# Studies in Nonbridgehead Fused Nitrogen Heterocycles. Fused 1,2,3-Triazoles

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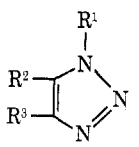
1-Benzyl-4,5-diamino-1,2,3-triazole (**5**) was prepared by the Curtius rearrangement of 5-amino-1-benzyl-1,2,3-triazole-4-carboxylic acid hydrazide (**2**). The diamine **5** was readily condensed with α-diketones, affording the 5,6-substituted 1,2,3-triazolo[4,5-*b*]pyrazines (**6**–**9**). If the condensation was carried out with ethyl acetoacetate and the intermediate crotonate **10** was refluxed with sodium ethoxide, 4*H*,6*H*-1-benzyl-7-methyl-1,2,3-triazolo-[5,4-*b*][1,4]diazepin-5-one (**11**) resulted as a mixture of tautomers. Acetylation of **5** produced 4-acetamido-5-amino-1-benzyl-1,2,3-triazole (**13**) or 4,5-diacetamido-1-benzyl-1,2,3-triazole (**15**) depending upon the reaction conditions employed. The enhanced reactivity of the 4-amino group of **5** was demonstrated by the unambiguous synthesis of 5-acetamido-1-benzyl-1,2,3-triazole (**14**).

In a search for novel nitrogen heterocycles which might possess insect chemosterilizing properties, suitably substituted 1,2,3-triazoles appeared to be attractive candidates for elaboration into fused derivatives. Some early work by Thiele[1] with 4,5-diamino-2-phenyl-1,2,3-triazole provided interesting but insufficient background material. In addition, two other factors influenced our decision: the 1,2,3-triazole ring had been shown to occur in nature[2] as 8-azaguanine, and, although considerable attention had been directed toward the thermal homolytic ring cleavage,[3,4] and acid-catalyzed heterolytic ring scission[5–7] of these compounds, to our knowledge no one had investigated the possibility of photochemical[8] ring fission of fused 1,2,3-triazoles.

Based on the antimetabolic activity reported for 8-azaguanine[9] and on the somewhat tenuous empirical relationship that exists between chemosterilants and antimetabolites, it was anticipated that some interesting fused heterocycles could be prepared from the previously unknown 1-benzyl-4,5-diamino-1,2,3-triazole. In addition, such compounds would have the potential for rapid photolytic decomposition, making them short lived. The results reported below indicate our progress toward these goals.

## Results and Discussion

The condensation of benzyl azide with ethyl cyanoacetate in the presence of 1 equiv of sodium ethoxide afforded ethyl 5-amino-1-benzyl-1,2,3-triazole-4-carboxylate (**1**) under conditions that were modified slightly from those reported in the literature (see Experimental Section).[10] Likewise, 5-amino-1-benzyl-1,2,3-triazole-4-carboxamide (**1a**) resulted when benzyl azide was condensed with cyanoacetamide. The condensation of benzyl azide with acetylenedicarboxylic acid and with dimethyl acetylenedicarboxylate gave 1-benzyl-1,2,3-triazole-4,5-dicarboxylic acid (**1b**)[11] and its dimethyl ester (**1c**),[12] respectively, in excellent yield.



**1**, $R^1 = C_6H_5CH_2$; $R^2 = NH_2$; $R^3 = CO_2C_2H_5$
**1a**, $R^1 = C_6H_5CH_2$; $R^2 = NH_2$; $R^3 = CONH_2$
**1b**, $R^1 = C_6H_5CH_2$; $R^2 = R^3 = CO_2H$
**1c**, $R^1 = C_6H_5CH_2$; $R^2 = R^3 = CO_2CH_3$
**1d**, $R^1 = C_6H_5CH_2$; $R^2 = R^3 = CONHNH_2$

When compound **1a** was heated with sodium hypobromite in aqueous base under conditions used to effect the Hofmann rearrangement, no reaction occurred. Also, the diamide resulting from the treatment of compound **1c** with alcoholic ammonia failed to undergo the Hofmann rearrangement. This apparent lack of reactivity is most likely the result of the insolubility of the two compounds in the aqueous or methanolic base employed in the reaction. The dicarboxylic acid **1b** was decomposed to tars when treated with sodium azide in sulfuric acid (98%) in an attempt to bring about the Schmidt rearrangement. The dimethyl ester **1c** could be readily converted to the dihydrazide **1d** with hydrazine hydrate. However, when the dihydrazide **1d** was subjected to the Curtius rearrangement, no identifiable carbamates were isolated. This result verifies some earlier work reported by Curtius.[11] Finally, when compound **1** was treated with hydrazine hydrate at reflux and the resulting hydrazide (**2**) was treated with nitrous acid at 0°, an off-white precipitate (**3**) could be isolated. The formation of the heterocyclic acyl azide function was confirmed by the presence of a band at 2200 $cm^{-1}$ in the infrared spectrum. The acyl azide **3** was stable at room temperature in the presence of air for many months, but it did explode when heated at 150°. When compound **3** was dissolved in absolute ethanol and refluxed, the evolution of a colorless, odorless gas presumed to be nitrogen was noted and the product of the Curtius rearrangement, ethyl 5-amino-1-benzyl-1,2,3-triazole-4-carbamate (**4**), was isolated in yields varying from 50 to 80%. The carbamate was readily identified from its infrared spectrum, which showed the $NH_2$ and NH stretching bands at 3300 and 3150 $cm^{-1}$, respectively. The carbonyl stretching absorption at

(1) J. Thiele and K. Schleussner, *Justus Liebigs Ann. Chem.*, **295**, 129 (1897).

(2) K. Anzai and S. Suzuki, *J. Antibiot., Ser. A*, **14**, 253 (1961); K. Anzai, J. Nagatsu, and S. Suzuki, *ibid.*, 340 (1961); *Chem. Abstr.*, **56**, 8849, 10677 (1962).

(3) W. D. Crow and C. Wentrup, *Tetrahedron Lett.*, 6149 (1968).

(4) D. J. Anderson, T. L. Gilchrist, G. E. Gymer, and C. W. Rees, *Chem. Commun.*, 1518 (1971).

(5) J. H. Boyer and L. T. Wolford, *J. Amer. Chem. Soc.*, **80**, 2741 (1958).

(6) G. Tennant, *J. Chem. Soc. C*, 2290 (1966).

(7) G. Tennant, *ibid.*, 1279, 2658 (1967).

(8) R. Valvarajan and J. H. Boyer, *J. Heterocycl. Chem.*, **9**, 87 (1972), recently reported the photodegradation of 4-phenyl- and 4,5-diphenyl-1,2,3-triazoles, but did not investigate any fused ring triazoles.

(9) R. O. Roblin, Jr., J. O. Lampen, J. P. English, Q. P. Cole, and J. R. Vaughan, Jr., *J. Amer. Chem. Soc.*, **67**, 290 (1945).

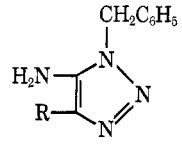
(10) J. R. E. Hoover and A. R. Day, *J. Amer. Chem. Soc.*, **78**, 5832 (1956).

(11) T. Curtius and K. Raschig, *J. Prakt. Chem.*, **125**, 466 (1930).

(12) J. C. Sheehan and C. A. Robinson, *J. Amer. Chem. Soc.*, **73**, 1207 (1951).

1680 $cm^{-1}$ was also in agreement with that expected for a carbamate.

Attempts to hydrolyze the carbamate **4** in acid using a sealed tube[13] were completely unsuccessful, producing dark-colored solutions which did not afford any recognizable organic materials. This result is in agreement with that of Albert and Tratt,[14] who reported a similar degradataion of 5-amino-1-benzyl-1,2,3-triazole-4-carboxamide. When the carbamate was refluxed in aqueous sodium hydroxide,[15] it was smoothly cleaved to 1-benzyl-4,5-diamino-1,2,3-triazole (**5**). Compound **5** was identified by its infrared spectrum, in which the $NH_2$ stretching and bending frequencies occurred at 3300, 3150, and 1600 $cm^{-1}$, respectively. The pmr spectrum indicated the presence of four hydrogens attached to nitrogen at $\delta$ 3.10, all four being exchanged upon treatment with $D_2O$. The presence of methylene protons of the benzyl group at $\delta$ 5.35 and of the aromatic protons in a multiplet centered at $\delta$ 7.30 suggested the presence of the intact 1,2,3-triazole nucleus.



**2**, R = $CONHNH_2$
**3**, R = $CON_3$
**4**, R = $NHCO_2C_2H_5$
**5**, R = $NH_2$
**5a**, R = $N{=}CHC_6H_5$

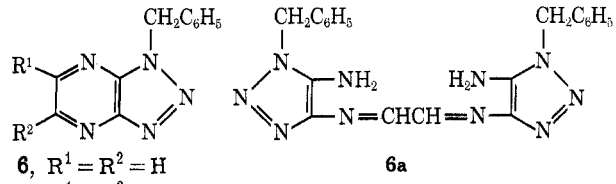
The diamine **5** was moderately water soluble and formed a monopicrate when treated with 1 equiv of picric acid. It also formed the mono-*N*-benzylidene derivative **5a** when treated with an excess of benzaldehyde. The structure of **5a** was established by infrared and pmr spectral data (see Experimental Section). A complete discussion of the enhanced reactivity of one amino group when compared to the other will be discussed below.

1-Benzyl-4,5-diamino-1,2,3-triazole (**5**) was treated with an aqueous solution of glyoxal, sodium bisulfite, and a catalytic amount of hydrochloric acid and formed a mixture of two products. 1-Benzyl-1,2,3-triazolo-[4,5-*b*]pyrazine (**6**) was separated from the mixture as a methylene chloride soluble fraction and its structure was confirmed by its proton magnetic resonance spectrum, which contained two doublets at $\delta$ 8.74 and 8.65 ($J$ = 1.5 Hz). This coupling is in excellent agreement with the reported ortho coupling constant for the pyrazine ring.[16] The remaining resonances in the spectrum were readily assigned. The paramagnetic shift ($\delta$ 5.92 *vs.* 5.35 in compound **5**) of the methylene protons indicates that an appreciable ring current exists in the fused system above that present in the 1,2,3-triazole nucleus alone. This effect is present in all fused rings examined.

(13) P. A. S. Smith in "Organic Reactions," Vol. III, Wiley, New York, N. Y., 1946, p 380.
(14) A. Albert and K. Tratt, *J. Chem. Soc. C*, 344 (1968).
(15) G. B. Jambuserwala, S. Holt, and F. A. Mason, *J. Chem. Soc.*, 373 (1931).
(16) M. H. Palmer, "Heterocyclic Compounds," St. Martins Press, New York, N. Y., 1967, p 68.

In addition to **6**, a methylene chloride insoluble material was isolated (**6a**). The infrared spectrum of **6a** showed the characteristic $NH_2$ stretching and bending frequencies at 3300, 3150, and 1590 $cm^{-1}$. The pmr spectrum exhibited a singlet at $\delta$ 8.65 integrating for two protons and a broad singlet at 6.30. The latter was exchangeable in $D_2O$ and integrated for four protons. The data are consistent with a structure such as **6a**, the result of an intermolecular condensation between one molecule of glyoxal and two of the diamine. The structure was confirmed when treatment at room temperature with aqueous hydrochloric acid produced a mixture of **5** and **6**. The formation of **6a** could never be completely eliminated, but the yield could be significantly reduced by adding the glyoxal–bisulfite solution dropwise to a solution of **5**.

Similarly, 1-benzyl-5,6-diphenyl-1,2,3-triazolo[4,5-*b*]-pyrazine (**7**) and 1-benzyl-5,6-dimethyl-1,2,3-triazolo[4,5-*b*]pyrazine (**8**) were prepared by condensing benzil or butane-2,3-dione with compound **5**. In the latter case, a yield approaching quantitative was realized. Both compounds **7** and **8** were characterized by means of their spectral data.



**6**, $R^1 = R^2 = H$
**7**, $R^1 = R^2 = C_6H_5$
**8**, $R^1 = R^2 = CH_3$
**9a**, $R^1 = CH_3$; $R^2 = H$
**9b**, $R^1 = H$; $R^2 = CH_3$

**6a**

Compound **8** was refluxed in aqueous hydrochloric acid for 5 hr and recovered unchanged in quantitative yield, indicating the resistance of the 1,2,3-triazolo-[4,5-*b*]pyrazine ring to acid hydrolysis. The ultraviolet absorption maxima measured in 50% aqueous ethanol for compound **6** were completely unaffected by either acid or base, indicating that covalent hydration is extremely unlikely in this ring system.[17] Covalent hydration has been implicated as the driving force in the acid hydrolysis of 8-azapurines.[18] In addition, compound **8** was unaffected by aqueous base and by nucleophiles such as hydrazine hydrate. Hydrazine hydrate has caused the cleavage of the pyrazine ring of some pteridines.[19]

When the diamino-1,2,3-triazole **5** was treated with pyruvic aldehyde, a single condensation product was isolated. The structure assigned (**9a** or **9b**) was based upon the pmr spectrum, in which the pyrazine ring proton appeared at $\delta$ 8.56 as a singlet and the methyl group appeared at 2.76, also a singlet. Differentiation by spectral means between **9a** and **9b** was impossible and the absolute structure remains in doubt.

When the 5,6-dimethyl derivative **8** was treated with sodium in liquid ammonia, a technique which has been used successfully to remove the 1-benzyl group,[10] it failed to effect debenzylation. A second attempt to

(17) See ref 14. Albert reported a bathochromic shift of 33 nm upon addition of acid when measuring the uv spectra of some 8-azapurines in aqueous ethanol. This shift can be attributed to the loss of double-bond character *via* covalent hydration.
(18) A. Albert, *J. Chem. Soc. C*, 2379 (1969).
(19) J. Clark and G. Neath, *ibid.*, 1112 (1966).

remove the 1-benzyl group with hydrogen, palladium on charcoal, and magnesium oxide in ethanol[14] also failed to bring about debenzylation of compound **8**. These results were rather unexpected, since the isomeric 1,2,3-triazolo[4,5-*d*]pyrimidine nucleus undergoes ready debenzylation,[14,20] as does the parent 1,2,3-triazole ring.

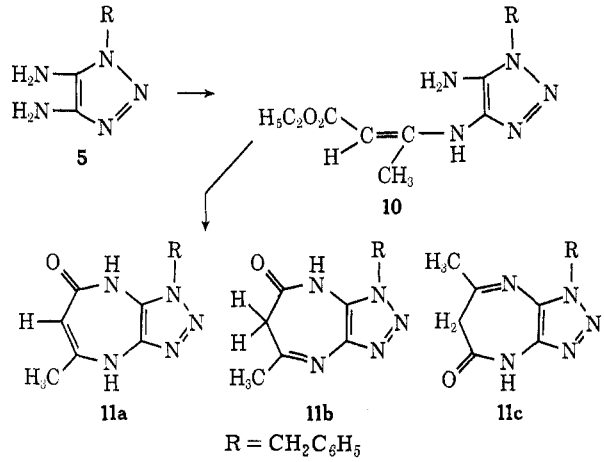
When attempts were made to extend the condensation discussed above to α-keto acids or α-keto esters such as glyoxylic acid or diethyl mesoxylate, no ring-closed products were isolated. In both cases, complex mixtures which did not lend themselves to common separation techniques were observed by tlc.

The addition of **5** to ethyl acetoacetate at 60° afforded compound **10**, which was identified by its infrared and pmr spectra. Ring closure of **10** with sodium ethoxide gave a material whose infrared spectrum contained carbonyl bands at 1700 and 1620 $cm^{-1}$. Heating the crude product in benzene produced a soluble and an insoluble fraction. The infrared spectrum of the insoluble fraction contained a single carbonyl band at 1620 $cm^{-1}$. Structures such as **11b** or **11c**, based on the findings of Israel and coworkers[21] for similar systems, would be consistent with that carbonyl absorption. The pmr spectrum contained, among other resonances, a two-proton singlet at δ 3.30, also consistent with **11b** or **11c** (the olefinic proton in **10** appeared at δ 4.75). Structure **11c** is considered unlikely in light of the enhanced reactivity of the 4-amino group (*vide infra*).[22]

The infrared spectrum of the benzene-soluble fraction contained carbonyl bands at 1700 and 1620 $cm^{-1}$. Israel and coworkers[21] have assigned structures such as **11a** to compounds having the 1700-$cm^{-1}$ carbonyl absorption. Attempts to detect **11a** by pmr were unsuccessful and experiments, such as vacuum sublimation, designed to isolate pure **11a** also failed. (See Scheme I.)

Compound **5** could be monoacetylated yielding compound **12** when treated with acetic anhydride for short periods of time at room temperature. If the acetylation was accomplished at reflux, or at room temperature for longer periods of time, a diacetyl derivative **15** could be isolated. The structure of compound **12** was established by spectral means and the diacetyl product **15** was similarly identified. The presence of two acetyl methyl groups at δ 2.25 and 2.08 were invaluable in the structural assignment of **15**. Structure **15** rather than **15a** is proposed since the carbonyl band at 1660 $cm^{-1}$ is much lower than the

SCHEME I




carbonyl frequencies reported by Sutherland and Tennant[25] for ring nitrogen acetylated 1,2,3-triazoles. Also, these workers observed ring nitrogen acetyl methyl resonances at approximately δ 2.8, much more deshielded than the methyl resonances observed[22] for **12** and **15**.

The final proof of the structure of the monoacetylated derivative **12** was obtained as follows. **12** was diazotized in the presence of sodium fluoroborate, and the diazonium fluoroborate salt was isolated. Without further characterization the diazonium salt was dissolved in methanol and treated with an excess of sodium borohydride.[26] This procedure effected smooth displacement of the diazonium group, yielding 4-acetamido-1-benzyl-1,2,3-triazole (**13**). The loss of the amino group was demonstrated by the presence of a single absorption at 3180 $cm^{-1}$ in the infrared spectrum of **13** (secondary amide). In addition, the 5 proton was clearly visible at δ 8.02 in the proton magnetic resonance spectrum. In order to demonstrate unequivocally that acetylation had occurred on the 4-amino group and not on the 5-amino group, 5-acetamido-1-benzyl-1,2,3-triazole was prepared by the following route. Benzyl azide was condensed with cyanoacetic acid, affording 5-amino-1-benzyl-1,2,3-triazole-4-carboxylic acid (**16**) in the same fashion as described previously. The carboxylic acid was readily decarboxylated in refluxing dimethyl aniline,[10] giving 5-amino-1-benzyl-1,2,3-triazole in respectable yield. Acetylation with acetic anhydride in the presence of a small amount of sulfuric acid[25] afforded 5-acetamido-1-benzyl-1,2,3-triazole (**14**) in low yield. Compound **14** was different in all respects from **13**. The Experimental Section contains the spectral data for the two isomers and the reactions are summarized in Scheme II.

The facile acetylation with acetic anhydride thwarted attempts to prepare the imidazolo[4,5-*d*]-1,2,3-triazole ring system with either acetic anhydride or acetic anhydride–ortho esters. In fact, heating **5** with ortho esters (triethyl orthoformate) for 24 hr followed by addition of acetic anhydride produced **13** in excellent yield.

## Experimental Section

The pmr spectra were determined on a Varian HA-100 spectrophotometer; infrared spectra were measured on a Perkin-

(20) G. Nübel and W. Pfleiderer, *Chem. Ber.*, **98**, 1060 (1965).

(21) M. Israel, L. C. Jones, and E. J. Modest, *J. Heterocycl. Chem.*, **4**, 659 (1967).

(22) Albert[23] has recently reported a somewhat more facile Dimroth rearrangement in base of 4-amino-3-benzyl 5-substituted 1,2,3-triazoles than had previously been noted or expected for the bulky benzyl group. However, 4-amino-3-benzyl-1,2,3-triazole-5-carboxamide does not undergo the rearrangement when heated to 180° in alcoholic ammonia.[24] It appears that the rearrangement is quite sensitive to both heat and base and not well understood when a benzyl substituent is present. The chemical shifts for the methylene protons of the benzyl group in **10** and **11** are in good agreement with Albert's[23] values for triazole ring substitution. Furthermore, he noted an upfield shift of the methylene protons and coupling between the NH and $CH_2$ when the benzyl group rearranged to the adjacent exocyclic amino group. No such shift or coupling was observed for **11**. With that data in hand, we believe that the Dimroth rearrangement plays an insignificant role in this reaction. Likewise, the same argument, based upon spectral evidence, can be advanced for the acid-catalyzed condensation of **5** with the α-diketones and the reaction of **5** with acetic anhydride.

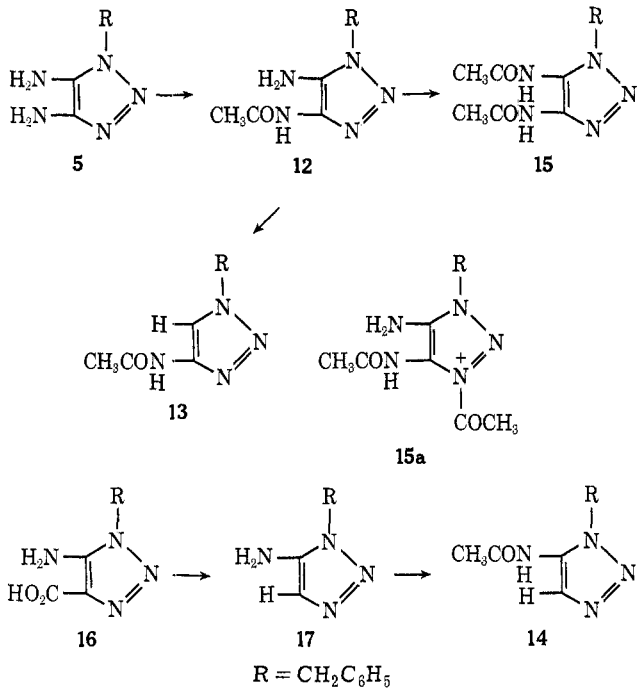
(23) A. Albert, *J. Chem. Soc. C*, 230 (1970).

(24) A. Albert, *ibid.*, 152 (1969).

(25) D. R. Sutherland and G. Tennant, *ibid.*, 706 (1971).

(26) J. B. Hendrickson, *J. Amer. Chem. Soc.*, **83**, 1251 (1961).

SCHEME II




Elmer 137 Infracord spectrophotometer. All melting points are uncorrected and were taken on a Thomas-Hoover melting point apparatus. Elemental analyses were performed by Midwest Microlab, Ltd., Indianapolis, Ind. 46226.

**Ethyl 5-Amino-1-benzyl-1,2,3-triazole-4-carboxylate (1).**—To a solution of 11.0 g (0.5 mol) of sodium in 250 ml of absolute ethanol was added 56.5 g (0.5 mol) of ethyl cyanoacetate and 61.3 g (0.5 mol) of benzyl azide.[27] A white precipitate formed immediately and gradually dissolved during the course of 1 hr. The yellow solution which resulted was poured into 2 l. of ice-water and the crude yellow precipitate was collected. Recrystallization from ethanol afforded colorless needles: mp 153–154° (lit.[10] mp 154°); ir (KBr) 3400, 3250, 3100, 1700, 1620, 1500, 1200, 730 cm$^{-1}$.

**5-Amino-1-benzyl-1,2,3-triazole-4-carboxylic Acid Hydrazide (2).**—A mixture of 45.0 g (0.2 mol) of **1** and 200 ml of 85% hydrazine hydrate was refluxed for 1.5 hr. The pale yellow solution was cooled and the colorless plates were collected, mp 196–198° (lit.[10] mp 195°).

**5-Amino-1-benzyl-1,2,3-triazole-4-carbonyl Azide (3).**—A solution of 15.0 g (0.07 mol) of **2** in 200 ml of 10% hydrochloric acid was cooled to 5°. A solution of 4.5 g (0.07 mol) of sodium nitrite in water was added dropwise. The white precipitate that formed immediately became yellow with time and was collected. The precipitate was washed with cold ether and was recrystallized by dissolving in acetone and precipitating with hexane. This treatment gave 16.4 g (74%) of white, irregular prisms: mp 150° dec; ir (KBr) 3300, 3200, 2200, 1650, 1620, 1200, 980 cm$^{-1}$.

**Ethyl 5-Amino-1-benzyl-1,2,3-triazole-4-carbamate (4).**—A mixture of 6.0 g (0.04 mol) of **3** and 100 ml of absolute ethanol was refluxed for 20 hr. The darkened solution was cooled to room temperature and the off-white, irregular prisms that formed were collected. Crystallization from ethanol gave 5.40 g (52%) of **4**: mp 206° dec; ir (KBr) 3300, 3150, 1680, 1600, 1260, 700 cm$^{-1}$; pmr (DMSO-$d_6$) $\delta$ 7.37–7.14 (m, 5, aromatic), 5.33 (s, 2, $BzCH_2$), 4.10 (q, $J$ = 6 Hz, $CH_2$ ethyl), 1.20 (t, $J$ = 6 Hz, $CH_3$ ethyl).

*Anal.* Calcd for $C_{12}H_{15}N_5O_2$: C, 55.16; H, 5.79; N, 26.81. Found: C, 54.81; H, 5.54; N, 26.81.

**1-Benzyl-4,5-diamino-1,2,3-triazole (5).**—A mixture of 1.0 g (0.004 mol) of **4**, 2 ml of ethanol, and 15 ml of 1 $N$ sodium hydroxide was refluxed for 3 hr. The yellow solution was extracted with 4 × 50 ml of methylene chloride. The methylene chloride was dried over magnesium sulfate and finally evaporated to dryness *in vacuo*. Crystallization from benzene gave 0.4 g (55%) of **5**: mp 115°; ir (KBr) 3350, 3150, 1640, 1600, 1400, 740 cm$^{-1}$; pmr ($CDCl_3$) $\delta$ 7.36–7.18 (m, 5, aromatic), 5.35 (s, 2, $BzCH_2$), 3.08 (broad s, 4, $NH_2$).

*Anal.* Monopicrate, calcd for $C_{15}H_{14}N_8O_7$: C, 42.96; H, 3.58; N, 26.73. Found: C, 42.90; H, 3.56; N, 26.72.

**5-Amino-1-benzyl-4-(*N*-benzylidene)-1,2,3-triazole (5a).**—To a solution of **5** (0.85 g, 0.004 mol) in ethanol was added 1.25 g of benzaldehyde. The yellow precipitate (1.1 g, mp 177°) was collected. The material was recrystallized twice from benzene: mp 178°; pmr (acetone-$d_6$) $\delta$ 9.08 (s, 1, $C_6H_5CH$), 8.00–7.20 (series of three complex multiplets, 10, aromatic), 5.47 (s, 2, $BzCH_2$), 5.27 (broad s, 2, $NH_2$).

*Anal.* Calcd for $C_{16}H_{15}N_5$: C, 69.30; H, 5.45; N, 25.25. Found: C, 69.25; H, 5.55; N, 25.28.

**1-Benzyl-1,2,3-triazolo[4,5-*b*]pyrazine (6).**—A solution of 0.31 g of 40% glyoxal and 1.04 g (0.01 mol) of sodium bisulfite was added to a solution of 1.0 g (0.005 mol) of **5** in water. The orange precipitate that formed did not dissolve when warmed to 80°. The somewhat oily precipitate was collected and air dried. The precipitate was treated with hot methylene chloride and the bright yellow insoluble fraction (**6a**) was set aside. The methylene chloride solution was evaporated *in vacuo* until a viscous syrup remained. Upon cooling, the syrup deposited 0.55 g of crystals. These crystals were chromatographed on silica gel (100 g, ethyl acetate) and the first fraction afforded 0.3 g of buff prisms. Final purification by means of vacuum sublimation gave colorless microprisms of **6**: mp 91.5°; ir (KBr) 1500, 1440, 1240, 1180, 950, 745, 700 cm$^{-1}$; pmr ($CDCl_3$) $\delta$ 8.75–8.65 (d, $J$ = 1 Hz, total area 2, pyrazine ring protons), 7.55–7.22 (m, 5, aromatic), 5.92 (s, 2, $BzCH_2$).

*Anal.* Calcd for $C_{11}H_9N_5$: C, 62.54; H, 4.29; N, 33.16. Found: C, 62.53; H, 4.30; N, 33.16.

The yellow, irregular prisms were identified as **6a** on the basis of the following spectral data: ir (KBr) 3300, 3150, 1630, 1590, 1500, 1310, 1210, 1000, 800, 690 cm$^{-1}$; pmr (DMSO-$d_6$) $\delta$ 8.65 (s, 2, N=CHCH=N), 7.40–7.20 (m, 10, aromatic), 6.30 (broad s, 4, $NH_2$), 5.40 (s, 4, $BzCH_2$).

**1-Benzyl-5,6-diphenyl-1,2,3-triazolo[4,5-*b*]pyrazine (7).**—To a solution of 1.5 g (0.008 mol) of **5** and 1.65 g (0.009 mol) of benzil in ethanol was added 3 drops of concentrated HCl. After refluxing for 5 hr the solution had become dark red. Concentration *in vacuo* gave a red oil which was chromatographed on 100 g of silica gel, using ethyl acetate as eluting solvent. The first fraction was identified as unreacted benzil and the second fraction was evaporated to dryness *in vacuo*. Two recrystallizations from methanol gave 0.5 g (33%) of **7**: mp 110°; ir (KBr) 3000, 1440, 1340, 1180, 1120, 755, 700 cm$^{-1}$; pmr ($CDCl_3$) $\delta$ 7.60–7.10 (m, 15, aromatic), 5.94 (s, 2, $BzCH_2$).

*Anal.* Calcd for $C_{23}H_{17}N_5$: C, 76.01; H, 4.72; N, 19.27. Found: C, 75.90; H, 4.89; N, 19.38.

**1-Benzyl-5,6-dimethyl-1,2,3-triazolo[4,5-*b*]pyrazine (8).**—To a solution of 3.0 g (0.03 mol) of butane-2,3-dione and 1.0 g (0.005 mol) of **5** in 50% aqueous ethanol was added 3 drops of concentrated HCl. After refluxing for 2 hr and concentrating *in vacuo*, cooling the oil afforded 1.1 g of crude **8**. Recrystallization from 50% aqueous methanol gave pure **8**: mp 131°; ir (KBr) 1500, 1440, 1265, 1025, 950, 700 cm$^{-1}$; pmr ($CDCl_3$) $\delta$ 7.46–7.24 (m, 5, aromatic), 5.84 (s, 2, $BzCH_2$), 2.72 (s, 6, $CH_3$).

*Anal.* Calcd for $C_{13}H_{13}N_5$: C, 65.26; H, 5.47; N, 29.27. Found: C, 65.05; H, 5.73; N, 29.23.

**1-Benzyl-5- (or 6-) methyl-1,2,3-triazolo[4,5-*b*]pyrazine (9).**—To a solution of 1.0 g of 40% aqueous pyruvic aldehyde and 1.0 g (0.005 mol) of **5** in ethanol was added 3 drops of concentrated HCl. The addition of HCl caused an immediate red color. The solution was warmed at 60° for 1 hr. Concentration *in vacuo* produced a red syrup, which was chromatographed on 100 g of silica gel and eluted with ethyl acetate. The first fraction afforded 0.3 g (30%) of crude **9**. Three recrystallizations from ether–hexane gave **9**: mp 69°; pmr ($CDCl_3$) $\delta$ 8.56 (s, 1, pyrazine ring proton), 7.50–7.20 (m, 5, aromatic), 5.86 (s, 2, $BzCH_2$), 2.76 (s, 3, $CH_3$).

*Anal.* Calcd for $C_{12}H_{11}N_5$: C, 63.99; H, 4.92; N, 31.09. Found: C, 63.70; H, 4.74; N, 31.08.

**Ethyl 3-[(5-Amino-1-benzyl-1,2,3-triazol-4-yl)amino]crotonate (10).**—A solution of 1.0 g (0.005 mol) of **5** in 5.0 g (0.04 mol) of ethyl acetoacetate was heated at 60° for 15 min. The orange solution which resulted was diluted with chloroform and then treated with a large excess of hexane. The precipitate was collected and recrystallized by repeating the above procedure. This treatment produced 1.35 g (90%) of **10**: mp 125°; ir (KBr) 3400, 3300, 3190, 1650, 1600, 1240, 800, 700 cm$^{-1}$; pmr ($CDCl_3$) $\delta$ 9.61

(27) R. H. Wiley, K. F. Hussung, and J. Moffat, *J. Org. Chem.*, **21**, 190 (1956).

(s, 1, NH), 7.44–7.10 (m, 5, aromatic), 5.39 (s, 2, $BzCH_2$), 4.75 (s, 1, C=CH), 4.11 (q, $J$ = 7 Hz, ethyl $CH_2$), 3.43 (s, 2, $NH_2$), 1.84 (s, 3, $CH_3$), 1.25 ($t$, $J$ = 7 Hz, ethyl $CH_3$).

*Anal.* Calcd for $C_{15}H_{19}N_5O_2$: C, 59.79; H, 6.35; N, 23.24. Found: C, 59.77; H, 6.38; N, 22.90.

**4*H*,6*H*-1-Benzyl-7-methyl-1,2,3-triazolo[5,4-*b*][1,4]diazepin-5-one (11).**—To a solution of 0.1 g (0.004 mol) of sodium in absolute alcohol was added 1.0 g (0.003 mol) of **10**. The yellow solution was refluxed for 5 hr. Concentration *in vacuo* afforded yellow, irregular prisms. The prisms were dissolved in water, the solution was made acid with hydrochloric acid, and the precipitate was collected. Treatment with hot benzene produced an insoluble bright yellow crop of crude **11b** or **11c**. The benzene solution afforded a crop of off-white, irregular prisms consisting of a mixture of **11a** and **11b**: ir (KBr) 3000, 1700, 1660, 1620, 1400, 1300, 710 $cm^{-1}$. Treatment of the mixture with chloroform, pyridine, or dimethyl sulfoxide converted it to pure **11b** or **11c**.

The yellow, irregular prisms (**11b** or **11c**) were collected: mp 244° dec; ir (KBr) 3200, 3100, 2990, 1610, 1580, 700 $cm^{-1}$; pmr (pyridine-$d_5$) $\delta$ 7.38–7.02 (m, 5, aromatic), 5.70 (s, 2, $BzCH_2$), 3.30 (s, 2, $CH_2$), 2.21 (s, 3, $CH_3$).

*Anal.* Calcd for $C_{18}H_{13}N_5O$: C, 61.19; H, 5.10; N, 27.44. Found: C, 60.90; H, 5.39; N, 27.47.

**4-Acetamido-5-amino-1-benzyl-1,2,3-triazole (12).**—A mixture of 1.0 g (0.005 mol) of **5** and 10 g of acetic anhydride was stirred at room temperature for 10 min. The precipitate that formed was collected and air dried. Two recrystallizations from water afforded 0.8 g (53%) of **12**: mp 177°; ir (KBr) 3350, 3200, 1660, 1650, 1600, 1280 $cm^{-1}$; pmr ($CDCl_3$) $\delta$ 7.41–7.18 (m, 5, aromatic), 5.36 (s, 2, $BzCH_2$), 2.20 (s, 3, $COCH_3$).

*Anal.* Calcd for $C_{11}H_{13}N_5O$: C, 57.13; H, 5.66; N, 30.28. Found: C, 57.19; H, 5.63; N, 30.66.

**4-Acetamido-1-benzyl-1,2,3-triazole (13).**—Compound **12** (0.5 g, 0.003 mol) was converted to 0.7 g (100%) of the corresponding diazonium fluoroborate in the usual fashion.[28] After air drying for 3 hr, the diazonium salt was dissolved in 50 ml of methanol at 0° and treated with 0.05 g of sodium borohydride. The solution was stirred for 15 min, diluted with an equal volume of water, and extracted with 4 × 50 ml of methylene chloride. After drying over magnesium sulfate, the methylene chloride extract was concentrated *in vacuo* to a viscous syrup. The syrup was chromatographed on silica gel (100 g, ethyl acetate). Concentration of the first fraction afforded **13** in the form of buff, irregular prisms. Solution in methylene chloride, decolorization with charcoal, and precipitation with hexane gave 0.12 g of pure **13**: mp 197.5–198.5°; ir (KBr) 3180, 3000, 1660, 1560, 1420, 1280, 1045, 841, 715 $cm^{-1}$; pmr ($CDCl_3$) $\delta$ 8.02 (s, 1, C-5 proton), 7.40–7.22 (m, 5, aromatic), 6.02 (broad s, 1, NH), 5.28 (s, 2, $BzCH_2$), 2.27 (s, 3, $COCH_3$).

*Anal.* Calcd for $C_{11}H_{12}N_4O$: C, 60.87; H, 5.94; N, 25.82. Found: C, 60.81; H, 5.65; N, 25.76.

**5-Acetamido-1-benzyl-1,2,3-triazole (14).**—A solution of 1.0 g (0.006 mol) of 5-amino-1-benzyl-1,2,3-triazole in 7.5 ml of acetic anhydride was treated with 0.5 ml of sulfuric acid. The yellow solution was stirred at room temperature for 24 hr. The crude precipitate and solution were poured onto crushed ice, and the aqueous solution was concentrated *in vacuo* to a viscous oil. Treatment of the oil with hexane produced off-white, irregular prisms of **14**. Final purification by column chromatography using 100 g of silica gel and ethyl acetate as solvent afforded pure **14**: mp 132°; ir (KBr) 3300, 3200, 3000, 1690, 1550, 1230, 980, 705 $cm^{-1}$; pmr ($CDCl_3$) $\delta$ 9.39 (broad s, 1, NH), 7.78 (s, 1, C-4 proton), 7.36–7.02 (m, 5, aromatic), 5.50 (s, 2, $BzCH_2$), 2.04 (s, 3, $COCH_3$).

*Anal.* Calcd for $C_{11}H_{12}N_4O$: C, 60.87; H, 5.94; N, 25.82. Found: C, 60.90; H, 5.82; N, 25.79.

**4,5-Diacetamido-1-benzyl-1,2,3-triazole (15).**—A solution of 0.1 g (0.001 mol) of **5** in 1.0 g of acetic anhydride was kept at room temperature overnight. The precipitate that formed was collected and washed with water. Three recrystallizations from water afforded 0.12 g (45%) of analytically pure **15**: mp 194°; ir (KBr), 3445, 3250, 1660, 1610, 1570, 1520, 705 $cm^{-1}$; pmr ($CDCl_3$) $\delta$ 8.08 (broad s, 1, NH), 7.38–7.10 (m, 5, aromatic), 5.61 (s, 2, $BzCH_2$), 2.75 (s, 3, $COCH_3$), 2.08 (s, 3, $COCH_3$).

*Anal.* Calcd for $C_{13}H_{15}N_5O_2 \cdot {}^1/_4H_2O$: C, 56.21; H, 5.44; N, 25.21. Found: C, 56.15; H, 5.60; N, 25.11.

(28) R. Adams, "Organic Reactions," Wiley, New York, N. Y., 1949, p 193.

**Registry No.**—**1**, 20271-33-4; **3**, 36540-25-7; **4**, 36540-26-8; **5**, 36540-27-9; **5** monopicrate, 36540-28-0; **5a**, 36540-29-1; **6**, 36540-30-4; **6a**, 36540-31-5; **7**, 36540-32-6; **8**, 36540-33-7; **9a**, 36540-34-8; **9b**, 36540-35-9; **10**, 36540-36-0; **11a**, 36540-37-1; **11b**, 36540-38-2; **11c**, 36540-39-3; **12**, 36540-40-6; **13**, 36540-41-7; **14**, 36540-42-8; **15**, 36540-43-9.

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# Cyclic Peroxides. XVII.[1] Solvolysis of Di-*n*-butylmalonoyl Peroxide[2]

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It is postulated that in the solvolysis of di-*n*-butylmalonoyl peroxide (**1**) in methanol or ethanol initially the monoperoxy malonic acid half ester **12** is formed. Analogous to simple peroxy acids, it is proposed that in methanol this peroxy acid intermediate suffers concerted deoxygenation to produce hydrogen methyl di-*n*-butylmalonate (**6**) as the major product, but in ethanol **12** undergoes homolysis of the peroxide bond, leading to di-*n*-butylmalonic acid (**10**) as the major product. In both cases, inhibition experiments indicate that a chain process involving the hydroxyalkyl radical, derived from the solvent, contributes in a minor way. Even at relatively low temperatures, in both solvents some decarboxylation of the malonoyl peroxide **1** occurs to give α-lactone **2**.

Recently we reported[4] on the synthesis of malonoyl peroxide **1**, a novel class of cyclic diacyl peroxides, which on photolysis decarboxylates to generate α-lactones **2** (eq 1). At −196° the α-lactone **2** is perfectly stable and can be preserved indefinitely, but on further photolysis **2** decarbonylates to afford ketone **4**.[5] Warming up to −100°, α-lactone **2** rapidly polymerizes into polyester **5**,[5] which can also be obtained in high yield by photolysis of a benzene solution of malonoyl peroxide **1**.[4] On the other hand, on photolysis of **1** in alcoholic solvents such as methanol or ethanol, the α-alkoxy acid **3** is produced in high yield, as expected from the addition of R'OH to the dipolar structure of

(1) This paper is dedicated to Professor Dr. Rudolf Criegee on his 70th birthday.

(2) Part XVI: W. Adam and J. C. Liu, *J. Amer. Chem. Soc.*, **94**, 2894 (1972).

(3) Presented in part at the Cyclic Peroxide Symposium, Metrochem 71, Regional Meeting of the American Chemical Society, San Juan, Puerto Rico, April 30, 1971.

(4) W. Adam and R. Rucktäschel, *J. Amer. Chem. Soc.*, **93**, 557 (1971).

(5) W. Adam, O. L. Chapman, O. Rodriguez, R. Rucktäschel, and P. W. Wojtkowsky, *ibid.*, **94**, 1365 (1972).