IV. In

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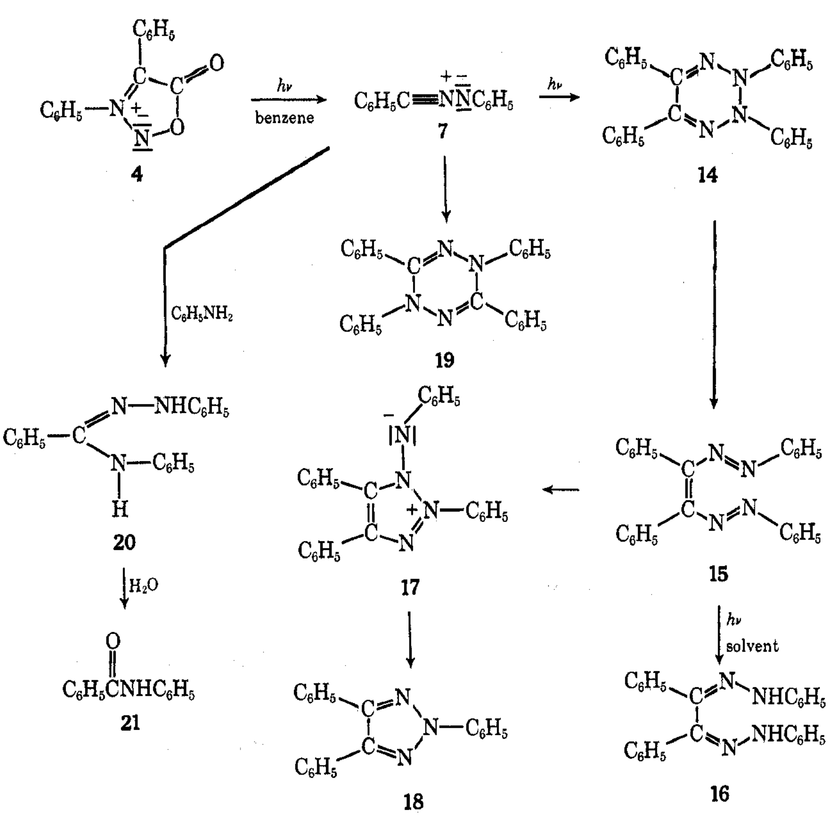
[8] C. H. Krauch, J. Kuhls, and H. J. Piek, *Tetrahedron Lett.*, 4043 (1966).

[9] For some photosensitized isomerizations of diethyl maleate and diethyl fumarate, see G. S. Hammond, J. Saltiel, A. A. Lamole, N. J. Turro, J. S. Bradshaw, D. O. Cowan, R. C. Counsell, V. Vogt, and C. Dalton, *J. Amer. Chem. Soc.*, **86**, 3197 (1964).

Scheme IV



this scheme we assume that the nitrileimine **7**, formed from **4**, undergoes a photochemical cycloaddition to give 2,3,5,6-tetraphenyl-2,3-dihydro-1,2,3,4-tetrazine (**14**). A nitrileimine such as **7** is essentially a four-electron system (those involved in addition reactions) and therefore its photochemical dimerization to give **14** would be an allowed 4 + 4 addition reaction.[4] The thermal dimerization of **7** is reported to give rise to 2,3,5,6-tetraphenyl-2,5-dihydro-1,2,4,5-tetrazine (**19**)[10] and this reaction in all probability may be proceeding by a nonconcerted process. The dihydrotetrazine **14** can then undergo ring opening either thermally or photochemically to give the bisazoethylene derivative **15**, which in turn can exist in the zwitterionic from **17**.[11,12] This intermediate **17** can then be converted to 2,4,5-triphenyl-1,2,3-triazole (**18**), either thermally or photochemically through the loss of phenylnitrene. The exact mode of formation of benzil osazone (**16**) is not very clear. However, it might arise through a free-radical process involving the hydrogen abstraction from the solvent of a possible diradical species generated from either **14** or **15**, under photochemical conditions. The formation of small amounts of benzanilide (**21**) can be explained in terms of the reaction of aniline, one of the possible side products in this reaction, with the nitrileimine **7** to give *N*-phenylbenzanilide phenylhydrazone (**20**)[10] which may undergo hydrolysis either during the reaction or work-up.

A second possible route to the formation of the triazole **18** is through the reaction of the nitrileimine **7** with benzonitrile which could arise from the fragmentation of **7**. The fact that there was not any appreciable increase in the yield of the triazole **18**, when the photolysis of **4** was carried out in presence of benzonitrile, strongly suggests that the triazole formation may not be taking place through this route, in the photolysis of the sydnone **4**.

Our next objective was to study the thermal and photochemical transformations of the dihydrotetrazine **14** which have been postulated as intermediates in the sequence of reactions shown in Scheme IV. Photolysis of **14** in benzene solution for 2 hr led to the formation of a 14% yield of 2,4,5-triphenyl-1,2,3-triazole (**18**) and 2% yield of benzil osazone (**16**).[13] It is therefore reasonable to assume that both the triazole **18** and benzil osazone (**16**) are formed through the dihydrotetrazine **14** in the photolysis of *N*,*C*-diphenylsydnone. In this connection, it might be mentioned that the triazole **18** is formed in a 85% yield on heating the dihydrotetrazine alone for about 15 min around 175°. The thermal transformation of **14** may also be taking place through the intermediates **15** and **17**, as shown in Scheme IV.

With a view to finding out whether 1,3,4,6-tetraphenyl-1,4-dihydro-1,2,4,5-tetrazine (**19**) is involved as an intermediate in the formation of either the triazole **18** or benzil osazone (**16**) in the photolysis of **4**, we have examined the photolysis of this dihydrotetrazine also. When **19** was photolyzed in benzene solution for 3 hr, practically no change occurred and most of the material was recovered unchanged. The fact that **19** is not undergoing any further transformation

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[10] R. Huisgen, J. Sauer, and M. Seidel, *Chem. Ber.*, **94**, 2503 (1961).

[11] For a similar zwitterionic repesentation of the oxidation product of dibenzoylosazone of biacetyl, see S. Petersen and H. Heitzer, *Angew. Chem. Int. Ed. Engl.*, **9**, 67 (1970).

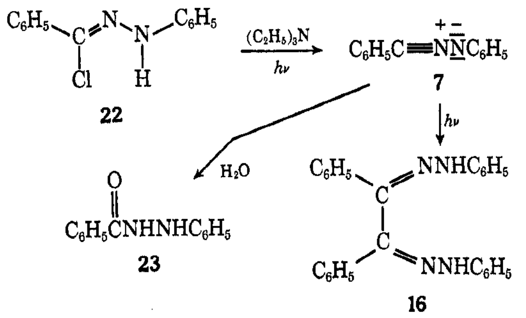
[12] For some of the 1,3-dipolar cycloaddition reactions of **17**, see C. S. Angadiyavar, K. B. Sukumaran, and M. V. George, *Tetrahedron Lett.*, 633 (1971).

[13] On completion of our studies, we came across a recent report concerning the formation of the triazole **18** from the bisazoethylene **15** [C. Wintner, *ibid.*, 2275 (1970)].

suggests that it is not being formed as an intermediate in the photolysis of **4**.

If the triazole **18** and benzil osazone (**16**) are formed from **7** in the photolysis of **4**, then it would be reasonable to assume that the nitrileimine **7**, generated by other methods, should also be capable of undergoing a photochemical transformation leading to the same products. In this connection, we have attempted the photolysis of **7** generated *in situ* by treatment of triethylamine with α-chlorobenzaldehyde phenylhydrazone (**22**).[6] From this reaction, however, the only products that could be isolated were a trace of benzil osazone and a 19% yield of benzoylphenylhydrazide (**23**) (Scheme V).

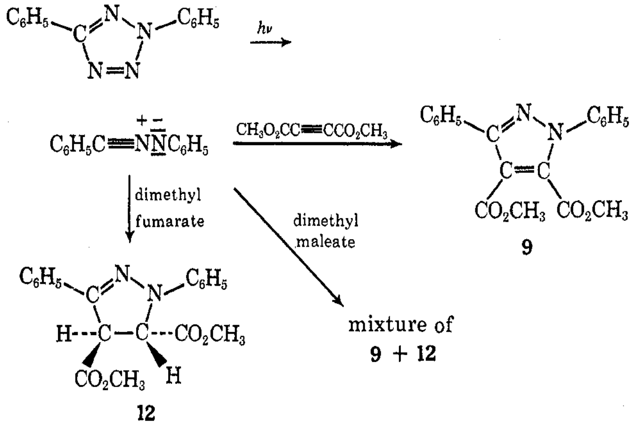
SCHEME V



The formation of **23** could be explained in terms of the reaction of the nitrileimine **7** with water during the course of the reaction or work-up. It has been reported[14] that triethylamine itself undergoes photolysis to give a mixture of the meso and racemic forms of 2,3-bisdiethylaminobutane and this complicating side reaction may be responsible for the poor yield of the desired products. It was then felt necessary to study the photolysis of the nitrileimine intermediate **7** in the absence of other reagents which might interfere with the desired reaction.

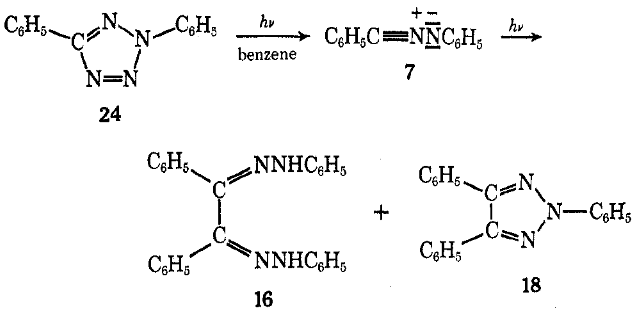
The thermal decomposition of tetrazoles are reported to give rise to a variety of products and it has been suggested that nitrileimines are involved as intermediates in some of these reactions.[15] It would be reasonable to expect that nitrileimines are also involved in the photochemical decompositions of tetrazoles. The observation that a mixture of isomeric pyrazolines are formed in the photochemical reaction between 2,5-diphenyltetrazole (**24**) and methyl crotonate strongly suggests that *N*,*C*-diphenylnitrileimine is involved as an intermediate in this reaction.[15c] Further, we find that 2,5-diphenyltetrazole (**24**) undergoes photochemical cycloaddition with different dipolarophiles leading to products which are identical with those obtained from the thermal reactions of *N*,*C*-diphenylnitrileimine with these dipolarophiles. Thus, in the photolysis of a mixture of **24** and dimethyl acetylenedicarboxylate, a 81% yield of the pyrazole **9** is obtained. Similarly, the photoreaction of **24** with dimethyl fumarate gives rise to a 73% yield of the *trans*-pyrazoline **12**. The photochemical reaction between **24** and dimethyl maleate, on the other hand, leads to a mixture of the pyrazoline **12** and pyrazole **9**. The formation of these products could be rationalized in terms of the reactions of the nitrileimine **7**, as shown in Scheme VI. The recent report on the photochemical cycloaddition reaction of 3,4-diphenyl-Δ^2-1,2,4-oxazolinone-5 with various dipolarophiles may also be explained in terms of the reaction of *N*,*C*-diphenylnitrileimine, a possible intermediate in this reaction.[16]

SCHEME VI



If *N*,*C*-diphenylnitrileimine (**7**) is formed as an intermediate in the photolysis of 2,5-diphenyltetrazole (**24**), then one would expect that the photolysis of **24** in the absence of any dipolarophile to give rise to products identical with those formed in the photolysis of *N*,*C*-diphenylsydnone. Irradiation of a benzene solution of **24** for 1.5 hr gave a 28% yield of the triazole **18** and a 3% yield of benzil osazone (**16**) (Scheme VII).

SCHEME VII



The formation of products such as **16** and **18** in the photolysis of **24** can be rationalized in terms of the nitrileimine intermediate **7**, as shown in Scheme IV. It might be mentioned in this connection that Fraser and coworkers have recently reported that the photolysis of 2-methyl-5-phenyltetrazole in dioxane medium gives rise to a mixture of products consisting of 2-methyl-4,5-diphenyl-1,2,3-triazole, 1,2-di(methylazo)-1,2-diphenylethylene, and 1-methyl-3,5-diphenyl-1,2,4-triazole.[17a] These authors have suggested that the starting material undergoes an initial 2 + 2 addition to give a dimeric product which then decomposes through the loss of nitrogen and methyl azide to give

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[14] K. Pfordte and G. Leuschner, *Justus Liebigs Ann. Chem.*, **646**, 25 (1961).

[15] For some of the thermal decomposition of tetrazoles, see (a) R. Huisgen, J. Sauer, and M. Seidel, *ibid.*, **654**, 146 (1962); (b) J. H. Markgraf, S. H. Brown, M. W. Kaplinsky, and R. G. Peterson, *J. Org. Chem.*, **29**, 2629 (1964); (c) J. S. Clovis, A. Eckell, R. Huisgen, and R. Sustmann, *Chem. Ber.*, **100**, 60 (1967).

[16] J. Sauer and K. K. Mayer, *Tetrahedron Lett.*, 325 (1968).

[17] (a) R. R. Fraser, Gurudatta, and K. E. Haque, *J. Org. Chem.*, **34**, 4118 (1969). (b) On completion of our work we became aware of a recent report on the photolysis of 2,5-diphenyltetrazole [P. Scheiner and J. F. Dinda, Jr., *Tetrahedron*, **26**, 2619 (1970)] wherein a similar 2 + 2 cycloaddition has been postulated.

the observed products.[17b] The ease with which tetrazoles lose nitrogen, and also undergo photochemical cycloaddition in the presence of dipolarophiles, would suggest that the dimerization of tetrazoles through a 2 + 2 addition may not be the only path to be considered under these conditions.

Experimental Section

All melting points are uncorrected. All irradiation experiments were carried out using a Hanovia medium-pressure mercury lamp (450 W).

Starting Materials.—*N,C*-Diphenylsydnone,[18] mp 185° (56%), 2,5-diphenyltetrazole,[19] mp 102° (68%), 2,3,5,6-tetraphenyl-2,3-dihydro-1,2,3,4-tetrazine,[20] mp 170° (54%), and 1,3,4,6-tetraphenyl-1,4-dihydro-1,2,4,5-tetrazine,[21] mp 204° (26%), were prepared by reported procedures. Benzene used for photolysis was purified by standard procedures and dried over sodium.

Photochemical Reaction of *N,C*-Diphenylsydnone with Dimethyl Acetylenedicarboxylate.—A mixture of 0.48 g (0.002 mol) of *N,C*-diphenylsydnone and 0.57 g (0.004 mol) of dimethyl acetylenedicarboxylate was irradiated in benzene solution (175 ml) for 2 hr. Removal of the solvent under vacuum gave a product which on treatment with a small portion of ethanol gave 0.45 g (67%) of dimethyl 1,3-diphenylpyrazole-4,5-dicarboxylate (**9**) which melted at 156° after recrystallization from ethanol. There was no depression in the melting point of **9** when mixed with an authentic sample.[6]

Attempted Photochemical Isomerization of Dimethyl 1,5-Diphenylpyrazole-3,4-dicarboxylate (11).—A solution (175 ml) of the pyrazole **11** (0.5 g, 0.0016 mol) in benzene was irradiated for 6 hr. Removal of the solvent under vacuum gave a product which on fractional crystallization from ethanol gave 0.49 g (98%) of the unchanged starting pyrazole **11**, mp 98–99° (mmp).

Photochemical Reaction of *N,C*-Diphenylsydnone with Dimethyl Fumarate.—Irradiation of a benzene solution (175 ml) of a mixture of **4** (0.48 g, 0.002 mol) and dimethyl fumarate (0.29 g, 0.002 mol) for 2 hr and removal of the solvent under vacuum gave a residue which on fractional crystallization from methanol gave 0.19 g (28%) of dimethyl 1,3-diphenylpyrazoline-*trans*-4,5-dicarboxylate (**12**), mp 154° (mmp). From the mother liquor was isolated 50 mg (6%) of **9**, mp 156° (mmp).

In a repeat run, 0.48 g (0.002 mol) of **4** was irradiated with 0.58 g (0.004 mol) of dimethyl fumarate in 175 ml of benzene for 2 hr to give 0.35 g (52%) of **12**, mp 154° (mmp).

Photochemical Reaction of *N,C*-Diphenylsydnone with Dimethyl Maleate.—A benzene solution (175 ml) of a mixture of **4** (0.48 g, 0.002 mol) and dimethyl maleate (0.29 g, 0.002 mol) was irradiated for 2 hr. Removal of the solvent under vacuum gave a solid which on fractional crystallization from methanol gave a 20% yield (0.14 g) of **12**, mp 154° (mmp). From the mother liquor was isolated 27% (0.18 g) of **9**, mp 156° (mmp).

Photochemical Dehydrogenation of 12 Using Dimethyl Maleate.—A benzene solution (175 ml) of a mixture of 0.34 g (0.001 mol) of **12** and 0.44 g (0.005 mol) of dimethyl maleate was irradiated for 2 hr. Removal of the solvent gave a residue which was fractionally crystallized from methanol to give 0.16 g (47%) of **9**, mp 156° (mmp), and 0.13 g (38%) of unchanged starting material **12**, mp 154° (mmp).

Photochemical Dehydrogenation of 12 Using Dimethyl Fumarate.—A mixture of 0.34 g (0.001 mol) of **12** and 0.44 g (0.003 mol) of dimethyl maleate in 175 ml of benzene was irradiated for 2 hr. Work-up of the mixture as in the earlier case gave 0.08 g (24%) of **9**, mp 156° (mmp), and 0.19 g (56%) of unchanged starting material **12**, mp 154° (mmp).

Photochemical Isomerizations of Dimethyl Maleate and Dimethyl Fumarate.—Irradiation of a solution of 0.57 g (0.004 mol) of dimethyl maleate in benzene (175 ml) for 2 hr and work-up in the usual manner gave 0.14 g (24%) of dimethyl fumarate, mp 104° (mmp), and 0.38 g (67%) of unchanged dimethyl maleate, bp 201°.

In a similar run, irradiation of a benzene solution (175 ml) of dimethyl fumarate (0.57 g, 0.004 mol) for 2 hr resulted in the isolation of a 63% yield (0.36 g) of dimethyl maleate, bp 201°, and 18% (0.1 g) unchanged dimethyl fumarate, mp 104° (mmp).

Photolysis of *N,C*-Diphenylsydnone.—A solution of 0.48 g (0.002 mol) of **4** in benzene (175 ml) was irradiated for 2 hr. Removal of the solvent under vacuum gave a product which was chromatographed on alumina. Elution with petroleum ether (bp 60–80°) gave 0.04 g (14%) of 2,4,5-triphenyl-1,2,3-triazole (**18**) which melted at 124° after recrystallization from petroleum ether (bp 60–80°). There was no depression in the melting point of **18** when mixed with an authentic sample.[22]

Further elution of the alumina column with a mixture (3:1) of petroleum ether (bp 60–80°) and benzene gave 0.01 g (3%) of benzil osazone (**16**), mp 234° (mmp). Subsequent elution of the column with benzene gave 0.01 g (3%) of benzanilide (**21**), mp 167° (mmp).

Photolysis of 2,3,5,6-Tetraphenyl-2,3-dihydro-1,2,3,4-tetrazine (14).—A solution of 0.39 g (0.001 mol) of **14** in 175 ml of benzene was irradiated for 2 hr. Removal of the solvent under vacuum gave a product which was chromatographed on alumina. Elution with petroleum ether (bp 60–80°) gave 0.04 g (14%) of 2,4,5-triphenyl-1,2,3-triazole (**18**), mp and mmp 124°. Further elution of the column with a mixture (3:1) of petroleum ether and benzene gave 6 mg (2%) of benzil osazone, mp and mmp 154°.

Thermal Decomposition of 2,3,5,6-Tetraphenyl-2,3-dihydro-1,2,3,4-tetrazine (14).—The dihydrotetrazine **14** (0.2 g, 0.5 mmol) was heated in a sealed tube around 175–180° in an oil bath for 15 min and the product mixture was chromatographed on alumina. Elution with petroleum ether (bp 60–80°) gave 0.13 g (85%) of the triazole **18**, mp 124° (mmp).

Attempted Photolysis of 1,3,4,6-Tetraphenyl-1,4-dihydro-1,2,4,5-tetrazine (19).—A solution of 0.4 g (0.001 mol) of **19** in 175 ml of benzene was photolyzed for 3 hr. Removal of the solvent under vacuum and work-up as in the previous case gave 0.39 g (96%) of the starting material, mp 204° (mmp).

Photolysis of *N,C*-Diphenylnitrileimine (7) Generated from α-Chlorobenzaldehyde Phenylhydrazone.—A solution of triethylamine (1 g, 0.01 mol) in benzene (20 ml) was gradually added to a benzene solution (150 ml) of α-chlorobenzaldehyde phenylhydrazone[6] (0.46 g, 0.002 mol), kept inside the photochemical reactor. The addition was completed in about 30 min, but the irradiation was continued for a further period of 2 hr. Removal of the solvent under vacuum gave a product which was chromatographed on alumina. Elution of the column with a mixture (3:1) of petroleum ether (bp 60–80°) and benzene gave a trace of benzil osazone identified on a tlc plate by comparison with an authentic sample. Further elution of the column with a mixture (3:1) of benzene and ethyl acetate gave 0.08 g (19%) of benzoylphenylhydrazine, mp and mmp 172° (lit.[23] mp 168°).

Photochemical Reaction of 2,5-Diphenyltetrazole with Dimethyl Acetylenedicarboxylate.—A mixture of 0.45 g (0.002 mol) of 2,5-diphenyltetrazole and 0.43 g (0.002 mol) of dimethyl acetylenedicarboxylate was irradiated in benzene solution (175 ml) for 2 hr. Removal of the solvent under vacuum gave a product which on treatment with a small amount of ethanol gave 0.55 g (81%) of dimethyl 1,3-diphenylpyrazole-4,5-dicarboxylate which melted at 156° after recrystallization from ethanol. There was no depression in the melting point on admixture with an authentic sample.[6]

Photochemical Reaction of 2,5-Diphenyltetrazole with Dimethyl Fumarate.—Irradiation of a mixture of 0.45 g (0.002 mol) of the tetrazole **24** and 0.29 g (0.002 mol) of dimethyl fumarate in benzene solution (175 ml) for 1.5 hr and work-up as in the previous case gave 0.48 g (73%) of dimethyl 1,3-diphenyl-*trans*-pyrazoline-4,5-dicarboxylate, mp 154° (mmp).

Photochemical Reaction of 2,5-Diphenyltetrazole with Dimethyl Maleate.—A benzene solution (175 ml) of a mixture of 2,5-diphenyltetrazole (0.45 g, 0.002 mol) and dimethyl maleate (0.29 g, 0.002 mol) was irradiated for 1.5 hr. Removal of the solvent gave a mixture of products which was fractionally crystallized from methanol to give 0.27 g (40%) of the *trans*-pyrazoline **12**, mp 154° (mmp), and 55 mg (8%) of the pyrazole **9**, mp 156° (mmp).

Photolysis of 2,5-Diphenyltetrazole.—A solution of 0.45 g (0.002 mol) of the tetrazole **24** in 175 ml of benzene was irradiated for 1.5 hr. Removal of the solvent under vacuum gave a mixture

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of products which was chromatographed on alumina. Elution with petroleum ether (bp 60–80°) gave 80 mg (28%) of 2,4,5-triphenyl-1,2,3-triazole (**18**), mp 124° (mmp). Further elution of the column with a mixture (3:1) of petroleum ether and benzene gave 10 mg (3%) of benzil osazone, mp 234° (mmp). No other product could be isolated from this run.

Registry No.—**4,** 28638-85-9; **7,** 834-27-5; **12,** 17679-79-7; **14,** 28595-91-7; **24,** 18039-45-7; dimethyl acetylenedicarboxylate, 762-42-5; dimethyl fumarate, 624-49-7; dimethyl maleate, 624-48-6.

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A New Synthesis of 5-Amino-1-(β-D-ribofuranosyl)imidazole-4-carboxamide (AICA Riboside) *via* the Reduction of 1-(β-D-Ribofuranosyl)-5-(3,3-dimethyl-1-triazeno)imidazole-4-carboxamide (DIC Riboside)[1]

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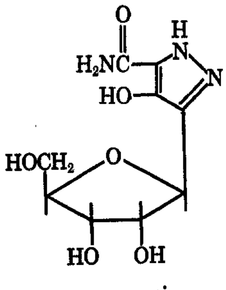
1-(β-D-Ribofuranosyl)-5-(3,3-dimethyl-1-triazeno)imidazole-4-carboxamide (**5**, DIC riboside) and 1-(β-D-ribofuranosyl)-4-(3,3-dimethyl-1-triazeno)imidazole-5-carboxamide (**6**, iso-DIC riboside) have been synthesized by the direct ribosidation of the trimethylsilyl derivative of 5(4)-(3,3-dimethyl-1-triazeno)imidazole-4(5)-carboxamide (DIC). The assignment of anomeric configuration and proof for the site of glycosidation of these nucleosides (**5** and **6**) were achieved by catalytic cleavage of the –N═N– double bond to afford the imidazole nucleosides 5-amino-1-(β-D-ribofuranosyl)imidazole-4-carboxamide (**7**) and 4-amino-1-(β-D-ribofuranosyl)imidazole-5-carboxamide (**8**) of established structure.

The isolation and characterization[3] of 5-amino-1-(β-D-ribofuranosyl)imidazole-4-carboxamide (AICA riboside) from the culture medium of sulfonamide-inhibited *E. coli* was followed by the enzymatic conversion of AICA riboside to 5-amino-1-(β-D-ribofuranosyl)imidazole-4-carboxamide 5′-phosphate (AICAR).[4] The synthesis of AICA riboside was subsequently accomplished by ring opening of certain purine nucleosides,[5] fermentation,[6] and direct ribosidation of an imidazole derivative followed by functional group transformations.[7] A renewed interest in the chemical synthesis of AICA riboside and related derivatives has been prompted by the report[6] that AICA riboside can function effectively as a substrate for a kinase which results in a facile conversion of AICA riboside to AICAR.[8] Also of considerable interest is the recent isolation and characterization of pyrazomycin[9] as a five-membered heterocyclic riboside which is structurally very similar to AICA riboside. Previous investigations from our laboratory[10–13] on the direct glycosidation of various imidazole derivatives by the fusion procedure have usually resulted in the successful isolation of only one isomer. However, after the appropriate functional group transformations had been accomplished, the actual site of glycosidation was established as being at the ring nitrogen adjacent to the carboxamide group (iso-AICA riboside and derivatives) rather than the ring nitrogen adjacent to the exocyclic amino group (AICA riboside and derivatives) by ring annulation to afford 7-ribosylpurines. We now wish to report a convenient synthesis of both isomers (AICA riboside and iso-AICA riboside).



pyrazomycin

5(4)-(3,3-Dimethyl-1-triazeno)imidazole-4(5)-carboxamide (DIC)[14] was treated with hexamethyldisilazane to afford the trimethylsilyl derivative **1** which was then condensed with 2,3,5-tri-*O*-acetyl-D-ribofuranosyl bromide in acetonitrile. This procedure furnished two major components (**3**, 17.4%; **4**, 32.2%) which were separated by column chromatography. 1-(2,3,5-Tri-*O*-acetyl-β-D-ribofuranosyl)-4-(3,3-dimethyl-

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[14] The abbreviations used are DIC, 5(4)-(3,3-dimethyl-1-triazeno)-imidazole-4(5)-carboxamide, NSC-45388; AIC, 4(5)-aminomidazole-5(4)-carboxamide; AICA riboside, 5-amino-1-(β-D-ribofuranosyl)imidazole-4-carboxamide; iso-AICA riboside, 4-amino-1-(β-D-ribofuranosyl)imidazole-5-carboxamide; AICAR, 5-amino-1-(β-D-ribofuranosyl)imidazole-4-carboxamide 5′-phosphate.