Aliphatic Diazo Compounds. V. The Reaction of Diazoketones with Bases[1,2]

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The reaction of α-diazoacetophenone with sodium hydroxide in aqueous dioxane or ethanol has been found to give benzoic acid, acetophenone, 3-benzoyl-4-phenylpyrazole, 3-benzoyl-5-hydroxy-4-phenylpyrazole, hydrogen cyanide, hydroxylamine and ammonia; the same major products are formed by the action of ethanolic sodium ethoxide. Azibenzil has been shown to react with sodium hydroxide in water–methanol–ether to give benzoic acid, phenyldiazomethane, diphenylacetic acid, and benzilazine; analogous products have been obtained from its reaction with methanolic sodium methoxide. The reaction pathways leading to these products are discussed in terms of four processes: cleavage, solvolysis, reduction and condensation.

While the reaction of diazoketones with acids is now commonplace,[4,5] their decomposition in basic media has been little examined except under the special conditions of the Wolff rearrangement.[6] Although it has been stated that diazoketones are quite stable toward alkali[4] and cases have been recorded wherein diazoketones have been recovered from basic reaction mixtures,[7,8] several isolated accounts have appeared which indicate that diazoketones are susceptible to basic attack under relatively mild conditions. Thus, it was early reported that α-diazoacetophenone gives rise to a red coloration when treated with aqueous or alcoholic alkali[9] and that diazoacetone decomposes in concentrated alkali,[7b] but the nature of these changes was not elucidated. Treatment of α-diazo-o-nitroacetophenone with aqueous alcoholic alkali was found to give a red solution which on acidification yielded hydrogen cyanide and an amorphous, unidentified solid.[10] More recently Wilds and Meader[11] have observed that when p-chloro-α-diazoacetophenone is warmed in aqueous methanolic potassium hydroxide a gas is evolved and a 35% yield of p-chlorobenzoic acid is obtained on acidification along with much tarry material. On the basis of these fragmentary findings it seemed of interest to investigate further the reaction of diazoketones with basic reagents and the present report describes initial work with α-diazoacetophenone and azibenzil (benzoylphenyldiazomethane).

Results

α-**Diazoacetophenone.**—The reaction of α-diazoacetophenone with base pursued the same general course when conducted in dilute homogeneous solution with sodium hydroxide in aqueous

dioxane or ethanol, or under anhydrous conditions using ethanolic sodium ethoxide. When the reaction was carried out under heterogeneous conditions in aqueous base, similar major products were obtained, but resinification, already great in the homogeneous cases, occurred to a considerably higher degree. In all cases a red color developed rapidly at room temperature and an intensely wine-red solution was formed; preliminary runs showed that a reaction time of several hours at 75–90° was necessary to ensure total, irreversible consumption of the diazoketone. The crude reaction product was separated into three fractions: neutral and basic (A), acidic (bicarbonate-soluble) (B), and acidic (bicarbonate-insoluble) (C); the gaseous products also were examined.

Fraction A, a dark-brown, viscous oil, when triturated with ether gave a solid which on recrystallization yielded a compound, $C_{16}H_{12}N_2O$, m.p. 193–194°, infrared bands (KBr) at 3.27 and 6.05 μ. On the basis of its properties and source this product was considered to be 3-benzoyl-4-phenylpyrazole (I): this conclusion was confirmed by direct comparison with a sample prepared by the method of Smith and Pings.[12] The ethereal solution from the trituration on evaporation yielded a dark oil with the characteristic odor of acetophenone; that it consisted largely of this compound was shown by examination of its infrared spectrum and by the formation of a 2,4-dinitrophenylhydrazone, shown to be that of acetophenone.

Acidification of the basic reaction mixture after removal of fraction A resulted in the liberation of much hydrogen cyanide, identified by its odor and infrared spectrum; the acid solution gave a positive test for hydroxylamine.[13] The bicarbonate-soluble fraction B was obtained as a pale yellow solid; this consisted almost entirely of benzoic acid. The presence of mandelic, phenylacetic or other carboxylic acids could not be detected.

From the bicarbonate-insoluble fraction C was isolated a pale yellow crystalline compound, $C_{16}H_{12}N_2O_2$, m.p. 243.5–244.5° dec. This gave a positive ferric chloride test, and dissolved in 5% aqueous sodium hydroxide to give an intense yellow solution from which it was recovered unchanged on acidification; the basic solution immediately reduced aqueous potassium permanganate. On the basis of these properties, its infrared spectrum (bands at 3.09 and 6.15 μ) and mechanistic con-

(1) For earlier papers in this series see (a) P. Yates and B. L. Shapiro, *J. Org. Chem.*, **23**, 759 (1958); (b) P. Yates, B. L. Shapiro, N. Yoda and J. Fugger, THIS JOURNAL, **79**, 5756 (1957).

(2) From the Ph.D. Thesis of Bernard L. Shapiro, Harvard University, 1957; this work was supported in part by an institutional research grant from the American Cancer Society to Harvard University.

(3) Shell Foundation Fellow, 1955–1956.

(4) B. Eistert in "Newer Methods of Preparative Organic Chemistry," Interscience Publishers, Inc., New York, N. Y., 1948, p. 513.

(5) R. Huisgen, *Angew. Chem.*, **67**, 439 (1955).

(6) P. Yates, THIS JOURNAL, **74**, 5376 (1952), footnote 21.

(7) (a) H. Wieland and S. Bloch, *Ber.*, **39**, 1488 (1906); (b) L. Wolff, *Ann.*, **394**, 23 (1912).

(8) T. Reichstein, *et al.*, *Helv. Chim. Acta*, **20**, 1164 (1937); **22**, 1209 (1939); **37**, 45, 388, 443 (1954); J. R. Marshall and J. Walker, *J. Chem. Soc.*, 467 (1952).

(9) (a) L. Wolff, *Ann.*, **325**, 129 (1902); (b) R. Robinson and W. Bradley, *J. Chem. Soc.*, 1310 (1928).

(10) F. Arndt, B. Eistert and W. Partale, *Ber.*, **60**, 1364 (1927).

(11) A. L. Wilds and A. L. Meader, *J. Org. Chem.*, **13**, 763 (1948).

(12) L. I. Smith and W. B. Pings, *ibid.*, **2**, 23 (1937).

(13) F. Feigl, "Spot Tests," Vol. I, 4th edition, Elsevier Publishing Co., New York, N. Y., 1954, p. 230.

siderations it was considered to have one of the hydroxypyrazole structures II or III. It has been shown to possess structure III by comparison with a sample synthesized by an independent route.[14]

I

II

III
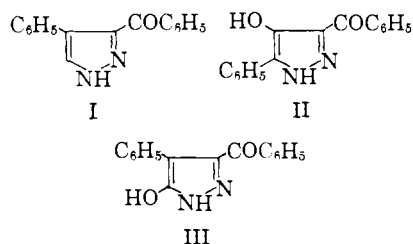
Infrared spectral examination of the gaseous products, trapped at −80 and −196°, showed the presence of trace amounts of ammonia but the absence of any nitrous oxide.

The products obtained in various solvent systems were substantially the same. In all cases the weight balance was poor, due to failure to resolve efficiently the complex mixture of components in the tarry reaction mixture: in Table I are given the products and yields from a run in aqueous dioxane. When sodium methoxide or ethoxide in the corresponding alcohol was used, benzoic acid was again isolated, but no evidence could be obtained for the presence of ethyl benzoate.

TABLE I

PRODUCTS FROM THE REACTION OF α-DIAZOACETOPHENONE WITH SODIUM HYDROXIDE IN AQUEOUS DIOXANE[a]

Product	Yield, %
Acetophenone	4.5[b]
Benzoic acid	27
3-Benzoyl-4-phenylpyrazole (I)	10
3-Benzoyl-5-hydroxy-4-phenylpyrazole (III)	1.7
Ammonia	Trace
Hydrogen cyanide	
Hydroxylamine	

[a] 0.11 and 0.40 molar in α-diazoacetophenone and sodium hydroxide, respectively. [b] As the 2,4-dinitrophenylhydrazone.

Azibenzil.—Like α-diazoacetophenone, azibenzil was found to undergo several types of reaction with base: however, in contradistinction, decomposition proceeded smoothly at room temperature with little or no resinification. When the reaction was carried out in homogeneous solution with sodium hydroxide in water–methanol–ether the products listed in Table II were obtained. The benzilazine separated from the reaction mixtures, the phenyldiazomethane and benzoin were found in the neutral fraction of the mixture, while the benzoic and diphenylacetic acids were isolated by fractional sublimation of the acidic fraction or estimated by infrared spectral analysis. With a large excess of base the reaction giving phenyldiazomethane and benzoic acid very largely predominated and provided a useful method for the preparation of phenyldiazomethane.[1a]

Reaction of azibenzil with sodium methoxide in homogeneous, methanol–ether solution gave a

(14) P. Yates and D. G. Farnum, unpublished results; evidence also has been obtained that when high concentrations of base are used for the decomposition of diazoacetophenone II also is formed together with several other new products.

TABLE II

PRODUCTS FROM THE REACTION OF AZIBENZIL WITH SODIUM HYDROXIDE IN WATER–METHANOL–ETHER[a]

	Yields, % Equiv. of NaOH per equiv. of azibenzil			
Product	8	2	1	0
Benzoic acid	90	37	22	<2
Phenyldiazomethane	70[b]	c	c	0
Diphenylacetic acid	6	34	42	60
Benzoin	<2	<2	<2	25
Benzilazine	<1	24	28	0

[a] The reaction in the absence of base was run in aqueous dioxane; the reaction times used ensured complete reaction of the azibenzil. [b] As benzyl p-nitrobenzoate or benzyl mandelate. [c] Presence indicated by color, odor and infrared spectrum of neutral fraction.

series of products analogous to those obtained in aqueous media, viz., methyl benzoate, phenyldiazomethane, methyl diphenylacetate and benzilazine.

In all of the reactions with base, the yield of benzilazine increased markedly if the reaction mixture separated into two layers. When an ethereal solution of azibenzil was stirred with 40% aqueous potassium hydroxide a high yield of benzilazine was obtained together with smaller amounts of the other products previously observed. A similar result was observed on stirring an ethereal solution of azibenzil with catalytic amounts of sodium methoxide, when a 90% yield of benzilazine was obtained.[15] However, when one to four equivalents of sodium methoxide were used, the suspension of azine first formed decreased in amount on further stirring and the color of the mixture became deep purple. When this mixture was poured into water the purple color was discharged immediately to give an orange-yellow ether solution containing much suspended benzilazine; the solution contained, in addition to products of the type observed previously, several new products. When the azine was treated with sodium methoxide under similar conditions a purple coloration was again observed and the following products were obtained: benzonitrile, methyl benzoate, benzamide and two new crystalline compounds, m.p. 124.5–125.5° and m.p. ca. 160° dec. The former was obtained as very pale yellow needles analyzing as $C_{22}H_{18}N_2O_2$ and has been shown to have the structure IV. The latter was isolated as a pale yellow, crystalline material analyzing as $C_{28}H_{22}N_2O_2$ and has been tentatively assigned the structure V.[16]
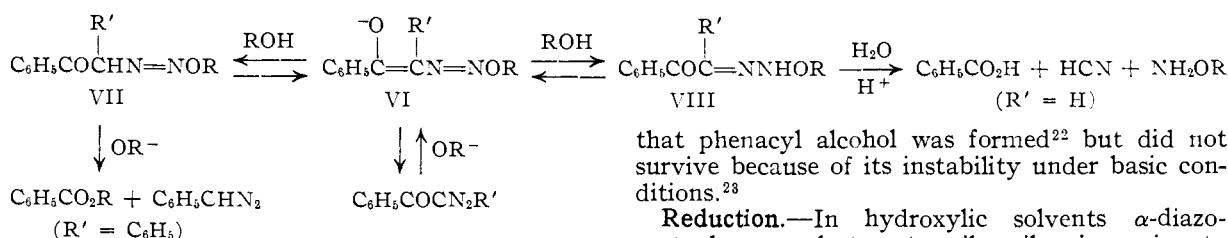

IV

V
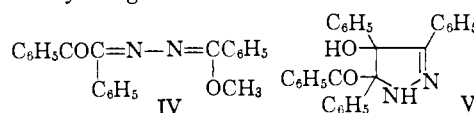
Discussion

Several pathways are followed in the reactions of α-diazoacetophenone and azibenzil with base, viz., cleavage, solvolysis, reduction, condensation, and are now considered individually.

(15) In the absence of methoxide, no benzilazine was formed: on prolonged standing of the ethereal azibenzil followed by treatment with water the only product isolated was diphenylacetic anhydride, indicating the formation of diphenylketene; cf. H. Staudinger, Ber., 38, 1735 (1905); [Ann., 356, 76 (1907).

(16) Since these products do not arise directly from azibenzil but from benzilazine they will be treated in detail in a separate report.

$$C_6H_5COCHN=NOR \xrightleftharpoons{ROH} C_6H_5\overset{-O}{\underset{}{C}}=\overset{R'}{\underset{}{C}}N=NOR \xrightleftharpoons{ROH} C_6H_5COC=NNHOR \xrightarrow[H^+]{H_2O} C_6H_5CO_2H + HCN + NH_2OR$$

$$\text{VII} \qquad\qquad \text{VI} \qquad\qquad \text{VIII} \qquad\qquad (R' = H)$$

$$\downarrow OR^- \qquad\qquad \downarrow\uparrow OR^-$$

$$C_6H_5CO_2R + C_6H_5CHN_2 \qquad C_6H_5COCN_2R'$$
$$(R' = C_6H_5)$$

Cleavage.—In both cases the cleavage of a C–C bond is witnessed by the formation of benzoic acid or methyl benzoate. The concomitant formation of phenyldiazomethane from azibenzil leads to the formulation (R = H or CH₃)

$$C_6H_5COCN_2C_6H_5 \xrightarrow[ROH]{OR^-} C_6H_5CO_2R + C_6H_5CHN_2$$
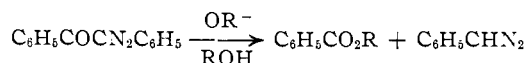
This type of cleavage has long been known in the case of α-diazo-β-diketones,[7b,17] and has been advanced by Wilds and Meader[11] to explain the formation of p-chlorobenzoic acid in the basic decomposition of p-chloro-α-diazopropiophenone. The preferred position for nucleophilic attack on diazoketones is at the terminal nitrogen atom to give a relatively highly stabilized mesomeric anion of type VI.[18] The probable pathway for the cleavage of azibenzil thus involves the formation of VI with subsequent attack at the carbonyl group of the protonated species VII.[19] In the case of α-diazoacetophenone we suggest that cleavage occurs *after acidification via* the protonated species VIII. This scheme allows the interpretation of (i) the unusual cleavage of the N–N bond[20] of the diazoketone, (ii) the detection of hydroxylamine in the reaction mixtures from reactions with aqueous base *only after acidification*, (iii) the formation of only trace amounts of ammonia: had appreciable cleavage to cyanide ion and hydroxylamine occurred in the hot basic solution it would be anticipated that these would not survive and that appreciable quantities of ammonia would have been formed.

Solvolysis.—Diphenylacetic acid and benzoin, formed from azibenzil in aqueous medium, may be considered as solvolysis products. They correspond to the products previously reported[21] from the thermal decomposition of azibenzil in methanol or ethanol, *i.e.*, alkyl diphenylacetate and benzoin alkyl ether. We have also observed the formation of methyl diphenylacetate in the reaction with methanolic sodium methoxide. No similar solvolysis products were isolated in the case of α-diazoacetophenone; infrared spectral examination showed the absence of significant amounts of phenylacetic acid in the acid fraction. It is likely

that phenacyl alcohol was formed[22] but did not survive because of its instability under basic conditions.[23]

Reduction.—In hydroxylic solvents α-diazoacetophenone, but not azibenzil, gives rise to reduction products, *i.e.*, acetophenone and I (which is considered under condensation below). In the case of reactions with sodium ethoxide in ethanol, this could occur by a path involving hydride transfer from alkoxide ion[24]; such a path is not possible, however, in the reactions with aqueous sodium hydroxide. A route involving the elimination of nitrous oxide from VII (R' = R = H) was rendered unlikely by the fact that no nitrous oxide could be detected in the effluent gases.[25] It is probable that the effective reducing agent is phenacyl alcohol, which is known to bring about reduction, or its decomposition products.[7b,23]

Condensation.—The formation of benzilazine from azibenzil is best formulated in the following fashion, which accounts for the observed basic catalysis of the reaction

$$\text{VI} + C_6H_5COCN_2C_6H_5 \longrightarrow$$
$$(R' = C_6H_5)$$

$$\begin{array}{ccc} & COC_6H_5 & COC_6H_5 \\ & | & | \\ RO-N=N-C-N=N-C^- \\ & | & | \\ & C_6H_5 & C_6H_5 \end{array} \longrightarrow$$

$$RO^- + N_2 + (C_6H_5CO-\underset{\underset{C_6H_5}{|}}{C}=N-)_2$$

The two condensation products from α-diazoacetophenone are in different oxidation states. The product in the lower oxidation state, I, can result from terminal attack by the anion of acetophenone, formed in the reduction reaction, in a manner entirely analogous to the mode of reaction of diazoketones with "active methylene" compounds.[18d] The other condensation product is formally derivable by the condensation of two molecules of diazoketone with loss of one molecule of nitrogen, and could arise *via* consecutive terminal attacks to give IX or by terminal attack of the anion of phenacyl alcohol on the diazoketone, followed by elimination of water.

$$\begin{array}{cc} C_6H_5CO & ^-CHCOC_6H_5 \\ | & | \\ CH & N \\ \diagdown & \diagup \\ RON=N & N \end{array} \longrightarrow \begin{array}{c} C_6H_5 \quad COC_6H_5 \\ O \diagup \diagdown \\ \diagdown N \\ N \end{array} \longrightarrow \text{III}$$
$$\qquad\qquad \text{IX}$$

In summary, it may be noted that, although the detailed pathways leading to the formation of the several products from the reaction of these two

(17) H. Wieland and S. Bloch, *Ber.*, **39**, 1488 (1906).

(18) *Cf.* the reactions with (a) cyanide ion: L. Wolff, ref. 9a, p. 148; ref. 7b, p. 41; M. O. Forster and W. B. Saville, *J. Chem. Soc.*, 753 (1920); (b) sulfite ion: E. Rimini, *Gazz. chim. ital.*, **26**, 290 (1896); (c) tertiary phosphines: H. Staudinger and J. Meyer, *Helv. Chim. Acta*, **2**, 619 (1919); H. Staudinger and G. Luscher, *ibid.*, **5**, 75 (1922); (d) carbanions: A. Klages, *J. prakt. Chem.*, [2] **65**, 387 (1902); L. Wolff, ref. 9a, p. 177; (e) Grignard reagents: M. O. Forster and D. Cardwell, *J. Chem. Soc.*, 861 (1913).

(19) There is no analogy for *direct* nucleophilic attack at the carbonyl group in the case of simple α-diazoketones.
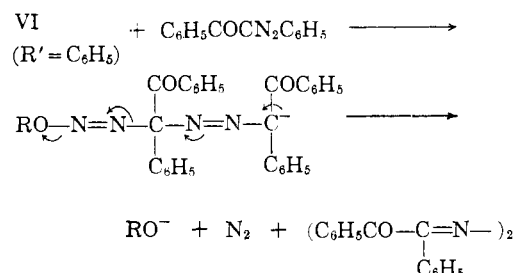
(20) The only other cases of such cleavage of which we are aware are those involving hydrogenation; *e.g.*, L. Birkofer, *Ber.*, **80**, 83 (1947).

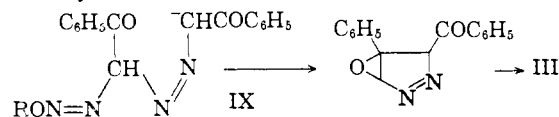(21) G. Schroeter, *ibid.*, **42**, 3361 (1909).

(22) Its formation in neutral medium has been observed (L. Wolff, ref. 7b) and we also have found that it is the major product when α-diazoacetophenone is heated in aqueous dioxane.

(23) P. Hunaeus and T. Zincke, *Ber.*, **10**, 1486 (1877); T. Zincke, *Ann.*, **216**, 305 (1883).

(24) *Cf.* W. von Doering and T. C. Aschner, THIS JOURNAL, **75**, 393 (1953); Y. Sprinzak, *ibid.*, **78**, 466 (1956).

(25) It was determined that nitrous oxide blown slowly through the hot reaction mixture readily could be trapped and detected.

diazoketones with bases remain to be defined, the formation of all of the products may be rationalized on the basis of initial terminal attack of the bases on the diazoketones.

Experimental[26]

α-Diazoacetophenone.—A procedure described earlier by Newman and Beal[27] was modified somewhat.[28] To a solution of diazomethane (25.5 g., 0.70 mole) and triethylamine (71 g., 0.70 mole) in ether (ca. 1100 ml.), cooled in an ice-salt-bath, was added dropwise with stirring a solution of benzoyl chloride (98 g., 0.70 mole) in ether (250 ml.) over a period of about 30 minutes.[29] The mixture was stirred at 0° for a further 30 minutes and then allowed to stand in the cold for 4 hours. The triethylamine hydrochloride which had precipitated was filtered and washed with ether until the washings were no longer yellow. The combined filtrate and washings were freed of solvent at room temperature under reduced pressure and the residue was maintained under reduced pressure (water aspirator) for 4 hours to remove traces of triethylamine. The yield of crude diazoketone was 91.7 g. (90%). This was purified by solution in "hexane" (a cut of b.p. 66–68° from technical hexane) at a temperature not above 35°; a small amount of insoluble, red oil was allowed to settle and the clear, supernatant solution decanted into a flask prewarmed at 35°. It was seeded with a small amount of crystalline material and on cooling slowly to room temperature and standing overnight in the refrigerator gave the diazoketone as bright yellow leaflets or spears. Three such crystallizations afforded pure α-diazoacetophenone, m.p. 47–48°.[30]

Reaction of α-Diazoacetophenone with Base. (i) Sodium Hydroxide in Aqueous Dioxane.—The reaction was carried out in a 1-l. three-necked flask fitted with a mechanical stirrer, a reflux condenser and a dropping funnel which had a side-arm through which nitrogen could be admitted to the system. The top of the condenser was connected by Tygon tubing to the following system of five U-shaped traps: two traps connected in parallel and removable individually which were kept at −80° (Dry Ice–chloroform–carbon tetrachloride), a second pair of traps similarly arranged and maintained at −196° (liquid nitrogen), and another trap at −196°. An empty gas-washing bottle and a gas-washing bottle containing concentrated sulfuric acid completed the train. A slow stream of purified nitrogen was used to blanket the reaction and to carry any gaseous products into the trapping system.

A solution of α-diazoacetophenone (14.6 g., 0.10 mole) in dioxane (250 ml.) was added dropwise over a period of two hours to a solution of sodium hydroxide (14.6 g., 0.365 mole) in a mixture of water (440 ml.) and dioxane (200 ml.). The reaction mixture was stirred and maintained at 85° throughout the period of addition and then for a further 12 hours. The addition of the first few ml. of diazoketone solution led to the formation of an orange-red color which gradually deepened; within 15 minutes the reaction solution had acquired a very intense wine-red coloration which persisted throughout the remainder of the reaction period. The infrared spectra of the contents of both the −80 and the −196° traps were examined after 6 and 12 hours. These spectra showed that the traps contained, in addition to dioxane and water, only very small amounts of ammonia. (In a control run when nitrous oxide was bubbled slowly through a similar hot reaction mixture and entrained with nitrogen, the −196° trap soon contained a volatile white solid whose infrared spectrum was identical with that of nitrous oxide.)

The reaction mixture was concentrated under reduced pressure to approximately one-third of its original volume, diluted with water (500 ml.) and subjected to continuous extraction with ether for 60 hours. The dark brown ether extract was dried and freed of solvent in vacuo to yield 4.96 g. of a dark brown, viscous oil (fraction A). The aqueous reaction mixture was cooled to 0° and acidified to pH 1 by the dropwise addition with stirring of cold, dilute sulfuric

(26) Melting and boiling points are uncorrected.

(27) M. S. Newman and P. Beal, THIS JOURNAL, 71, 1506 (1949).

(28) Evolved in collaboration with Dr. D. W. Wiley.

(29) It was found that to ensure maximum yield and purity it was important to maintain the reaction mixture below 0° and to add the benzoyl chloride solution slowly.

(30) For infrared spectrum see ref. 1b.

acid; acidification caused the liberation of much hydrogen cyanide, detected by its odor and by its infrared spectrum. The mixture then was extracted continuously with ether for 50 hours and filtered free of a small amount of solid material which separated at the interface; the aqueous acidic solution gave a positive test for the presence of hydroxylamine.[13,31] The orange-brown ethereal extract was shaken several times with 5% aqueous sodium bicarbonate: the combined bicarbonate extracts were cooled to 0°, acidified to pH 1 with concentrated hydrochloric acid and extracted continuously with ether for 30 hours. This ethereal extract was dried and freed of solvent in vacuo to yield 3.30 g. of a pale yellow solid (fraction B). The ethereal solution remaining after the bicarbonate extraction was treated similarly to give 1.52 g. of an orange-brown glassy solid (fraction C).

Fraction A was triturated with a small amount of ether, giving solid material which was filtered and washed with ether; yield 1.15 g. This was crystallized several times from ethyl acetate or chloroform to give fluffy, white needles, m.p. 193–194°; λ_{max}^{KBr} 3.27, 6.05 μ.

Anal. Calcd. for $C_{16}H_{12}N_2O$: C, 77.40; H, 4.87; N, 11.28. Found: C, 77.60; H, 4.78; N, 11.07.

The m.p. of this product was undepressed on admixture with 3-benzoyl-4-phenylpyrazole, m.p. 193–194°, obtained by oxidation of 3-benzoyl-4-phenyl-2-pyrazoline[12]; its identity with the authentic compound was confirmed by infrared spectral comparison. The ethereal solution remaining after removal of 3-benzoyl-4-phenylpyrazole was evaporated to give a dark oil which was taken up in 95% ethanol and treated with 2,4-dinitrophenylhydrazine reagent. The resulting orange precipitate was filtered: yield 1.36 g., m.p. 236–238° dec. Three recrystallizations from ethyl acetate gave shiny red-orange needles, m.p. 241–242° dec.; a mixed m.p. with acetophenone 2,4-dinitrophenylhydrazone showed no depression. The filtrate from the reaction with 2,4-dinitrophenylhydrazine was diluted with water and extracted with chloroform: the extract gave 1.68 g. of a dark brown oil. Attempted crystallization and chromatography failed to yield any further pure products.

Fraction B was crystallized from hot water to yield benzoic acid (m.p. undepressed by admixture with an authentic sample); its identity was confirmed by infrared spectral comparison. Examination of the infrared spectrum of the contents of the mother liquors failed to show the presence of mandelic, phenylacetic or other carboxylic acids in addition to benzoic acid.

A solution of fraction C in methylene chloride on standing at room temperature for several days deposited 0.220 g. of a pale yellow solid which was filtered and washed with methylene chloride and ether. This was crystallized five times from ethanol to give a soft, pale yellow crystalline solid, m.p. 243.5–244.5° dec.; λ_{max}^{KBr} 3.09, 6.15 μ; λ_{max}^{EtOH} 250 mμ (log ε 4.26), 281 mμ (inflection, log ε 3.97), ca. 330 mμ (inflection, log ε 3.42).

Anal. Calcd. for $C_{16}H_{12}N_2O_2$: C, 72.71; H, 4.58; N, 10.60. Found: C, 73.08; H, 3.95; N, 10.57.

This product was soluble in 5% aqueous sodium hydroxide from which it was recovered unchanged on acidification; it was unaffected by prolonged boiling in either 20% aqueous ethanolic potassium hydroxide or in a 1:1 mixture of concentrated hydrochloric acid and acetic acid. It gave a deep red coloration with ferric chloride in pyridine and chloroform.[32] A basic solution of the product immediately destroyed the purple color of aqueous potassium permanganate with the evolution of an odorless, neutral gas and the formation of the characteristic green color of the manganate ion. The methylene chloride mother liquors from the original isolation of this compound failed to yield any further solid material, but the infrared spectrum of their contents indicated the presence of 3-benzoyl-4-phenylpyrazole.

(ii) Aqueous–Ethanolic Sodium Hydroxide.—A solution of diazoacetophenone (14.6 g., 0.10 mole) and sodium hydroxide (40 g., 1.0 mole) in water (1 l.) and ethanol (750 ml.) was boiled under reflux for 10 hours in a nitrogen atmosphere. Most of the ethanol was removed from the resulting deep red solution at room temperature with a water aspirator and the residual solution was diluted with water and fractionated as in (i). The products were again shown by isolation and infrared spectral analysis to include benzoic

(31) Prior to acidification the test was negative.

(32) S. Soloway and S. H. Wilen, Anal. Chem., 24, 979 (1952).

acid (22%), 3-benzoyl-5-hydroxy-4-phenylpyrazole (6%), acetophenone and 3-benzoyl-4-phenylpyrazole; hydrogen cyanide also was detected on acidification of the base-soluble fraction.

(iii) **Ethanolic Sodium Ethoxide.**[33]—A solution of diazoacetophenone (4.4 g., 0.030 mole) in ethanol (40 ml.) was added slowly with stirring to a solution of sodium (6.9 g., 0.30 mole) in ethanol (150 ml.) under nitrogen at room temperature. The solution was boiled under reflux for 10 hours and worked up in the usual manner. Benzoic acid again was isolated (27% yield) and infrared spectral evidence was obtained for the formation of acetophenone, 3-benzoyl-5-hydroxy-4-phenylpyrazole and 3-benzoyl-4-phenylpyrazole; hydrogen cyanide was evolved on acidification of the reaction mixture. Infrared spectral examination of the neutral fraction and of fractions obtained by chromatography of this neutral fraction failed to reveal the presence of any ethyl benzoate.

(iv) **Aqueous Sodium Hydroxide.**—Diazoacetophenone (6.6 g., 0.045 mole) was added in small portions at a time to a stirred solution of sodium hydroxide (24.0 g., 0.60 mole) in water (300 ml.) heated on a steam-bath. The stirring and heating were continued for 6 hours; the reaction mixture never became homogeneous and finally consisted of an orange-brown solution together with dark tarry material. It was worked up as before and acetophenone, 3-benzoyl-4-phenylacetate and benzoic acid were shown to be formed; the last was obtained in substantial yield (40%).

Decomposition of α-Diazoacetophenone in Aqueous Dioxane.—A solution of diazoacetophenone (1.46 g., 0.010 mole) in water (40 ml.) and dioxane (40 ml.) was boiled under reflux in a nitrogen atmosphere for 20 hours: the solution remained clear with only a slight deepening of its yellow color. It was diluted with water and extracted with methylene chloride; the extract was dried and evaporated and the residue subjected to infrared spectral analysis, which showed the presence of phenacyl alcohol and unreacted diazoacetophenone only.

Reaction of Azibenzil with Base. (i) **Sodium Hydroxide in Water–Methanol–Ether.**—The reaction of azibenzil with 8 equivalents of sodium hydroxide in water–methanol–ether has been described elsewhere[1a]. Similar reaction conditions and work-up were used for the reactions of 1 and 2 equivalents of sodium hydroxide with azibenzil. In these cases benzilazine was deposited from the solution during the course of the reaction and was filtered before extraction of the solution; the product yields are given in Table II.

(ii) **Sodium Methoxide in Methanol–Ether.**—A solution of azibenzil (5.56 g., 0.025 mole) in ether (175 ml.) was added to a solution of sodium (2.3 g., 0.10 mole) in methanol (175 ml.) and the homogeneous reaction mixture was allowed to stand at room temperature for two days. The color of the solution became deep red and only a trace of solid material separated. The reaction mixture was separated into neutral and acidic fractions in the usual manner. The neutral fraction (4.0 g.) was found to consist almost entirely of a mixture of phenyldiazomethane and methyl benzoate by infrared spectral comparison: the presence of phenyldiazomethane was confirmed by the isolation of benzyl p-nitrobenzoate, m.p. 82.5–84.5°,[1a] from reaction of the neutral fraction with p-nitrobenzoic acid. The acidic fraction (0.44 g.) consisted of benzoic acid. A similar run using 0.18 g. (0.0078 mole) of sodium gave benzilazine (42%), most of which (1.99 g.) separated from the reaction mixture and could be filtered, a neutral ether–soluble fraction (2.5 g.) which contained additional benzilazine (0.17 g.) together with phenyldiazomethane, methyl benzoate and methyl diphenylacetate, identified spectroscopically, and an acidic fraction containing benzoic acid (0.11 g.).

(iii) **Sodium Methoxide in Ether.**—Sodium methoxide (5.4 g., 0.10 mole) was added to a solution of azibenzil (5.56 g., 0.025 mole) in ether (200 ml.) and the suspension stirred at room temperature for 70 hours. Within a few hours, a yellow suspension of benzilazine was formed in the ethereal solution, and the latter had begun to acquire a salmon-pink color. The color gradually deepened and after 30 hours was a very intense purple; this was accompanied by an apparent decrease in the amount of suspended azine. The reaction mixture was poured into water, causing the discharge of the purple color and the production of a yellow-orange ethereal layer containing suspended azine. The latter was filtered

and the ethereal solution dried and evaporated to give a semi-solid residue. Infrared spectral examination of this product mixture indicated the presence of benzilazine, phenyldiazomethane, methyl benzoate and benzonitrile along with smaller amounts of additional products. Since it was found that similar products (with the exception of phenyldiazomethane) could be obtained more directly from benzilazine (vide infra), the resolution of this mixture of products from azibenzil was not pursued. A similar series of color changes was observed when 1 equivalent of sodium methoxide per equivalent of azibenzil was used and a similar mixture of products was obtained; the only noteworthy difference was a considerably increased yield of benzilazine, which varied from 5% where 4 equivalents of sodium methoxide were used to 55% in the case of equimolar amounts of methoxide and azibenzil. When the amount of sodium methoxide was reduced to 0.072 equivalent, no purple color was produced: prolonged stirring (7 days) led to the gradual fading of the orange azibenzil color to a pale yellow with the formation of a copious precipitate of benzilazine, which was isolated in 90% yield.

Decomposition of Azibenzil. (i) **In Aqueous Dioxane.**—A solution of azibenzil (0.55 g., 0.0025 mole) in a mixture of dioxane (25 ml.) and water (18 ml.) was allowed to stand at room temperature for one week. The original orange colored solution gradually faded to a very pale yellow. The mixture was diluted with water (100 ml.), made basic with aqueous sodium hydroxide and extracted several times with chloroform. After drying and evaporation the combined extracts gave 0.131 g. (25%) of benzoin identified by m.p., mixed m.p. and infrared spectral comparison. The aqueous phase was cooled, acidified and extracted with chloroform to give 0.317 g. (60%) of diphenylacetic acid, identified by m.p., mixed m.p. and infrared spectral comparison; the infrared spectrum demonstrated the absence of any significant amount of benzoic acid.

(ii) **In Ether.**—A solution of azibenzil (5.56 g., 0.025 mole) in ether (150 ml.) was stirred at room temperature for 7 days; there was little change in color. The solution was filtered from a trace of solid, shaken with water, dried and evaporated to give a pale yellowish-white solid (3.9 g.) which after one recrystallization from ether afforded diphenylacetic anhydride as a white, powdery solid, m.p. 96.5–97.5°[34]; $\lambda_{max}^{CH_2Cl_2}$ 5.51, 5.71, 9.7 (broad) μ. Treatment of the product with aqueous ammonia gave a product m.p. 165–168°, undepressed on admixture with authentic diphenylacetamide, m.p. 166–168°.[35]

Reaction of Benzilazine with Sodium Methoxide.—Benzilazine (10.22 g., 0.025 mole) and sodium methoxide (4.43 g., 0.082 mole) were placed in a flask wrapped with aluminum foil. Ether (500 ml.) was distilled from sodium directly into the reaction flask. The mixture was heated with vigorous reflux under a blanket of prepurified nitrogen. After ca. one hour the ether had acquired a salmon-pink tint which gradually deepened on further refluxing; after 20 hours the mixture had a very intense, opaque purple appearance and the heating was continued for 10 days. The reaction mixture was worked up at night in subdued light, since one of the products was found to be very sensitive to light, especially sunlight; it was shaken with water (500 ml.) which very rapidly discharged the purple color to give an orange ethereal solution and a pale yellow aqueous phase. The latter was extracted with ether and the combined ethereal solutions were washed with water until neutral and dried in the dark. The dried solution was concentrated under reduced pressure in the dark at room temperature to ca. 75 ml. and allowed to stand in the dark for two days, during which time a pale yellow crystalline solid was deposited (1.28 g.). This product was highly sensitive to light and all experiments with it were performed in vessels wrapped in aluminum foil under subdued light. Attempts at purification by recrystallization were unsuccessful, decomposition being indicated by the appearance of new bands in its infrared spectrum and by erratic melting point behavior; attempted chromatographic purification also failed. A sample for analysis was therefore prepared by thorough washing of the original crystalline deposit with ether and drying at room temperature in vacuo: it had m.p. ca. 160° (dec., extremely dependent on rate of heating); $\lambda_{max}^{CH_2Cl_2}$ 3.01 (complex), 6.03

(33) In this and subsequent reactions in non-aqueous media careful precautions were taken to ensure complete dryness.

(34) C. D. Hurd, R. Christ and C. L. Thomas, THIS JOURNAL, 55, 2589 (1933), give m.p. 98°.

(35) F. R. Japp and J. Knox, J. Chem. Soc., 87, 681 (1905).

μ; $\mu_{max}^{CH_2Cl_2}$ 238 mμ (log ϵ 4.22), 288 mμ (log ϵ 4.15), 363 mμ (log ϵ 3.23).

Anal. Calcd. for $C_{23}H_{22}N_2O_2$: C, 80.36; H, 5.30; N, 6.69. Found: C, 80.40, 80.40; H, 5.22, 5.35; N, 6.88, 6.77.

The filtrate from the isolation of this product was freed of solvent *in vacuo* to give a viscous, yellow-orange oil. This was triturated with a little ether and the solution filtered from some benzilazine and evaporated. The residual oil was taken up in benzene and chromatographed on alumina (Woelm No. 1 Neutral). Elution with benzene gave a pale yellow, semi-solid product (0.90 g.) which yielded on trituration with a small amount of ether a pale yellow crystalline solid (0.82 g.). This product was recrystallized from ether to give very pale yellow needles, m.p. 124.5–125.5°, λ_{max}^{CH2Cl2} 5.95 μ; λ_{max}^{EtOH} 254 mμ (log ϵ 4.29), 285 mμ (log ϵ 4.21).

Anal. Calcd. for $C_{22}H_{18}N_2O_2$: C, 77.17; H, 5.30; N, 8.18; 1 OCH$_3$, 9.06. Found: C, 77.50, 77.14; H, 5.05, 5.02; N, 7.95, 8.35; OCH$_3$, 9.80.

Evaporation of the ethereal solution from the trituration gave an oil with a sweet odor which showed all the bands of methyl benzoate and of benzonitrile in its infrared spectrum. Later fractions from the chromatogram yielded only a considerable quantity of benzilazine and a small amount of benzamide, identified by mixed melting point and infrared spectral comparison: the total recovery from the chromatogram was low (*ca.* 50%). The basic aqueous layer from the treatment of the original reaction mixture with water yielded benzoic acid (0.54 g.).

When benzilazine was heated under reflux with excess sodium methoxide in methanol overnight no purple color was formed and the azine could be recovered unchanged.

CAMBRIDGE, MASS.

Azo Compounds.[1]   An Eight-membered Cyclic Azo Compound

BY C. G. OVERBERGER AND I. TASHLICK[2]

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The eight-membered cyclic azo compound, 3,8-diphenyl-1,2-diaza-1-cyclooctene (II), has been prepared and characterized. The spectral and kinetic properties of II have been investigated. This azo compound exhibited an unexpected thermal stability; its calculated rate of decomposition at 80° was 1/180 of that obtained for 1-azo-bis-1-phenylpropane. The decomposition of II gave 50% of 1,6-diphenyl-1-hexene and 43% of a mixture of *cis*- and *trans*-1,2-diphenylcyclohexane, the products expected from the disproportionation and combination of the 1,6-diphenyl-1,6-hexadiyl diradical.

The study of compounds which would thermally decompose to give moderately active diradicals in solution is being continued. We report here a synthesis of the eight-membered cyclic azo compound, 3,8-diphenyl-1,2-diaza-1-cyclooctene (II), its spectral properties, the kinetics of decomposition and the decomposition products.

Recent syntheses of cyclic azo compounds were reviewed in reference 7, the preparation and properties of the seven-membered analog of II were reported and the available data were interpreted.

A. Preparation of the Azo Compound.—The synthesis of the parent cyclic azine, 1,2-diazo-3,8-diphenyl-2,8-cyclooctadiene (I), has recently been

TABLE I

SPECTRAL AND KINETIC DATA OF AZO COMPOUNDS, R—N=N—R

R =	Rate constants (sec.$^{-1}$), 80°	Ultraviolet max. mμ	ϵ	E_a, kcal./mole	Ref.
CH$_3$–	6.9×10^{-16a}	340	4.5^{3a}	50.2	3b
	2.8×10^{-15a}			46.0	3c
(CH$_3$)$_2$CH–	2.9×10^{-12a}	355	18	40.9	4
PhCH(CH$_2$)$_2$CHPh	6×10^{-4}	387	775	. . .	5
PhCH(CH$_2$)$_3$CHPh	4.27×10^{-4}	390	127	29.7	7
PhCH(CH$_2$)$_4$CHPh	3.5×10^{-8b}	368	45	36.7	This work
PhCH(C$_2$H$_5$)	1.9×10^{-6b}	359	47	32.3	This work, 6

(1) (a) This is the 25th in a series of papers concerned with the preparation and decomposition of azo compounds. For the previous paper in this series, see C. G. Overberger and H. Gainer, THIS JOURNAL, **80**, 4561 (1958). (b) For a preliminary report of this work, see C. G. Overberger, J. G. Lombardino, I. Tashlick and R. G. Hiskey, *ibid.*, **79**, 2662 (1957).

(2) This paper comprises a portion of a dissertation submitted by I. Tashlick in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of the Polytechnic Institute of Brooklyn.

(3) (a) H. C. Ramsperger, THIS JOURNAL, **50**, 123 (1928); (b) O. K. Rice and D. V. Sickman, *J. Chem. Phys.*, **4**, 239, 242, 608 (1936); (c) M. Page, H. O. Pritchard and A. F. Trotman-Ackerman, *J. Chem. Soc.*, 3878 (1953).

(4) H. C. Ramsperger, THIS JOURNAL, **50**, 714 (1928); B. W. Langley, B. Lythgoe and L. S. Rayner, *J. Chem. Soc.*, 4191 (1952).

(5) S. G. Cohen, S. Hsaio, E. Saklad and C. H. Wang, THIS JOURNAL, **79**, 2661, 4400 (1957).

(6) S. G. Cohen, S. J. Groszos and D. B. Sparrow, *ibid.*, **72**, 3947 (1950).

reported.[1b] The preparation of the di-*p*-methoxy derivative has also been described recently.[8] The preparation of the azo compound from the azine was readily accomplished by the procedure employed in the syntheses of the 7-, 20-, 24- and 28-membered ring azo compounds.[7,9] The subsequent hydrogenation and oxidation steps afforded 56% of the cyclic azo compound II.

B. Kinetics of Decomposition.—The rates of decomposition were determined in duplicate in the manner previously described,[10] at four tempera-

(7) C. G. Overberger and J. G. Lombardino, *ibid.*, **80**, 2317 (1958).

(8) J. M. van der Zanden and G. DeVries, *Rec. trav. chim.*, **75**, 1159 (1956).

(9) C. G. Overberger, I. Tashlick, M. Bernstein and R. G. Hiskey, THIS JOURNAL, **80**, 6556 (1958).

(10) C. G. Overberger and H. Gainer, *ibid.*, **80**, 4561 (1958).