ether and subsequent sublimation *in vacuo* gave LIII as a white solid, m.p. 213–214°; $\lambda_{max}^{CHCl_3}$ 2.80, 2.90(shoulder), 5.80 μ; $\epsilon_{210\,m\mu}^{EtOH}$ 380.

Anal. Calcd. for $C_{14}H_{18}O_5$: C, 63.14; H, 6.81. Found: C, 62.47; H, 6.71.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, HARVARD UNIVERSITY, CAMBRIDGE 38, MASS.]

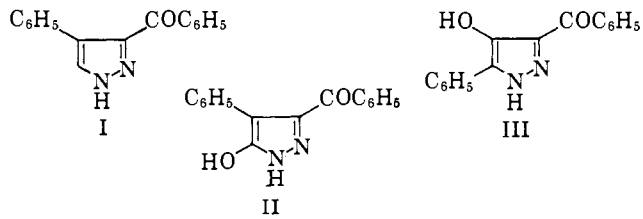
Aliphatic Diazo Compounds. VIII. The Reaction of Diazo Ketones with Bases. II[1,2]

BY PETER YATES[3] AND DONALD G. FARNUM[4]

RECEIVED FEBRUARY 23, 1963

The reaction of α-diazoacetophenone with sodium methoxide in concentrated solutions in methanol has been found to give 3-benzoyl-4-phenylpyrazole (I), 3-benzoyl-5-hydroxy-4-phenylpyrazole (II), 3-benzoyl-4-hydroxy-5-phenylpyrazole (III), 5-benzoyltetrazole (XXV), a compound, $C_{17}H_{11}N_5O$, considered to be most probably 3-benzoyl-5-phenyl-1,2,3-triazolo[3,4-*b*]-1,2,4-triazine (XLIII), benzoic acid, and methyl benzoate. The structures of compounds I, II, III, and XXV have been established by comparisons of these products with authentic samples prepared by rational, independent syntheses. The assignment of structure XLIII to the product $C_{17}H_{11}N_5O$ has been made largely on the basis of the base-induced cleavage of this compound to 4-benzamido-5-benzoyl-1,2,3-triazole (XXXV), whose structure has been established by independent synthesis.

It has previously been found[1] that the reaction of dilute solutions of α-diazoacetophenone in hydroxylic solvents with strongly basic reagents is complex and gives rise to a mixture of products which includes benzoic acid, acetophenone, 3-benzoyl-4-phenylpyrazole (I), and 3-benzoyl-5-hydroxy-4-phenylpyrazole (II) (*vide infra*). In all cases a reaction time of several hours at 75–90° was required to ensure total, irreversible consumption of the diazo ketone.



I II III

In a further investigation of the reaction of α-diazoacetophenone with bases, we have found that the addition of concentrated methanolic sodium methoxide to a concentrated solution of α-diazoacetophenone in methanol leads to a violent, exothermic reaction. We describe here the results of an investigation of the structures of the products formed under these conditions; we shall postpone discussion of the mechanistic implications of our results until the completion of further experiments currently in progress.[5]

A 7 *M* solution of sodium methoxide in methanol was added dropwise to a 5 *M* solution of diazoacetophenone in methanol; approximately equimolar amounts of base and diazo ketone were used. The reaction was moderated by efficient external cooling, which was necessary to prevent vigorous gas evolution with excessive foaming. After completion of the reaction the mixture was poured into dilute aqueous sodium bicarbonate and the crude product was separated into three fractions: acid (bicarbonate-soluble), weak acid (bicarbonate-insoluble, hydroxide-soluble), and neutral.

Acid Fraction.—From the bicarbonate-soluble fraction were isolated a pale yellow, crystalline, water-insoluble compound, $C_{16}H_{12}N_2O_2$, m.p. 248.5–250°, and a colorless, crystalline, water-soluble compound, $C_8H_6N_4O$, m.p. 139.5–140°. In addition, infrared spectral evidence indicated the presence of benzoic acid.

The compound $C_{16}H_{12}N_2O_2$ was shown to be identical with the product of this composition obtained previously[1] by the reaction of dilute solutions of diazoacetophenone with bases. The earlier work had shown that the compound is resistant to boiling aqueous ethanolic potassium hydroxide and to boiling 1:1 hydrochloric–acetic acid, dissolves readily in dilute aqueous sodium hydroxide to give a yellow solution which reduces potassium permanganate to manganate, and gives a red coloration with a solution of ferric chloride in chloroform–pyridine. On the basis of these properties and its origin it was considered to be one of the hydroxypyrazoles II or III. In the present work a choice between these alternatives was made possible on three counts. It was observed that the substance is soluble in aqueous potassium carbonate,[6] that it fails to give a coloration with ethanolic ferric chloride, and that on oxidation with perbenzoic acid it affords an amorphous solid, which upon crystallization from solvent mixtures containing ether yields a colorless, crystalline substance, $C_{32}H_{22}N_4O_4 \cdot C_4H_{10}O$. A significant difference between structure II and III is that the latter contains a chelated hydroxyl group, while the former contains a free hydroxyl group. Both the relatively strong acidity of the compound $C_{16}H_{12}N_2O_2$ and its failure to give a color test with ethanolic ferric chloride are in accord with the expected properties of a *nonchelated* aromatic hydroxyl group as is present in structure II.[7] The significance of these observations was markedly enhanced by the availability of an isomeric compound obtained from the weak acid fraction which exhibited the properties expected for the chelated hydroxyl compound III (*vide infra*). Finally, the formation of the compound $C_{32}H_{22}N_4O_4$ is readily interpreted as an oxidative coupling reaction of a type often observed with 5-pyrazolones,[8] leading to compound IV. The infrared spectrum of the oxidation product (bands at 3.13, 3.25, 5.68, and 6.04 μ)[9] is in accord with this assignment; the band at 6.04 μ is assigned to the benzoyl groups and that at 5.68 μ to the five-membered lactam carbonyl groups which have been modified by the inclusion of the amide nitrogen atom in a conjugated system of type $C_6H_5C(O^{\ominus})=C-N=\overset{\oplus}{N}H-$. An analogous shift to shorter

(1) For Part I of this sub-series see P. Yates and B. L. Shapiro, *J. Am. Chem. Soc.*, **81**, 212 (1959).

(2) A preliminary report on part of this work has appeared previously: P. Yates and D. G. Farnum, *Tetrahedron Letters*, **No. 17**, 22 (1960).

(3) Department of Chemistry, University of Toronto, Toronto, Canada; Alfred P. Sloan Foundation Fellow, 1957–1960.

(4) N.I.H. Fellow, 1957–1959.

(5) We have already made some proposals in regard to the reaction routes.[2]

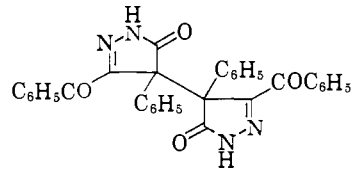
(6) Although the product was isolated from a bicarbonate-soluble fraction of the crude reaction product, in the pure state it is not soluble in aqueous sodium bicarbonate.

(7) H. Henecka, "Chemie der β-Dicarbonylverbindungen," Springer Verlag, Berlin, 1950, p. 111.

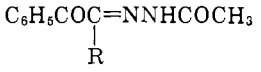
(8) T. L. Jacobs in "Heterocyclic Compounds," R. C. Elderfield, Ed., Vol. V, John Wiley and Sons, Inc., New York, N. Y., 1957, pp. 124, 125, 135.

(9) The spectrum of the crystalline product has a strong band at 9.1 μ, absent in the spectrum of the amorphous material, corroborating the presence of ether of crystallization in the crystalline product.

wave length of the carbonyl-stretching band in the case of a noncyclic amide is observed for benzil N-acetylhydrazone (V) (bands at 5.87 and 5.98 μ) and 1-phenyl-1,2-propanedione 2-N-acetylhydrazone (VI)[10] (bands at 5.80 and 5.91 μ).

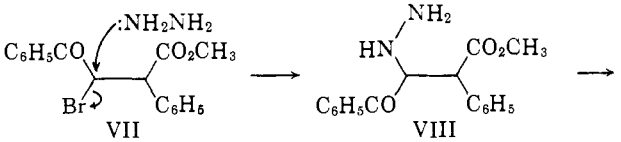


IV

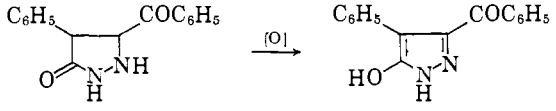


V, R = C_6H_5
VI, R = CH_3

The assignment of structure II was confirmed by an independent synthesis of II. The known methyl β-benzoyl-β-bromo-α-phenylpropionate (VII) (higher-melting epimer) was chosen as starting material in the expectation that it would give with hydrazine the displacement product VIII; although the possibility of dehydrobromination of the β-bromo ester was recognized, it was considered that the reactivity of the bromine in displacement reactions would be sufficiently enhanced by the adjacent carbonyl group to permit a competing displacement reaction.[11] Subsequent cyclization of the intermediate VIII would lead to IX, a dihydro derivative of II, which, since it is both a pyrazoline and an α-amino ketone, should be subject to facile oxidation to II.[12] When VII was treated with hydrazine and potassium carbonate and air was passed through the reaction solution, the carbonate-soluble fraction afforded II (yield 13%), identical with the product obtained from diazoacetophenone.

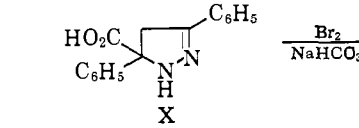


VII VIII

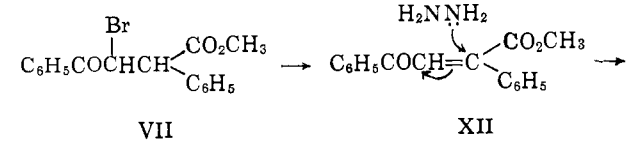


IX II

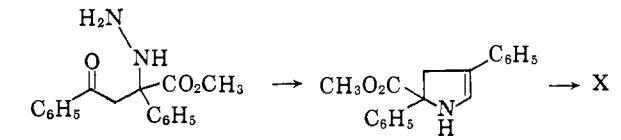
Two other crystalline products were isolated from the mixture resulting from the reaction of VII with hydrazine. The bicarbonate-soluble fraction afforded, upon crystallization from chloroform, a substance, $(C_{16}H_{14}N_2O_2)_2 \cdot CHCl_3$, with infrared bands at 3.0, 4.0, and 5.90 μ which is considered to be a chloroform solvate of 3,5-diphenyl-2-pyrazoline-5-carboxylic acid (X). Oxidative decarboxylation with bromine in aqueous sodium bicarbonate gave, as anticipated, 3,5-diphenylpyrazole (XI), identified by comparison with an authentic sample.[13] The formation of X may readily be seen to be the result of the expected competing dehydrobromination of VII. Addition of hydrazine to the α,β-unsaturated ketone system of the resultant product XII in the expected fashion,[14] followed by cyclization, would lead to the methyl ester XIII, which could undergo ready hydrolysis in the hot, basic reaction medium to give X.



X XI

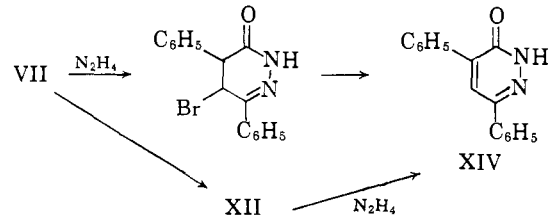


VII XII

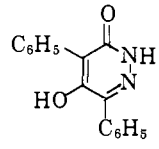


XIII

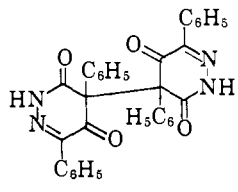
The third crystalline product, which was the major product of the reaction of VII with hydrazine, was obtained from the carbonate-insoluble, hydroxide-soluble fraction of the reaction mixture and was identified as the known 3,5-diphenyl-6-pyridazinone (XIV) by comparison with an authentic sample.[15] Its formation by condensation of hydrazine with either VII or XII is unexceptional.



The isolation of the pyridazinone derivative XIV led us to consider a conceivable alternative structure for the compound assigned structure II. It may be seen that the structure 3,5-diphenyl-4-hydroxy-6-pyridazinone (XV) possesses a number of features which qualify it for consideration. Base-solubility and a positive ferric chloride test in chloroform–pyridine are clearly to be expected for XV, and its infrared spectrum might well be compatible with that observed. Furthermore, the structure XV bears a fundamental resemblance to the bromo ester VII used in the independent synthesis, and a less straightforward, but amusing, resemblance to diazoacetophenone. The only piece of evidence adduced thus far which appears to be incompatible with this structure is the infrared spectrum of the oxidation product, $C_{32}H_{22}N_4O_4$. This would have to be assigned structure XVI on the basis of structure XV for its precursor. However, structure XVI provides no functional group which would be expected to give rise to the unusually short wave length carbonyl-stretching band observed at 5.68 μ. It was possible, fortunately, to obtain more decisive evidence on which to base the exclusion of structure XV as a result of an ancillary synthetic investigation in connection with structure II.



XV

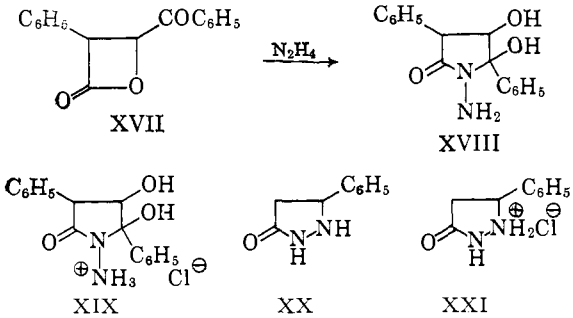


XVI

The reaction of hydrazine with the known β-lactone XVII (lower-melting epimer)[16] in benzene–methanol proceeded rapidly at room temperature to give a nearly quantitative yield of a compound, $C_{16}H_{16}N_2O_3$, considered to be the γ-lactam XVIII on the basis of the following evidence. Its solid-state infrared spectrum includes complex absorption in the 3 μ region (OH and

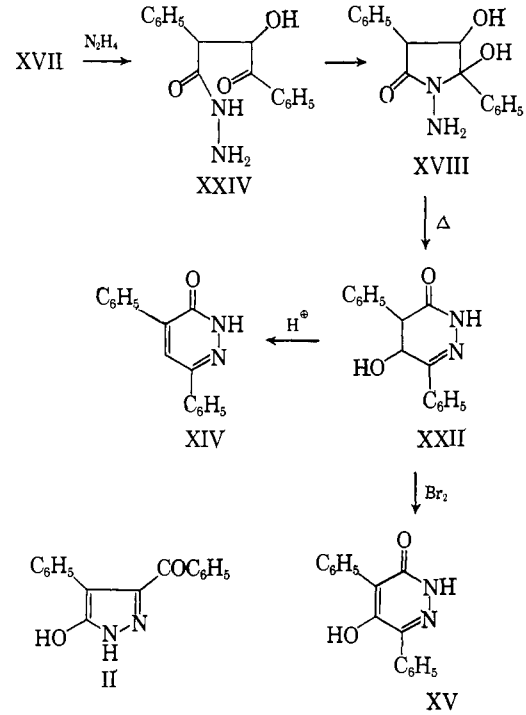
(10) H. A. Morrison, Ph.D. Thesis, Harvard University, 1961.
(11) P. D. Bartlett and E. N. Trachtenberg, *J. Am. Chem. Soc.*, **80**, 5808 (1958).
(12) P. L. Julian, E. W. Meyer, A. Magnani, and W. Cole, *ibid.*, **67**, 1203 (1945); *cf.*, also, P. Yates, *ibid.*, **74**, 5376 (1952).
(13) L. Knorr and P. Duden, *Ber.*, **26**, 111 (1893).
(14) N. H. Cromwell, P. L. Creger, and K. E. Cook, *J. Am. Chem. Soc.*, **78**, 4412 (1956).
(15) G. K. Almström, *Ann.*, **400**, 131 (1913).
(16) E. P. Kohler and R. H. Kimball, *J. Am. Chem. Soc.*, **56**, 729 (1934).

NH stretch) and bands at 5.82 μ (γ-lactam C=O stretch), 6.1 μ (NH_2 deformation) and 9.05 μ (OH deformation). The presence of a primary amine function was demonstrated by reaction with nitrous acid to give gas evolution, and reaction with benzaldehyde in the presence of sodium acetate to give a monobenzylidene derivative, $C_{23}H_{20}N_2O_3$ (infrared bands at 2.85, 3.0, 5.88, and 9.05 μ; no band at 6.1 μ). Further confirmation of the presence of the γ-lactam group of XVIII was forthcoming from the infrared spectrum of the hydrochloride of the β-lactone–hydrazine product. This possesses, in addition to bands ascribable to OH and $NH_3^{\oplus}$ groups, a sharp band at 5.75 μ. The shift in the carbonyl absorption from 5.82 to 5.75 μ is readily interpreted in terms of the transformation XVIII→XIX; thus the carbonyl-stretching band of 3-phenyl-5-pyrazolidinone (XX)[17] at 5.86 μ shifts to 5.71 μ on formation of the hydrochloride XXI. The absence of a conjugated phenyl group in the β-lactone–hydrazine product was demonstrated by the absence of strong ab-



XVII XVIII XIX XX XXI

sorption above 220 mμ in the ultraviolet spectrum of this substance. On treatment with boiling ethanolic hydrochloric acid it was converted to 3,5-diphenyl-6-pyridazinone (XIV).[15] This transformation could also be carried out in two stages: when the β-lactone–hydrazine product was heated in boiling nitromethane it was converted to a compound, $C_{16}H_{14}N_2O_2$, which was converted to XIV on treatment with ethanolic hydrochloric acid. The intermediate compound is assigned structure XXII, *i.e.*, 4,5-dihydro-4-hydroxy-3,5-diphenyl-6-pyri-



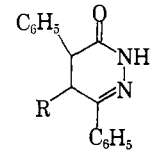
XXIV XVIII XIV XXII II XV

(17) L. A. Carpino, *J. Am. Chem. Soc.*, **80**, 599 (1958).

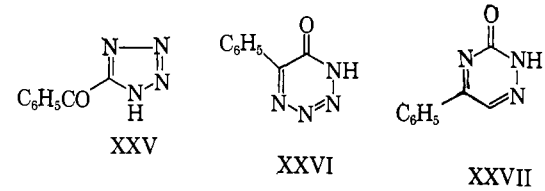
dazinone, on the basis of the close similarity of its spectra to those of 4,5-dihydro-3,5-diphenyl-6-pyridazinone (XXIII)[18] (Table I). These data are only compatible with the assignment of structure XVIII to the β-lactone–hydrazine product, which must arise *via* the hydrazide XXIV. The isolation of the hydroxydihydropyridazinone XXII now provided a ready source of the hydroxypyridazinone XV, the possible alternative formulation for the product from diazoacetophenone. Oxidation of XXII with bromine in dioxane yielded a base-soluble product, $C_{16}H_{12}N_2O_2$, whose solid-state infrared spectrum (broad absorption in the 3–4 μ region and a sharp band at 6.15 μ), although compatible with its formulation as XV, is different from that of the isomeric product from diazoacetophenone, which can now be formulated as II without ambiguity. It is interesting to note that the infrared spectrum of XV lacks the strong band in the region 10.7–11.2 μ, present in that of II, which has been found to be characteristic of nitrogen heterocycles bearing a C-benzoyl group.[19]

TABLE I

SPECTRA OF 4,5-DIHYDRO-3,5-DIPHENYL-6-PYRIDAZINONES

		Nujol λ_{max}, μ	λ_{max}^{EtOH}, mμ (log ϵ)
	XXII (R = OH)	2.95, 3.10, 3.20 5.97, 7.98, 9.25	288 (4.20)
	XXIII (R = H)	3.08, 3.20 5.98, 8.00	288 (4.21)

The other product, $C_8H_6N_4O$, isolated from the acid fraction from the reaction of diazoacetophenone and sodium methoxide, is soluble in aqueous sodium bicarbonate and forms a non-acidic, monomethyl derivative, $C_9H_8N_4O$, with diazomethane. The infrared spectrum (CH_2Cl_2) of the compound $C_8H_6N_4O$ includes bands at 2.95, 6.00, and 10.85 μ, while that of its methyl derivative has bands at 5.99 and 10.88 μ, but no band in the N–H stretching region. On the basis of these data and its origin, the product $C_8H_6N_4O$ appeared most likely to have structure XXV or XXVI.



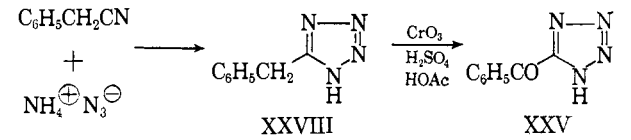
XXV XXVI XXVII

The tetrazole XXV, like other tetrazoles unsubstituted on nitrogen, was expected to be acidic[20] with this acidity enhanced by the inductive and resonance effects of the benzoyl group.[21] The solution infrared spectrum of the product also appeared to be compatible with structure XXV, as did the solid-state spectrum, which shows evidence of strong hydrogen bonding in the solid (NH bands at 3.7 and 3.85 μ). Although tetrazinones related to XXVI do not appear to have been described, it appeared likely that such a system could also account for the strong acidity and infrared spectrum of the product.[22] A preliminary choice was made between these alternatives on the basis of the failure of the prod-

(18) J. Druey and B. H. Ringier, *Helv. Chim. Acta*, **34**, 195 (1951).
(19) D. G. Farnum and P. Yates, *J. Org. Chem.*, **27**, 2209 (1962).
(20) F. R. Benson, *Chem. Rev.*, **41**, 4 (1947).
(21) Thus the K_a of tetrazole is 1.28×10^{-5}, while that of ethyl 5-tetrazolecarboxylate[20] is 4×10^{-5}.
(22) Thus its infrared spectrum resembles that of 4-phenyl-1,2,5-triazin-6-one (XXVII),[23] which is soluble in dilute aqueous sodium carbonate.
(23) L. Wolff, *Ann.*, **325**, 148 (1902).

uct to give a positive ferric chloride test. Since pyridones, pyridazinones, and triazinones give positive tests,[24] it seemed unlikely that XXVI would fail to do so. The rational synthesis of XXV was therefore undertaken.

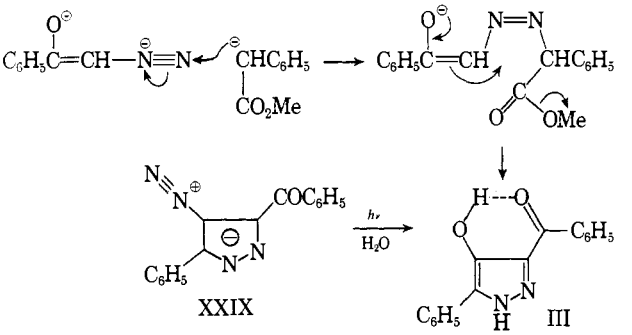
5-Benzyltetrazole (XXVIII) was prepared by the method of Finnegan, *et al.*,[25] and was oxidized with chromium trioxide to 5-benzoyltetrazole (XXV).[26] This product was found to be identical with the product $C_8H_6N_4O$ obtained from diazoacetophenone.



XXVIII XXV

Weak Acid Fraction.—From the hydroxide-soluble fraction was isolated a pale yellow, crystalline substance, $C_{16}H_{12}N_2O_2$. The remainder of the fraction after being heated afforded a bright yellow crystalline substance, $C_{17}H_{11}N_5O$, which did not dissolve in aqueous sodium hydroxide. Attempts to isolate the hydroxide-soluble precursor of the latter product were unsuccessful.

The compound $C_{16}H_{12}N_2O_2$ was obtained in two different crystalline modifications. There are considerable differences in the solid-state infrared spectra of these two forms, but the spectra resemble each other in having complex absorption in the 3 μ region, a sharp band at *ca.* 6.15 μ, and strong absorption near 11 μ. The product dissolves in dilute aqueous sodium hydroxide to give a yellow solution which reduces potassium permanganate, but is only slightly soluble in dilute aqueous sodium carbonate. It gives an intense blue-green coloration with ethanolic ferric chloride. The relationship of these properties to those of the isomeric product II suggested strongly that this compound has the chelated structure III, the alternative formulation earlier considered for the isomer. This assignment was supported, but not proved, by the observation that the same compound was obtained in moderate yield, together with other products,[27] by the reaction of diazoacetophenone with the pre-formed anion of methyl phenylacetate in ether. The formation of III in this latter reaction was expected to occur by a route of the type depicted below.[28] Conclusive corroboration of the structural assignment was obtained by the independent synthesis of III in good yield by the photolysis of 3-benzoyl-4-hydroxy-5-phenylpyrazole (XXIX) in aqueous acetone.[29]

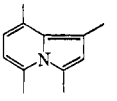
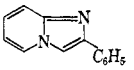
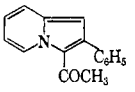


XXIX III

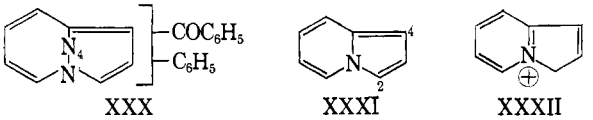
The compound $C_{17}H_{11}N_5O$ has in its infrared spectrum bands at 6.07, 6.50, and 11.00 μ but no absorption characteristic of NH or OH stretching vibrations. It exhibits a bright blue fluorescence under ultraviolet illumination either in the solid state or in solution in organic solvents. Solutions in sulfuric acid, from which it is recovered unchanged on dilution with water, are, however, nonfluorescent. On treatment with a boiling mixture of hydrochloric and acetic acids it gave benzoic acid and a colorless, blue-fluorescent oil with no NH or C=O stretching bands in its infrared spectrum. These data, together with the ultraviolet spectrum (Table II) of the compound $C_{17}H_{11}N_5O$, appeared to be most readily accommodated in terms of the tetraazapyrrocoline part-structure XXX. The fluorescence of pyrrocoline (XXXI) and its analogs is well known,[30,31] while the pyridinium cation system of the conjugate acid XXXII is nonfluorescent.[32] Although close models for the ultraviolet spectra of systems of type XXX are not available, the spectra of the derivatives of XXXI given in Table II provide some basis for comparison.

TABLE II

ULTRAVIOLET SPECTRA OF COMPOUNDS RELATED TO PYRROCOLINE

Compound	λ_{max}, mμ (log ϵ) Neutral medium	Acid medium	Ref.
$C_{17}H_{11}N_5O$	363 (3.99) 283 (4.36) 240 (4.32)	360 (4.43) 252 (4.40)	
	355 (3.4) 305 (3.7) 290 (3.7) 240 (4.1)	320 (3.8) 250 (3.85)	32
	333 (3.88) 248 (4.62)	303 (4.18) 239 (4.33)	31, 34
	365 (3.99) 264 (4.36) 233 (4.32)		35

The general characteristics of the spectra are similar, particularly in regard to the marked change observed in acid medium. The attachment of a benzoyl group to one of the heterorings was indicated by the band at 11.00 μ in the infrared spectrum of the compound.[19] Further, the facile formation of benzoic acid on acid-catalyzed hydrolysis suggested that the benzoyl group is attached to the five-membered ring, for ready hydrolytic loss of acyl substituents on the 2- or 4-position of the pyrrocoline system is well established.[33]



XXX XXXI XXXII

More detailed structural information was provided by a study of the cleavage of the compound $C_{17}H_{11}N_5O$ in alcoholic base. This was rapid and led to the formation of a colorless, base-soluble, crystalline compound, $C_{16}H_{12}N_4O_2$, which exhibits an intense yellow-green fluorescence in ultraviolet light. Its infrared spectrum includes bands at 3.12 (complex), 5.97, 6.11, 6.30, and 10.70 μ. It was recovered unchanged after treatment with sodium nitrite and concentrated hydrochloric acid in dioxane; the absence of a primary amine function was thus indicated. However, the presence of a *masked*

(24) H. S. Mosher in "Heterocyclic Compounds," R. C. Elderfield, Ed., Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1950, p. 526.

(25) W. G. Finnegan, R. A. Henry, and R. Lofquist, *J. Am. Chem. Soc.*, **80**, 3908 (1958).

(26) Since the completion of this work, an alternative synthesis of XXV has been reported: B. E. Fisher, A. J. Tomson, and J. P. Horwitz, *J. Org. Chem.*, **24**, 1650 (1959).

(27) D. G. Farnum and P. Yates, *Proc. Chem. Soc.*, 224 (1960).

(28) *Cf.* the formation of diethyl 4-hydroxypyrazole-3,5-dicarboxylate from ethyl diazoacetate and the sodium derivative of diethyl malonate: A. Bertho and H. Nüssel, *Ann.*, **467**, 278 (1927).

(29) D. G. Farnum and P. Yates, *J. Am. Chem. Soc.*, **84**, 1399 (1962).

(30) E. T. Borrows and D. O. Holland, *Chem. Rev.*, **42**, 624 (1948).

(31) J. D. Bower and G. R. Ramage, *J. Chem. Soc.*, 4506 (1957).

(32) J. E. Saxton, *ibid.*, 3239 (1951).

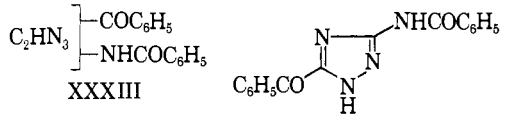
(33) Reference 30, p. 627.

(34) E. A. Chandross, private communication.

(35) Reference 30, p. 635.

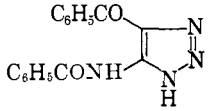
primary *aromatic* amine function was indicated by the fact that protracted warming with acidified *p*-dimethylaminobenzaldehyde in ethanol resulted in the formation of a deep red color.[36] Hydrolysis by prolonged boiling in a hydrochloric–acetic acid mixture or by brief boiling in alcoholic base resulted in extensive decomposition with the formation of benzoic acid as the only nonvolatile acidic product. The absence of an enolic, or potentially enolic, hydroxyl group was indicated by failure to give a color reaction with ferric chloride either in ethanol or in chloroform–pyridine.

These data suggested that the compound $C_{16}H_{12}N_4O_2$ might contain a benzamido group attached to an aromatic system (*cf.* infrared bands at 3.12, 5.97, and 6.30 μ) and that the benzoyl group attached to carbon, indicated to be present in its precursor, might remain intact (*cf.* infrared bands at 6.11 and 10.70 μ). We were thus led to consider the part-structure XXXIII. The disubstituted aromatic residue, C_2HN_3, could then be either 1,2,3- or 1,2,4-triazole. The base solubility of the compound and an observed bathochromic shift of 22 mμ in the position of its long wave length ultraviolet maximum in the basic solution further suggested that the triazole is unsubstituted on nitrogen.[37,38] Two alternative structures, XXXIV and XXXV, then emerged as possible formulations.[39] Since the amount of the degradation product available was small, attention was turned to the independent synthesis of the compounds XXXIV and XXXV.

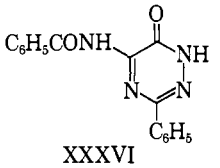


XXXIII

XXXIV

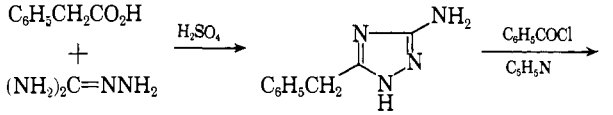


XXXV

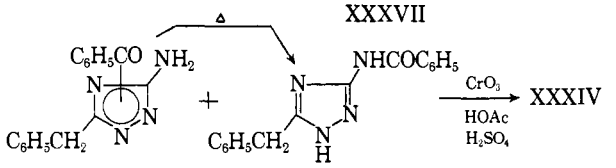


XXXVI

Compound XXXIV was synthesized by the route



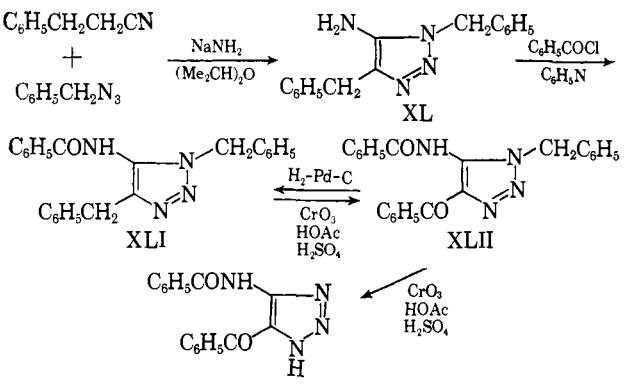
XXXVII



XXXVIII XXXIX

Although the condensation of phenylacetic acid with aminoguanidine nitrate in nitric acid[40] resulted in extensive tar formation, condensation could be effected with aminoguanidine sulfate in sulfuric acid to give a moderate yield of the aminotriazole XXXVII. Benzoylation then gave a mixture of two isomeric monobenzoyl derivatives. The lower-melting isomer (infrared bands at 2.95, 3.10, 5.90, 6.08, and 6.45 μ) was converted quantitatively to the higher-melting isomer (infrared bands at 3.2, 5.96, 6.35, and 6.45 μ) by being heated above its melting point. Comparison of their infrared spectra leads to the assignment of the nuclear benzoylated structure XXXVIII to the lower-melting isomer and the secondary amide structure XXXIX to the higher-melting isomer. Oxidation of the latter with chromic acid gave a quantitative yield of a colorless, crystalline, nonfluorescent substance, $C_{16}H_{12}N_4O_2$, whose properties (infrared bands at 2.95, 3.15, 5.90, 6.00, 6.23, and 10.82 μ) are in accord with its formulation as XXXIV. This substance is, however, different from the compound of the same composition formed by base cleavage of the compound $C_{17}H_{11}N_5O$.

Compound XXXV was synthesized by the route



XL XLI XLII XXXV

The condensation of nitriles with azides has been found to give 1,4-disubstituted 5-amino-1,2,3-triazoles,[41] and this method was investigated for the preparation of the aminotriazole XL. Although condensation of hydrocinnamonitrile and benzyl azide could not be effected with sodium ethoxide in boiling ethanol, nor with potassium *t*-butoxide in boiling *t*-butyl alcohol or in tetrahydrofuran,[42,43] the reaction could be effected by means of prolonged boiling with sodium amide in diisopropyl ether. There was thus obtained in moderate yield a substance, $C_{16}H_{16}N_4$ (infrared bands at 2.85, 2.95, and 6.08 μ), assigned structure XL. Benzoylation of this afforded the crystalline amide XLI (infrared bands at 2.95, 5.91, and 6.25 μ), which upon oxidation with two equivalents of chromium trioxide gave a quantitative yield of 5-benzamido-4-benzoyl-1-benzyl-1,2,3-triazole (XLII). The structure assigned to this product is based on its elemental analysis, infrared spectrum (bands at 3.12, 6.05, 6.12, and 10.82 μ), stability to boiling ethanolic potassium hydroxide,[44] and reconversion to XLI on hydrogenolysis over acid-washed palladium–charcoal. Cleavage of the N-benzyl function of XLII could not be effected by solvolysis, hydrogenolysis, treatment with boiling hydriodic acid, nor with sodium in liquid ammonia. Prolonged reaction with excess chromium trioxide in acetic acid–sulfuric acid, however, resulted in removal of the benzyl group, presumably *via* oxidation and hydrolytic cleavage, with the formation, albeit in low yield, of a colorless, crystalline, fluorescent substance, XXXV. This was shown to be identical with the product formed by cleavage of the compound $C_{17}H_{11}N_5O$ with base.

(36) F. Feigl, "Spot Tests," Vol. II, Elsevier Press, New York, N. Y., 1954, p. 203.

(37) F. R. Benson and W. L. Savell, *Chem. Rev.*, **46**, 6 (1950).

(38) Thus, the long wave length ultraviolet maximum of 3,5-diphenyl-1,2,4-triazole at 255 mμ in neutral medium is shifted to 276 mμ in basic medium: M. R. Atkinson, E. A. Parkes, and J. B. Polya, *J. Chem. Soc.*, 4256 (1954).

(39) If the retention of the C-benzoyl group is not assumed, phenylbenzamidotriazinones, *e.g.*, XXXVI, must also be considered. These can be excluded, however, because of the negative ferric chloride test.

(40) This is a generally successful method for the preparation of 5-substituted 3-amino-1,2,4-triazoles: M. R. Atkinson, A. A. Komzak, E. A. Parkes, and J. B. Polya, *J. Chem. Soc.*, 4508 (1954).

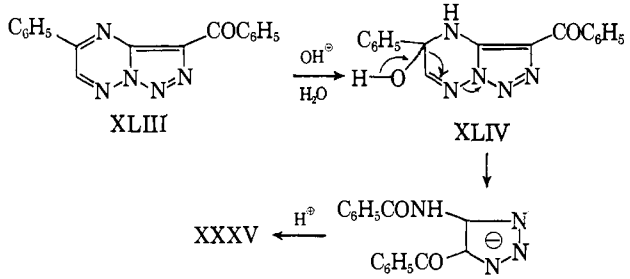
(41) Reference 37, p. 31.

(42) E. Lieber, T. S. Chao, and C. N. R. Rao, *J. Org. Chem.*, **22**, 654 (1957).

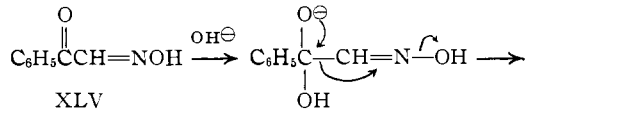
(43) The reaction in tetrahydrofuran gave a high yield of a crystalline substance which appears to be the Thorpe self-condensation product of hydrocinnamonitrile.

(44) Had oxidation of the N-benzyl function of XLI occurred, the product would have been a base-sensitive nuclear N-benzoylated triazole.

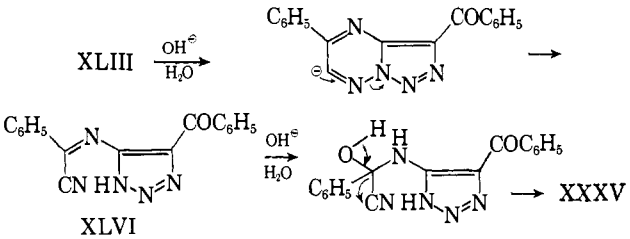
Ramifications of the part structure XXX for the compound $C_{17}H_{11}N_5O$ can now be considered on the basis of the formation of the triazole XXXV on hydrolysis with base. Two full structures, XLIII and XLVII, accommodate the facts and provide a basis for the postulation of reasonable interpretations of the course of the base cleavage reactions. In the case of XLIII the following scheme may be considered.



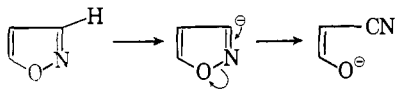
Hydration of XLIII to give XLIV followed by elimination of hydrogen cyanide could give the anion of XXXV. Such elimination finds analogy in the base-catalyzed hydrolysis of isonitrosoacetophenone (XLV) to benzoic acid and hydrogen cyanide.[45]



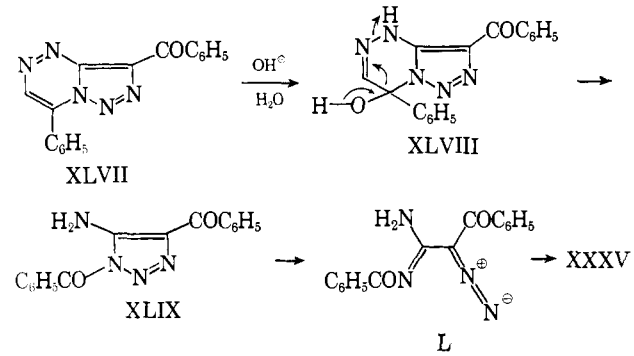
An alternative path from XLIII to XXXV could involve proton abstraction, ring cleavage to XLVI, and hydrolysis



This route finds analogy in the base-catalyzed cleavage of isoxazoles to β-keto nitriles[46]



In the case of XLVII, analogous routes to those considered for XLIII would lead to the triazole XLIX, *e.g.*, *via* XLVIII. This triazole could rearrange to the trizole XXXV by a well-established type of route[47] involving the intermediacy of the chain tautomer L.



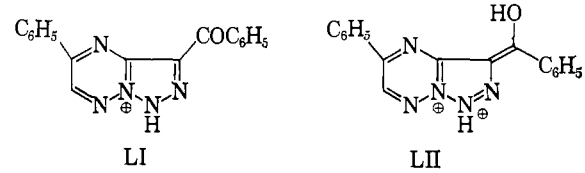
(45) L. Claisen and O. Manasse, *Ber.*, **20**, 2194 (1887).

(46) R. A. Barnes in ref. 8, p. 465.

(47) E. Lieber, C. N. R. Rao, and T. S. Chao, *J. Am. Chem. Soc.*, **79**, 5962 (1957).

No rigorous choice can be made between structures XLIII and XLVII for the compound $C_{17}H_{11}N_5O$ on the basis of the data currently available. However, structure XLIII is favored since its formation is more readily accommodated in terms of the mechanistic scheme[2] considered most likely to be operative in the reaction of diazoacetophenone with sodium methoxide.

A further point of interest concerning this compound is the fact that although its solutions in 50% aqueous sulfuric acid are colorless, solutions in concentrated sulfuric acid are yellow-orange. The latter show an intense maximum in the visible region at 420 mμ (log ϵ 4.64), and maxima in the ultraviolet region at 362 mμ (log ϵ 4.28), 300 mμ (log ϵ 3.67), and 240 mμ (log ϵ 3.85). The compound is recovered unchanged on dilution of these solutions with ice–water. These observations can be interpreted in terms of XLIII as due to the formation of the monocation LI by protonation on nitrogen in 50% sulfuric acid and of the dication LII by further protonation on oxygen in concentrated sulfuric acid, the fulvenoid system of the latter accounting for the visible absorption maximum.[48]

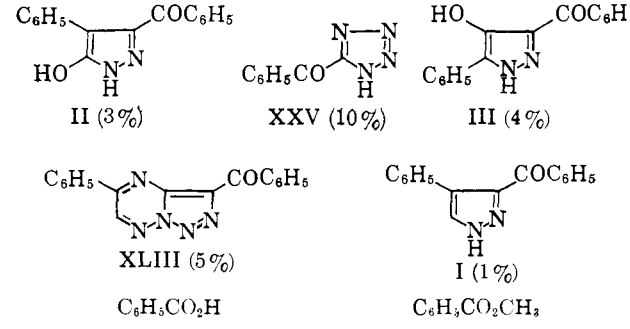


Neutral Fraction.—The only crystalline compound isolated from the neutral fraction was 3-benzoyl-4-phenylpyrazole (I), identified by comparison with an authentic sample.[1,49] This compound, traces of which were also isolated from the hydroxide-soluble fraction, had previously been found to be formed in the reaction of dilute solutions of diazoacetophenone with bases.[1] The remainder of the neutral fraction had the characteristic odor of methyl benzoate and its infrared spectrum exhibited all the bands present in the spectrum of methyl benzoate.

The products detected in the mixture obtained from the reaction of concentrated solutions of α-diazoacetophenone with methanolic sodium methoxide are summarized in Table III. The yields of compounds which

TABLE III

PRODUCTS (AND YIELDS ISOLATED) FROM THE REACTION OF α-DIAZOACETOPHENONE AND SODIUM METHOXIDE IN CONCENTRATED SOLUTION



have been isolated are also given. It may be noted that much of the complex reaction mixture remains unaccounted for, in spite of the identification of seven products.

(48) *Cf.* E. D. Bergmann and Y. Hirshberg, *Bull. soc. chim. France*, [5] **17**, 1091 (1950). An equivalent interpretation can, of course, be given in terms of structure XLVII.

(49) L. I. Smith and W. B Pings, *J. Org. Chem.*, **2**, 23 (1937).

Experimental[50]

A. The Reaction of α-Diazoacetophenone with Methanolic Sodium Methoxide.—α-Diazoacetophenone (14.6 g., 0.10 mole) was dissolved in the minimal amount of dry methanol (20 ml., distilled from magnesium), and a solution of sodium methoxide prepared by dissolving sodium (2.4 g., 0.11 g.-atom) in dry methanol (15 ml.) was added dropwise with efficient stirring and ice-bath cooling. The reaction mixture rapidly acquired an intense wine-red color and effervesced slowly. Cautious addition of the methoxide solution and efficient ice-bath cooling were necessary in order to prevent a violent, exothermic reaction resulting in vigorous frothing. After 30 min., the ice bath was removed, and the reaction was allowed to proceed at room temperature for an additional 2.5 hr. The intensely red, opaque mixture was poured into a vigorously stirred mixture of ice and excess aqueous sodium bicarbonate, and the yellow-orange granular precipitate was collected, washed well with aqueous 5% sodium bicarbonate and water, drained and pressed thoroughly, and dried in a vacuum desiccator to constant weight. The crude solid (11.0 g.) melted over a broad range, and had a readily detectable odor of methyl benzoate.

Acid Fraction.—The sodium bicarbonate solution and washings were combined, washed once with dichloromethane, and acidified with concentrated hydrochloric acid. The yellow precipitate was washed with water, dried, and digested with dichloromethane. A pale yellow crystalline deposit of **3-benzoyl-5-hydroxy-4-phenylpyrazole (II)** (400 mg., 3%), m.p. 248–250°, was thus obtained. The aqueous filtrates were extracted with several portions of dichloromethane and the extracts were filtered through anhydrous sodium sulfate and evaporated to dryness on the steam bath. The light brown residue (2.1 g.) crystallized on cooling; upon recrystallization from benzene it afforded light buff needles of **5-benzoyltetrazole (XXV)** (870 mg., 10%), m.p. 137–139°. Evaporation of the mother liquors to dryness gave a light brown solid (1.2 g.) with an infrared spectrum showing all the bands characteristic of **benzoic acid**, in addition to weaker bands characteristic of XXV.

Weak Acid Fraction.—The solid obtained on addition of the reaction mixture to aqueous sodium bicarbonate was dissolved in a small amount of dichloromethane, and the solution was diluted with ether. The light brown precipitate (2.0 g.) was filtered and washed with ether. The filtrate and washings were extracted with several portions of cold aqueous 2% potassium hydroxide. The initial extracts were intensely red, while the final extracts were pale yellow-orange. The combined basic extracts were washed twice with ether and poured into cold, excess aqueous sodium bicarbonate with vigorous stirring. The yellow-orange granular precipitate was washed with water, pressed and drained thoroughly, and dried in a vacuum desiccator to constant weight (5.4 g.). It was dissolved in a small amount of benzene and the solution was allowed to stand at room temperature for several days and then placed in the refrigerator for 1 week. A tan, crystalline deposit of **3-benzoyl-4-hydroxy-5-phenylpyrazole (III)** (530 mg., 4%), m.p. 207–209°, was thus obtained. The mother liquors were boiled to dryness on the steam bath. The residue was heated on the steam bath for a further 30 min. and then dissolved in methanol. After prolonged standing at room temperature, the solution deposited bright yellow needles of **compound XLIII** (500 mg., 5%), m.p. 198–201° dec. An acetone solution of the residue obtained upon evaporation of the mother liquors slowly deposited a very small amount (*ca.* 20 mg.) of an additional product as deep yellow, fluffy needles, m.p. 273–275° dec. Attempted isolation of further crystalline products from the remaining dark brown glass obtained upon evaporation of the mother liquors by attempted recrystallization from a variety of solvents, or by chromatography on Florisil, Woelm alumina (neutral, Grade 1), or silica gel was unsuccessful. A small amount of I (*vide infra*) could be obtained by elution with methanol from a column of strongly basic ion-exchange resin (Amberlite IRA-400 as the hydroxide) charged with a methanolic solution of this residue; elution with methanolic sodium hydroxide or with methanolic hydrochloric acid did not effect further separation into pure components.

The precipitate obtained earlier upon addition of ether to the solution in dichloromethane of the bicarbonate-insoluble solid from the reaction mixture yielded a small amount of XLIII upon crystallization from ether–methanol, but no further crystalline products could be isolated from the remaining resinous solid.

Neutral Fraction.—The combined ethereal layer and washings from the extraction with aqueous potassium hydroxide were washed once with dilute aqueous sodium bicarbonate and once with saturated aqueous ammonium chloride, dried over sodium sulfate, and stripped of solvent. The resulting brown glass (2.9 g.) was extracted with several portions of boiling petroleum ether, and the insoluble residue was dissolved in a small amount of benzene. The solution was chilled in the refrigerator for several days when it afforded a pale yellow crystalline deposit of **3-benzoyl-4-phenylpyrazole (I)** (125 mg., 1%), m.p. 192–193°. The infrared spectrum of the residue from evaporation of the mother liquors included all the bands characteristic of I, but further crystalline material could not be separated. The oily residue (2.0 g.) obtained upon evaporation of the petroleum ether extracts had a strong odor characteristic of **methyl benzoate** and its infrared spectrum included all of the bands present in that of methyl benzoate, in addition to weaker bands characteristic of α-diazoacetophenone.

B. Purification and Characterization of Products. 3-Benzoyl-5-hydroxy-4-phenylpyrazole (II).—Purification of II was effected by solution in boiling methanol, filtration of the hot solution through Norit, dilution of the filtrate with boiling water, and slow cooling of the solution to 0°. Several recrystallizations in this manner, or from chloroform–methanol, afforded analytical samples as small, pale yellow needles, m.p. 248.5–250°; λ_{max} (Nujol) 3.03, 3.18, 6.13, 6.50, 11.02 μ; λ_{max} (95% EtOH) 251 mμ (log ε 4.30), 283 mμ (log ε 4.12), 340 mμ (shoulder, log ε 3.40); λ_{max} (0.1 *N* KOH–95% EtOH) 251 mμ (log ε 4.31), 283 mμ (log ε 4.22), 3.85 mμ (log ε 3.24).

Anal. Calcd. for $C_{16}H_{12}N_2O_2$: C, 72.71; H, 4.58; N, 10.60. Found: C, 72.83, 72.65; H, 4.84, 5.01; N, 10.62.

The substance was soluble in dilute aqueous potassium carbonate and gave an intense red color with ferric chloride in chloroform containing pyridine. It was shown to be identical with the compound, $C_{16}H_{12}N_2O_2$, obtained by Yates and Shapiro[1] in the reaction of α-diazoacetophenone with sodium hydroxide in dilute solution by a mixture melting point determination and infrared spectral comparison.

Oxidation of II: Formation of IV.—To a slurry of compound II (260 mg., 1.0 mmole) in dichloromethane (5 ml.), methanol (2 ml.) was added. The solution was boiled gently, and 0.054 *N* perbenzoic acid in benzene (20 ml., 1.1 mmoles) was added. The undissolved solid slowly went into solution (*ca.* 15 min.) and boiling was continued for an additional 30 min. The solution was washed several times with aqueous 5% sodium bicarbonate and once with saturated aqueous sodium chloride. It was dried with anhydrous sodium sulfate, concentrated on the steam bath, diluted with hexane to the cloud point, and chilled. There was deposited a faintly yellow amorphous powder (180 mg.), λ_{max} (Nujol) 3.13, 3.25, 5.68, 6.04 μ. This was dissolved in hot ether (*ca.* 5 ml.) and the solution was concentrated on the steam bath until crystallization began. Cooling to −25° afforded very faintly yellow rhombs of IV (41 mg., 14%), m.p. 158–160°. Two recrystallizations from carbon tetrachloride–ether afforded an analytical sample, m.p. 169–171° (dried for 20 hr. at 25° and 0.2 mm. over phosphorus pentoxide); λ_{max} (Nujol) 3.13, 3.25, 5.68, 6.04, 9.1 μ.

Anal. Calcd. for $C_{32}H_{22}N_4O_4 \cdot C_4H_{10}O$: C, 71.98; H, 5.37; N, 9.33. Found: C, 72.48; H, 4.96; N, 9.33.

Attempted recrystallization from carbon tetrachloride alone gave only an amorphous powder, while the addition of ether to the hot carbon tetrachloride solution followed by slow cooling of the mixture resulted in the separation of colorless rhombs.

Oxidation of II with potassium permanganate in aqueous base, with bromine in acetic acid, or with potassium ferricyanide in aqueous ethanol led to crude products with infrared spectra identical with that of the crude IV obtained above.

5-Benzoyltetrazole (XXV).—Several recrystallizations of crude XXV from benzene afforded an analytical sample as colorless needles, m.p. 139.5–140°; λ_{max} (CH_2Cl_2) 2.95, 6.00, 10.85 μ; λ_{max} (Nujol) 3.70, 3.85, 6.03, 10.80 μ.

Anal. Calcd. for $C_8H_6N_4O$: C, 55.17; H, 3.47; N, 32.17; mol. wt., 174. Found: C, 55.34; H, 3.32; N, 32.23; neut. equiv., 175, 176.

The substance was slightly soluble in water, dissolved readily in cold, dilute, aqueous sodium bicarbonate with gas evolution, and gave a negative color test with ferric chloride in ethanol or in chloroform–pyridine. Solution in concentrated sulfuric acid followed by heating on the steam bath resulted in the slow evolution of a gas; decomposition was complete in 12 hr. with the formation of benzoic acid, identified by comparison with an authentic sample.

Methylation of XXV.—Compound XXV (124 mg., 0.7 mmole) was dissolved in a few ml. of ether, and a solution of diazomethane in ether was added slowly with swirling until gas evolution ceased and the yellow color of diazomethane persisted. The solvent was evaporated on the steam bath and the residual oil was chilled and scratched to initiate crystallization. The almost colorless crystalline solid upon recrystallization from ether afforded faintly yellow rhombs (74 mg., 56%), m.p. 80.5–81.5°. Several recrystallizations from hexane yielded an analytical sample as colorless rhombs, m.p. 83–83.5°; λ_{max} (CH_2Cl_2) 5.99, 10.88 μ.

Anal. Calcd. for $C_9H_8N_4O$: C, 57.44; H, 4.29; N, 29.77. Found: C, 57.63; H, 4.33; N, 30.13, 29.86.

(50) Melting and boiling points are uncorrected. Infrared bands in the 5 and 6 μ regions were calibrated against the bands of polystyrene film at 5.14 and 6.24 μ, respectively.

3-Benzoyl-4-hydroxy-5-phenylpyrazole (III) could be recrystallized from chloroform–methanol to give pale yellow, fluffy needles, m.p. 210–210.5°; λ_{max} (Nujol) 2.97 (s), 3.07 (w), 6.16, 8.60, 10.28, 11.05 μ, or from benzene to give pale yellow rhombs, m.p. 210–210.5°; λ_{max} (Nujol) 2.95 (w), 3.05 (s), 6.14, 8.55, 10.90 μ; λ_{max} (95% EtOH) 243 mμ (shoulder, log ϵ 3.98), 274 mμ (log ϵ 4.49), 285 mμ (shoulder, log ϵ 4.41), 345 mμ (log ϵ 3.32); λ_{max} (0.1 *N* KOH–EtOH) 242 mμ (log ϵ 4.18), 290 mμ (log ϵ 4.22), 410 mμ (log ϵ 3.89).

Anal. Calcd. for $C_{16}H_{12}N_2O_2$: C, 72.71; H, 4.58; N, 10.60. Found: C, 72.75, 72.69; H, 4.98, 4.89; N, 10.87. Sample from benzene: C, 73.33; H, 4.59; N, 10.64.

The substance was soluble in dilute aqueous sodium hydroxide to give a yellow solution, but only very slightly soluble in dilute aqueous sodium carbonate. It gave an intense, blue-green coloration with ferric chloride in ethanol or in chloroform–pyridine.

Compound XLIII.—Purification of XLIII could be effected by recrystallization from 95% ethanol to give long, bright yellow needles, m.p. 202–203° dec., exhibiting a blue-green fluorescence under ultraviolet illumination. Several recrystallizations of this material from benzene afforded an analytical sample as golden yellow leaflets, m.p. 203–204° dec., with a blue-green fluorescence in the ultraviolet light; λ_{max} (KBr or Nujol) 6.07, 6.50, 11.00 μ; λ_{max} (CH_3OH) 240 mμ (log ϵ 4.32), 283 mμ (log ϵ 4.36), 363 mμ (log ϵ 3.99); λ_{max} (50% H_2SO_4) 252 mμ (log ϵ 4.40), 360 mμ (log ϵ 4.43); λ_{max} (H_2SO_4) 240 mμ (log ϵ 3.85), 300 mμ (log ϵ 3.67), 362 mμ (log ϵ 4.28), 420 mμ (log ϵ 4.64).

Anal. Calcd. for $C_{17}H_{11}N_5O$: C, 67.76; H, 3.68; N, 23.25. Found: C, 67.98, 67.83; H, 3.99, 3.57; N, 23.44.

The substance was insoluble in dilute aqueous sodium hydroxide, dissolved in cold, 50% aqueous sulfuric acid to give a colorless, nonfluorescent solution or in concentrated sulfuric acid to give a yellow-orange solution with a pale green fluorescence in ultraviolet light and was regenerated upon dilution of these solutions with ice–water. Boiling a solution of a small sample of XLIII in acetic acid–concentrated hydrochloric acid for 30 min. gave a nonacidic, colorless oil; λ_{max} (CH_2Cl_2) 6.46, 6.62, 10.05 μ, exhibiting a blue fluorescence under ultraviolet light, and benzoic acid, identified by infrared spectral comparison with an authentic sample.

Base Hydrolysis of XLIII: Formation of XXXV.—Compound XLIII (270 mg., 0.9 mmole) was dissolved in boiling 95% ethanol (20 ml.), aqueous 40% potassium hydroxide (2 ml.) was added, and boiling was continued for *ca.* 5 min. The deep orange solution was rapidly cooled, acidified with acetic acid, and poured into aqueous 5% sodium bicarbonate. The precipitated solid was collected and recrystallized from ethyl acetate. **Compound XXXV** was thus obtained as fluffy, white needles (60 mg., 25%), m.p. 266–268° dec., with an intense yellow-green fluorescence in ultraviolet light. Samples for analysis (m.p. 266–268° dec., λ_{max} (Nujol) 3.12, 5.97, 6.11, 6.30, 10.70 μ; λ_{max} (CH_3OH) 247 mμ (log ϵ 4.29), 304 mμ (log ϵ 4.19); λ_{max} (2% NaOH–CH_3OH) 248 mμ (log ϵ 4.30), 326 mμ (log ϵ 4.09)) were prepared by recrystallization of the product from ethyl acetate or from acetone–95% ethanol.

Anal. Calcd. for $C_{16}H_{12}N_4O_2$: C, 65.75; H, 4.14; N, 19.17. Found: C, 66.09, 65.96; H, 4.35, 4.07; N, 18.82, 18.72, 19.37.

The substance was soluble in dilute aqueous sodium hydroxide, gave no color reaction with ferric chloride in ethanol or in chloroform–pyridine, and was recovered unchanged after treatment with sodium nitrite and concentrated hydrochloric acid in dioxane. A deep red color was formed after protracted warming with acidified *p*-dimethylaminobenzaldehyde in ethanol. Prolonged boiling of solutions of the compound in hydrochloric–acetic acid, or brief boiling in ethanolic potassium hydroxide, led to extensive decomposition with the formation of benzoic acid, which was the only nonvolatile bicarbonate-soluble product.

3-Benzoyl-4-phenylpyrazole (I), m.p. 193–194°, λ_{max} (Nujol) 3.25, 6.06, 10.88 μ, was identified by comparison with an authentic sample[1,49] (lit.[1] m.p. 193–194°).

C. Synthetic Experiments. 3-Benzoyl-5-hydroxy-4-phenylpyrazole (II) (and Compounds X and XIV).—The higher melting epimer of methyl α-phenyl-β-bromo-β-benzoylpropionate[16] (1.04 g., 3.0 mmoles) was dissolved in warm 95% ethanol (*ca.* 25 ml.). A slurry of sodium carbonate (500 mg.) in a solution of 95% hydrazine (0.2 ml.) in 95% ethanol (*ca.* 5 ml.) was added, and the mixture was boiled gently on the steam bath for 30 min. in a slow stream of air. The deep yellow mixture was then diluted with aqueous 5% sodium carbonate, washed once with dichloromethane, and neutralized with concentrated hydrochloric acid. The precipitate was extracted with ethyl acetate and the extracts were dried over sodium sulfate and boiled to dryness on the steam bath. The residue was taken up in dichloromethane and chilled to 0°. The pale yellow needles (100 mg., 13%), m.p. 252–254°, which deposited were shown to be identical with II by a mixture melting point determination and infrared spectral comparison.

The dichloromethane filtrate, upon prolonged standing, deposited colorless rhombs of **compound X** (200 mg., 25%), which, upon recrystallization from chloroform–methanol, afforded a sample for analysis as colorless, square plates, m.p. 152–155° dec.; λ_{max} (Nujol) 3.00, 4.0 (broad), 5.30 (broad, weak), 5.90, 6.30, 6.42, 7.90, 11.15, 13.2 μ.

Anal. Calcd. for $(C_{16}H_{14}N_2O_2)_2 \cdot CHCl_3$: C, 61.07; H, 4.47; N, 8.63. Found: C, 61.07; H, 4.57; N, 8.93.

This substance dissolved in dilute aqueous sodium bicarbonate with gas evolution. Dropwise addition of bromine to this solution resulted in the formation of a faintly yellow precipitate which, upon recrystallization from 95% ethanol, yielded colorless rhombs, m.p. 203–204°, identified as 3,5-diphenylpyrazole (lit.[13] m.p. 200°) by a mixture melting point determination and infrared spectral comparison with an authentic sample.[13]

The dichloromethane extracts of the original reaction mixture were extracted with several portions of aqueous 2% sodium hydroxide, and the extracts were acidified with concentrated hydrochloric acid. The resultant precipitate, upon recrystallization from 95% ethanol, afforded faintly yellow needles of **3,5-diphenyl-6-pyridazinone** (**XIV**) (370 mg., 50%), m.p. 185.5–186.5°, identified by a mixture melting point determination and infrared spectral comparison with an authentic sample (*vide infra*).

4,5-Dihydro-3,5-diphenyl-6-pyridazinone (**XXIII**)[18] was obtained in quantitative yield from α-phenyl-β-benzoylpropionic acid and hydrazine as colorless needles, m.p. 166.5–167° (lit.[18] m.p. 164°); λ_{max} (Nujol) 3.08, 3.20, 5.98, 8.00 μ; λ_{max} (95% EtOH) 288 mμ (log ϵ 4.21).

3,5-Diphenyl-6-pyridazinone (**XIV**) was prepared in quantitative yield by oxidation of the dihydro compound XXIII with one molar equivalent of bromine in acetic acid at room temperature: m.p. 185.5–186.5° (lit.[15] m.p. 184°), λ_{max} (CH_2Cl_2) 2.95, 6.05 μ.

N-Amino-2,4-diphenyl-3,4-dihydroxybutyrolactam (**XVIII**).—α-Phenyl-β-benzoylpropiolactone (low melting epimer)[16] was obtained in 73% yield as long, colorless needles, m.p. 93.5–94° (lit.[16] m.p. 95°); λ_{max} (CH_2Cl_2) 5.41, 5.87, 9.0 μ.

The lactone (5.04 g., 0.020 mole) was dissolved in benzene (*ca.* 35 ml.), and a 10% solution of anhydrous hydrazine in methanol (6.4 ml., 0.020 mole) was added dropwise to the swirled solution. Colorless needles began to separate when addition neared completion (warming was evident). The mixture was digested for *ca.* 5 min. on the steam bath and cooled to room temperature. The resulting white needles (5.32 g., 94%), m.p. 157.5–159° dec., upon recrystallization from nitromethane afforded an analytical sample, m.p. 154–155.5° dec.; λ_{max} (Nujol) 2.90 (broad), 5.82, 6.1, 9.05 μ; λ_{max} (dioxane) *ca.* 215 mμ; λ_{max} (2% NaOH–dioxane) *ca.* 215 mμ.

Anal. Calcd. for $C_{16}H_{16}N_2O_3$: C, 67.59; H, 5.67; N, 9.85. Found: C, 67.27; H, 5.78; N, 10.00.

When acetonitrile rather than benzene was used as solvent the same product was obtained. However, it was soluble in this medium and was isolated by concentration of the reaction mixture on the steam bath and dilution with hexane. The yield was comparable to that obtained with benzene as solvent.

The product gave no color reaction with ferric chloride in ethanol or in chloroform–pyridine, was insoluble in dilute aqueous sodium carbonate, but gave a colorless solution with cold, dilute aqueous sodium hydroxide from which it was reprecipitated unchanged by the addition of saturated aqueous sodium bicarbonate. It was soluble in concentrated hydrochloric acid, insoluble in dilute hydrochloric acid, and, with dry hydrogen chloride in dioxane, gave a colorless, crystalline precipitate (XIX), dec. *ca.* 240°; λ_{max} (Nujol) 2.88, 3.05, 3.7, 5.75, 9.0 μ. Addition of this precipitate to dilute aqueous sodium bicarbonate regenerated XVIII. Reaction with sodium nitrite and hydrochloric acid in aqueous dioxane resulted in vigorous gas evolution.

Benzylidene Derivative of XVIII.—A solution of XVIII in hot 95% ethanol was treated with benzaldehyde and a little sodium acetate. The solution was boiled briefly, diluted with water, and cooled. The resulting viscous oil was extracted into dichloromethane, and the organic extracts were filtered through sodium sulfate and evaporated to dryness. The residual viscous oil, upon crystallization from benzene–hexane, afforded colorless rhombs, dec. *ca.* 240°. Several recrystallizations from ethanol gave a sample for analysis as colorless rhombs, dec. *ca.* 240°; λ_{max} (CH_2Cl_2) 2.85, 3.0(w), 5.88, 9.05, μ.

Anal. Calcd. for $C_{23}H_{20}N_2O_3$: C, 74.17; H, 5.41; N, 7.52. Found: C, 74.04; H, 5.58; N, 7.47.

4,5-Dihydro-4-hydroxy-3,5-diphenyl-6-pyridazinone (**XXII**).—A solution of XVIII in hot nitromethane (500 mg., 1.75 mmoles) was boiled under reflux for 1 hr. The resultant solution was concentrated to a small volume, and the remainder of the solvent was removed under reduced pressure. The residual glass was crystallized from 95% ethanol to give faintly yellow rhombs of XXII (300 mg., 65%), m.p. 156–157.5°. Recrystallization from 95% ethanol afforded an analytical sample as colorless

rhombs, m.p. 157–158°; λ_{max} (Nujol) 2.95, 3.10, 3.20, 5.97, 7.98, 9.25 μ; λ_{max} (95% EtOH) 288 mμ (log ϵ 4.20).

Anal. Calcd. for $C_{16}H_{14}N_2O_2$: C, 72.16; H, 5.30; N, 10.52. Found: C, 72.15; H, 5.21; N, 10.42.

Treatment of a boiling, alcoholic solution of this substance with a little hydrochloric acid, dilution of the resultant solution with water, and cooling, afforded a crystalline deposit of 3,5-diphenyl-6-pyridazinone (XIV), identified by a mixture melting point determination and infrared spectral comparison with an authentic sample (*vide supra*).

Acid Treatment of XVIII: Formation of 3,5-Diphenyl-6-pyridazinone (XIV).—Compound XVIII (200 mg., 0.70 mmole) was dissolved in a few ml. of boiling 95% ethanol, concentrated hydrochloric acid (1 ml.) was added, and the hot solution was diluted to the cloud point with water. Chilling to 0° caused the separation of colorless needles (160 mg., 92%), m.p. 185.5–186.5°; λ_{max} (CH_2Cl_2) 2.95, 6.05 μ. This substance was shown as above to be identical with authentic 3,5-diphenyl-6-pyridazinone.

4-Hydroxy-3,5-diphenyl-6-pyridazinone (XV).—A solution of bromine (160 mg., 1.0 mmole) in dioxane was added dropwise to a cold solution of XXII (270 mg., 1.0 mmole) in dioxane. The resultant mixture was allowed to stand at room temperature for 1 hour, then poured into water. The precipitate thus obtained was extracted into ethyl acetate containing 20% methanol. The organic extracts were dried over sodium sulfate and concentrated on the steam bath until colorless crystals of XV separated. This crude product (70 mg., 26%), m.p. *ca.* 300° dec. upon recrystallization from nitromethane, afforded a sample for analysis, m.p. *ca.* 300° dec.; λ_{max} (Nujol) 3–4 (broad), 6.15, 6.32, 6.38, 6.52 μ.

Anal. Calcd. for $C_{16}H_{12}N_2O_2$: C, 72.71; H, 4.58; N, 10.60. Found: C, 72.95, H, 4.67; N, 10.70.

This substance dissolved in dilute, aqueous sodium hydroxide and was recovered from the solution upon acidification. It gave a red color with ferric chloride in chloroform containing pyridine.

5-Benzoyltetrazole (XXV).—5-Benzyltetrazole, m.p. 123.5–124.5° (lit.[25] m.p. 123–125°), λ_{max} (Nujol) 3.75, 3.90, 6.45, 6.52 μ, was synthesized in 78% yield by the method of Finnegan, Henry, and Lofquist.[25]

5-Benzyltetrazole (6.4 g., 0.04 mole) was dissolved in warm acetic acid (*ca.* 10 ml.), and a solution of chromium trioxide (6.0 g., 0.06 mole) dissolved in a few ml. of water was added cautiously with intermittent cooling in an ice bath. Concentrated sulfuric acid (5 ml.) was added dropwise with cooling and swirling, and the solution was kept at room temperature for 10 hr. The resulting green solution and green precipitate were washed into ice–water and the mixture was stirred to dissolve the inorganic material. The clear, green solution was extracted several times with dichloromethane (300 ml. in all). The extracts were filtered through anhydrous sodium sulfate and concentrated on the steam bath to *ca.* 10 ml. Dilution of the hot solution to *ca.* 50 ml. with carbon tetrachloride and seeding with a crystal of XXV caused the immediate separation of a copious precipitate. The mixture was digested briefly on the steam bath, chilled to −10°, and the colorless leaflets were collected and air-dried. The product thus obtained (4.6 g., 66%), m.p. 136–137°, was shown to be identical with XXV by a mixture melting point and infrared spectral comparison. The methyl derivative, prepared with diazomethane, was likewise shown to be identical with that of XXV (*vide supra*).

3-Amino-5-benzyl-1,2,4-triazole (XXXVII).—Aminoguanidine bicarbonate (13.6 g., 0.1 mole) was added in small portions to concentrated sulfuric acid (12 ml., 0.22 mole). The resulting pasty mass was stirred and broken up, and phenylacetic acid (15 g., 0.11 mole) and water (*ca.* 5 ml.) were added. The hot mixture was then brought to *ca.* 140° by immersion of the reaction vessel in refluxing xylene vapors, and maintained at that temperature for 48 hr. Loss of phenylacetic acid by sublimation was compensated by the periodic addition of further portions of phenylacetic acid (totaling *ca.* 10 g.). The reaction mixture was then cooled below 100°, diluted with water, and poured slowly into excess, dilute, aqueous potassium carbonate. The resultant mixture was extracted with several portions of 20% methanol–80% ethyl acetate (totaling 1 l.). The organic extracts were dried over sodium sulfate, filtered, concentrated on the steam bath until crystallization began, and then chilled to 0°. The resultant colorless needles (7.0 g., 40%), m.p. 169–169.5°, upon recrystallization from methanol–ethyl acetate afforded an analytical sample, m.p. 169–169.5°; λ_{max} (Nujol) 2.90, 3.0, 6.18, 6.50 μ.

Anal. Calcd. for $C_9H_{10}N_4$: C, 62.05; H, 5.79; N, 32.17. Found: C, 62.19; H, 5.96; N, 32.12.

Diazotization of a small sample of the product with sodium nitrite in cold, concentrated hydrochloric acid afforded a colorless, crystalline precipitate. Addition of this slurry to a solution of β-naphthol in dilute aqueous base gave an intensely red solution.

Substitution of mandelic acid for phenylacetic acid in this procedure led to extensive decomposition with the formation of much tarry material. Substitution of polyphosphoric acid for sulfuric acid gave little or no reaction, while the use of slightly more than an equivalent of nitric acid rather than sulfuric acid according to the general method for the synthesis of 3-amino-1,2,4-triazole derivatives resulted in violent decomposition with the formation of dark tars.

3-Benzamido-5-benzyl-1,2,4-triazole (XXXIX) and XXXVIII.—Compound XXXVII (3.5 g., 0.02 mole) was dissolved in cold, dry pyridine (*ca.* 50 ml.), and benzoyl chloride (5 ml.) was slowly added to the swirled solution. After 10 min., the mixture was poured into dilute aqueous potassium carbonate, and the mixture was stirred at room temperature for 30 min., then chilled in the refrigerator. The resultant colorless, granular precipitate (5.4 g., 97%) was washed well with cold water. The product partially melted at 150°, then resolidified and melted at 280–281° dec. Recrystallization of a portion of the product from aqueous acetic acid afforded colorless needles of XXXIX, m.p. 281–282°. The mother liquors, upon dilution with water and chilling, afforded colorless needles of XXXVIII, m.p. *ca.* 140°, resolidifying and melting at 281–282°.

The crude product (500 mg.) was heated above 150° for a few minutes until the initial melt had resolidified and then digested in ethyl acetate. The insoluble, colorless needles thus obtained (500 mg., 100%), m.p. 281–282°, were identical with the product of m.p. 281–282° obtained above.

Recrystallization of a sample of XXXIX from 95% ethanol afforded an analytical sample, m.p. 284–285°; λ_{max} (Nujol) 3.2, 5.96, 6.35, 6.45 μ.

Anal. Calcd. for $C_{16}H_{14}N_4O$: C, 69.05; H, 5.07; N, 20.13. Found: C, 68.78; H, 5.18; N, 20.12.

Several recrystallizations of a sample of XXXVIII from benzene–hexane afforded an analytical sample, m.p. 142.5–143°; λ_{max} (Nujol) 2.95, 3.10, 5.90, 6.08, 6.45 μ.

Anal. Calcd. for $C_{16}H_{14}N_4O$: C, 69.05; H, 5.07; N, 20.13. Found: C, 68.82; H, 5.20; N, 19.87.

5-Benzamido-3-benzoyl-1,2,4-triazole (XXXIV).—Compound XXXIX (280 mg., 1.0 mmole) was dissolved in the minimal amount of acetic acid (*ca.* 3 ml.) at room temperature. A solution of chromium trioxide (150 mg., 1.5 mmoles) in a little water was added, followed by concentrated sulfuric acid (5 drops). A small portion of the solution was withdrawn, heated strongly on the steam bath until precipitation of green chromic sulfate was evident, then returned to the main reaction mixture. The solution was maintained at 40° overnight, during which time the precipitation of a mixture of colorless needles and green solid took place. The reaction mixture was diluted with water (*ca.* 15 ml.) until all the green chromic sulfate dissolved, then chilled. The resulting colorless nonfluorescent needles (290 mg., 100%), m.p. 249–249.5°, upon recrystallization from 95% ethanol afforded an analytical sample, m.p. 251.5–252°; λ_{max} (Nujol) 2.95, 3.15, 5.90, 6.00, 6.23, 10.82 μ.

Anal. Calcd. for $C_{16}H_{12}N_4O_2$: C, 65.75; H, 4.14; N, 19.17. Found: C, 65.59; H, 4.24; N, 19.26.

5-Amino-1,4-dibenzyl-1,2,3-triazole (XL).—A solution of hydrocinnamonitrile (5.2 g., 0.04 mole) in a little ether was added slowly to a refluxing, stirred suspension of sodium amide (1.8 g., 0.046 mole) in ether (100 ml.). The mixture was stirred under reflux for 30 min., then benzyl azide (5.2 g., 0.04 mole) in a little ether was added dropwise. The mixture was stirred under reflux for 40 hr. Infrared inspection of the ethereal solution indicated no change in the intensity of the absorption at 4.8 μ characteristic of benzyl azide. The ether was then displaced with diisopropyl ether by distillation through the condenser, and the mixture was boiled under reflux for 1 week (infrared spectral inspection of the material obtained from evaporation of an aliquot of the supernate indicated the presence of *ca.* 40% unconsumed benzyl azide). The reaction mixture was poured into ice–water, the residue was washed into the aqueous mixture with methanol, and the organic layer was separated. The aqueous layer was extracted with dichloromethane, and the combined organic fractions were dried over sodium sulfate and evaporated to dryness on the steam bath. The residue was dissolved in an ether–benzene mixture, 70% perchloric acid (*ca.* 5 ml.) was added slowly with cooling, and the mixture was kept overnight at room temperature. The supernate was decanted from the gummy residue, which was washed with benzene. The residue was stirred with excess dilute aqueous potassium hydroxide, and the precipitated gummy solid was extracted with dichloromethane. The dichloromethane extracts were dried over sodium sulfate and evaporated to dryness on the steam bath; the residue was crystallized from benzene. Light buff needles (2.5 g., 24%), m.p. 133–137°, were thus obtained. Several recrystallizations from benzene afforded an analytical sample, m.p. 139.5–140°; λ_{max} (CH_2Cl_2) 2.85, 2.95, 6.08 μ.

Anal. Calcd. for $C_{16}H_{16}N_4$: C, 72.70; H, 6.10; N, 21.20. Found: C, 72.33; H, 6.42; N, 21.00.

Attempts to carry out this condensation with potassium *t*-butoxide in *t*-butyl alcohol, or with sodium ethoxide in ethanol, were ineffectual. Infrared inspection of aliquots of the reaction mixtures even after several weeks at the reflux temperature indicated the presence of *ca.* 90% unconsumed benzyl azide.

Gradual addition of a solution of a slight excess of potassium *t*-butoxide in tetrahydrofuran (freshly distilled over lithium aluminum hydride) to a cold equimolar mixture of hydrocinnamonitrile and benzyl azide in tetrahydrofuran according to the general procedure of Lieber, *et al.*,[42] led to the formation of a product (90%, if assumed to be the Thorpe condensation product of hydrocinnamonitrile), m.p. 88–90°; λ_{max} (CH_2Cl_2) 2.95, 3.01, 4.50, 6.25 (complex) μ.

5-Benzamido-1,4-dibenzyl-1,2,3-triazole (XLI).—Benzoyl chloride (0.3 ml., 2.2 mmoles) was added dropwise to a cooled solution of the aminotriazole XL (5.30 mg., 2.0 mmoles) in pyridine (*ca.* 5 ml.). The mixture was kept at room temperature for 30 min., poured into dilute hydrochloric acid, and the precipitated solid was collected. Recrystallization from benzene–hexane afforded colorless needles of XLI (500 mg., 68%), m.p. 177–178°. Several recrystallizations from benzene–hexane afforded an analytical sample, m.p. 178.5–179°; λ_{max} (CH_2Cl_2) 2.95, 5.91, 6.25, 6.69, 6.87 μ.

Anal. Calcd. for $C_{23}H_{20}N_4O$: C, 74.98; H, 5.47; N, 15.21. Found: C, 74.90; H, 5.25; N, 14.96.

5-Benzamido-4-benzoyl-1-benzyl-1,2,3-triazole (XLII).—A solution of chromium trioxide (140 mg., 1.4 mmoles) in a little water was added to a warm solution of the benzamidotriazole XLI (370 mg., 1.0 mmole) in acetic acid (*ca.* 5 ml.). The mixture was cooled, and concentrated sulfuric acid (10 drops) was added. A small sample of the mixture was withdrawn, heated strongly on the steam bath until a green precipitate was observed, then returned to the reaction mixture. After 6 hr. at room temperature, the mixture of white crystals and green precipitate was diluted with water, stirred to effect solution of inorganic salts, and the white needles of XLII (380 mg., 100%) were collected and washed well with water. Several recrystallizations from benzene afforded an analytical sample, m.p. 201.5–202°; λ_{max} (Nujol) 3.12, 6.05, 6.12, 10.82 μ.

Anal. Calcd. for $C_{23}H_{18}N_4O_2$: C, 72.23; H, 4.74; N, 14.65. Found: C, 72.11; H, 4.74; N, 14.43.

Attempted hydrogenolysis of this substance in ethanol in the presence of acid-washed 10% palladium–charcoal catalyst at room temperature and atmospheric pressure resulted in the uptake of more than one equivalent of hydrogen without a sharp break in the hydrogenation curve. The crude product obtained upon evaporation of the solvent, after removal of an insoluble hydroxyl-containing component (λ_{max} (Nujol) 2.88, 3.07, 5.95, 6.26, 9.60 μ) by crystallization from ethanol, exhibited an infrared spectrum identical with that of XLI. Chromic acid oxidation of the total crude product according to the procedure used above quantitatively regenerated XLII.

Addition of a large excess of metallic sodium, in small portions, to a stirred slurry of XLII in liquid ammonia resulted in the formation of a transient chocolate-brown coloration and a yellow precipitate. Isolation of the organic product from this reaction by the addition of excess solid ammonium chloride, evaporation of the solvent, and extraction with boiling ethanol afforded a 90% recovery of XLII.

A solution of XLII and excess potassium thiocyanate in hot 95% ethanol was boiled under reflux for 24 hr. Upon cooling of the solution, XLII was quantitatively recovered as a deposit of colorless needles.

A solution of XLII in hot, concentrated hydriodic acid was boiled under reflux for 1 hr. The fluorescent organic material isolated from this reaction mixture by dilution with water and extraction with ethyl acetate showed, in its infrared spectrum, all of the characteristic bands of XLII and only weak absorption characteristic of XXXV.

4-Benzamido-5-benzoyl-1,2,3-triazole (XXXV).—A solution of chromium trioxide (140 mg., 1.4 mmoles) in a little water was added to a slurry of the benzoyltriazole XLII (380 mg., 1.0 mmole) in acetic acid (*ca.* 5 ml.). Concentrated sulfuric acid (10 drops) was then added, and a small portion of the mixture was withdrawn, heated strongly on the steam bath, and returned to the main reaction mixture. After 1 week at room temperature, the resultant suspension containing white crystals and green solid was diluted with water, stirred to effect solution of the inorganic material, and allowed to stand overnight at room temperature. The faintly yellow, crystalline precipitate thus obtained was recrystallized from ethyl acetate to give faintly yellow needles (80 mg., 27%), m.p. 266–268°, exhibiting a bright yellow-green fluorescence under ultraviolet light. The melting point of this product was undepressed upon admixture with XXXV and the infrared spectra (Nujol) of the two products were identical.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, IOWA STATE UNIVERSITY, AMES, IOWA]

Solvent Effects in the Reactions of Free Radicals and Atoms. VIII. The Photochlorination of Aralkyl Hydrocarbons[1,2]

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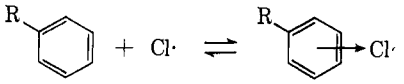
RECEIVED APRIL 1, 1963

In the side-chain photochlorination of aralkyl hydrocarbons, high selectivity is often observed because of complex formation between the aromatic nucleus and the chlorine atom. This complexed chlorine atom displays considerably greater selectivity in hydrogen abstraction reactions than the free chlorine atom. Dilution of aralkyl hydrocarbons by inert noncomplexing solvents destroys the high selectivity often noted in photochlorination. Extrapolation of selectivity data to an infinite dilution of the aralkyl hydrocarbon yields reactivity data toward the free chlorine atom.

Previous communications have emphasized the importance of specific solvent effects, particularly of aromatic solvents, in the reactions of chlorine atoms.[4] This has prompted us to re-examine the photochlorination of aralkyl hydrocarbons since in these cases the substrate itself could also act as a specific complexing agent for the chlorine atom.[5] The results obtained have been in complete agreement with those obtained in a study of solvent effects in the photochlorination of aliphatic substances. Thus, the addition of an aromatic solvent in the photochlorination of a branched-chain hydrocarbon, such as 2,3-dimethylbutane, makes the chlorine atom more selective in its attack on the 3°- and 1°-hydrogen atoms, the effect becoming more pronounced at the higher concentration of aromatic solvent.[4] In the chlorination of aralkyl hydrocarbons, such as ethylbenzene, cumene, indan, and tetralin, the present work has demonstrated the same effect. Dilution of the aralkyl substrate by an aliphatic solvent, such as carbon tetrachloride or cyclohexane, or by a weakly basic aromatic such as nitrobenzene, has a pronounced effect on the reactivity of the chlorine atom, dilution favoring a lower selectivity in the attack of the chlorine atom upon a system of 1°-, 2°-, and 3°-carbon–hydrogen bonds. By extrapolation to infinite dilution it is possible to obtain for the first time the relative reactivities of the hydrogen atoms in the side



(1) Directive Effects in Aliphatic Substitutions. Part XX.

(2) This research was supported by the Air Force Office of Scientific Research and by a grant from the Petroleum Research Fund administered by the American Chemical Society. Grateful acknowledgment is hereby made to the donors of these funds.

(3) Alfred P. Sloan Foundation Fellow, 1959–1963.

(4) G. A. Russell, *J. Am. Chem. Soc.*, **79**, 2977 (1957); **80**, 4987, 4997, 5002 (1958).

(5) G. A. Russell and H. C. Brown, *ibid.*, **77**, 4031 (1955).