and with a smaller concentration of suspended KC_8 catalyst. Surprisingly, the main product now was *n*-propylbenzene instead of 3-phenylpentane; the product mixture contained a 48% yield of *n*-propylbenzene, a 17% yield of 3-phenylpentane, and a small quantity of higher alkylated products. The product distribution in the side-chain alkylation of toluene is thus apparently quite sensitive to changes in the reaction conditions.

In order to establish the generality of the KC_8 catalyzed side-chain alkylation reaction, an attempt was made to ethylate isopropylbenzene with ethylene. A 42% conversion to *tert*-amylbenzene was obtained.

It thus appears that the potassium graphite inclusion compound, KC_8, is a powerful and effective catalyst for the side-chain alkylation of aromatic hydrocarbons with ethylene and possibly with other olefins. It appears to be particularly useful for side-chain ethylations of aromatic hydrocarbons, containing at least one α-hydrogen, leading to highly branched alkylbenzenes.

EXPERIMENTAL

Materials. The materials used were all C.P. reagents and/or were rectified followed by drying with sodium ribbon.

General procedure[8]*—ethylation of isopropylbenzene.* Two grams of KC_8 and 25 ml. of isopropylbenzene (dried over sodium ribbon) were charged into a 100 ml. Magne-Dash autoclave. The system was purged and then pressurized with ethylene to 300 p.s.i.g. It was then heated to 200° and and repressurized to 700 p.s.i.g. with ethylene. The reaction was carried out for 24 hr. at 200°. The system was then cooled to room temperature, quenched with 50 ml. of water, and filtered. The organic layer was red-brown in color. On rectification it gave 2.3 g. of isopropylbenzene (11% recovery), 21.9 g. of fractions b.p. 172–267°/760 mm. (corr), and 3.9 g. of residue, b.p. >267°/760 mm. (corr). The fractions of b.p. 172–267° contained principally a pure fraction of *tert*-amylbenzene, b.p. 192°/760 mm; the total *t*-amylbenzene, estimated from an analysis of the rectification data, amounted to 11.1 g, or a 42% conversion. The graphite filter cake, 3.3 g., was extracted with 100 ml. of *m*-xylene for 6 hr. in a Soxhlet extractor. The extract was then cooled to room temperature, and about 25–50 ml. of 2B ethanol was added to precipitate a very small quantity of a gelatinous white solid. This material was not investigated.

The alkylations of benzene and toluene were carried out by similar procedures, except for the temperature and time employed (see Table I).

Acknowledgment. The authors wish to thank Dr. R. L. Hudson and Mr. J. B. Sigrest for the infrared and rectification work, respectively.

BATON ROUGE 1, LA.

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[8] See ref. 1 for procedure used to prepare KC_8.

[CONTRIBUTION FROM AVERY LABORATORY, THE UNIVERSITY OF NEBRASKA]

An *O*-Aroylglycollate and Carboxylic Anhydrides from the Attempted *C*-Aroylation of Methyl Diazoacetate[1]

J. H. LOOKER AND DONALD N. THATCHER[2]

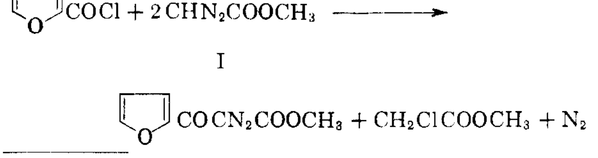
Received August 2, 1957

3,5-Dinitrobenzoyl chloride reacts with methyl diazoacetate containing water to give methyl *O*-(3,5-dinitrobenzoyl)glycollate. Under similar conditions, α- and β-naphthoyl chloride, and *o*-iodobenzoyl chloride give carboxylic anhydrides. Possible mechanisms are discussed.

In a previous communication from this laboratory,[3] it was shown that reduction of methyl benzoyldiazoacetate affords DL-*erythro*-β-phenylserine (allophenylserine) in good yield. Extension of this reaction would require synthesis of additional aroyldiazo esters. The present paper describes the attempted synthesis of the latter class by the action of four aromatic carboxylic acid chlorides on methyl diazoacetate, prepared in the usual manner and used without distillation.

Previous work indicates that benzoyl bromide reacts smoothly with methyl diazoacetate (I) to give the crystalline methyl benzoyldiazoacetate,[4] whereas benzoyl chloride gives with I an oily product which was not identified.[4] In other instances, acid chlorides react with I to give the acyl- or aroyldiazo ester. Thus several aliphatic acid chlorides give liquid diazo esters,[4] and α-furoyl chloride[5] gives the crystalline methyl α-

$$C_6H_5COBr + 2\ CHN_2COOCH_3 \longrightarrow C_6H_5COCN_2COOCH_3 + CH_2BrCOOCH_3 + N_2$$



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[1] Taken in part from a portion of a thesis submitted by Donald Nixon Thatcher in partial fulfillment of requirements for the Ph. D. degree, 1954.

[2] Du Pont Teaching Assistant, 1953–1954.

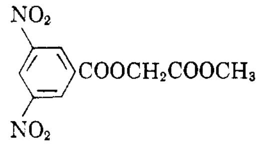
[3] J. H. Looker and D. N. Thatcher, *J. Org. Chem.*, **22**, 1233 (1957).

[4] H. Staudinger, J. Becker, and H. Hirzel, *Ber.* **49**, 1978 (1916).

[5] T. Reichstein and H. J. Morsman, *Helv. Chim. Acta*, **17**, 1120 (1934).

furoyldiazoacetate. The crystallinity of diazo esters is important in projected arylserine syntheses, since such esters are readily and safely purified by crystallization techniques. The purification of liquid diazo esters by vacuum distillation is hazardous unless very low pressures are used.[4] Because acid chlorides are more accessible than the bromides, the possibility of obtaining aroyldiazo esters from 3,5-dinitrobenzoyl chloride (II), α-naphthoyl chloride (III), β-naphthoylchloride (IV), and *o*-iodobenzoyl chloride (V) has been investigated.

Reaction of II with I gave in 68% yield a colorless product which contained neither diazo group[6] nor halogen.[7] Analysis and molecular weight determination indicated a formula of $C_{10}H_8N_2O_8$, and infrared spectral data indicated the possible presence of two ester groups. These data led to the speculation that the product was methyl *O*-(3,5-dinitrobenzoyl)glycollate (VI). An independent synthesis of VI by the method of Einhorn and Seuffert[8] indicated that this conjecture was correct. 3,5-Dinitrobenzoic acid also reacts with I to give VI, but in only 18% yield.



VI

The acid chlorides III, IV, and V take a different course in reacting with I. On the basis of combustion analyses and presence of infrared maxima in the region 1760–1790 cm.$^{-1}$, which are attributed to the anhydride carbonyl function,[9] the products are considered to be carboxylic anhydrides. In addition, α- and β-naphthoic anhydrides thus prepared gave melting pionts in reasonable agreement with the literature values. Apparently, *o*-iodobenzoic anhydride has not been previously reported.

It becomes evident that three reaction paths are shown by acid chlorides in reaction with I containing water: formation of the aroyldiazo ester,[5] of the *O*-aroylglycollate, and of the carboxylic anhydride. Although the present work is not sufficiently detailed to permit formulation of precise mechanisms, several interpretations of the general reaction course in terms of current theory[10] are possible and are presented. Formation of the aroyldiazo ester has been explained previously by assuming a diazonium betaine intermediate.[11]

In this study, two procedures were employed: reaction of the acid chloride with I in methyl acetate, and with I without added solvent. In either procedure, water could be present. Methyl diazoacetate was not distilled, and although the procedure employed called for drying of the ethereal extracts of I, the residual diazo ester was not dried after solvent removal. Storage at 0–5° also could lead to condensation of considerable quantities of water. Methyl acetate, which was used as received, undoubtedly contained water, and possibly methanol and acetic acid from hydrolysis as well. The presence of water appears important, since it is probable that the acid chlorides are hydrolyzed in the presence of methyl diazoacetate, which acts as a base. One possible route leading to the glycollate is considered in Chart I.

CHART I

$$(1)\quad ArCOCl + 2H_2O \longrightarrow ArCOOH + H_3O^+ + Cl^-;\qquad Ar = \text{3,5-Dinitrophenyl}$$

$$(2)\quad ArCOOH + H_2O \rightleftharpoons ArCOO^- + H_3O^+$$

$$(3)\quad \{:N{\equiv}\underset{..}{\overset{+}{N}}{-}\overset{-}{C}H{-}COOOCH_3 \longleftrightarrow \underset{I}{}$$

$$\underset{..}{\overset{-}{N}}{=}\overset{+}{N}{=}CH{-}COOCH_3\} + H_3O^+ \rightleftharpoons \underset{VII}{\overset{..}{N}{\equiv}\overset{+}{N}{-}CH_2{-}COOCH_3} + H_2O$$

$$(4)\quad (a)\ ArCOO^- + VII \longrightarrow ArCOOCH_2COOCH_3 + N_2$$

$$\text{or } (b)\ VII \longrightarrow N_2 + {}^+CH_2COOCH_3$$

$${}^+CH_2COOCH_3 + ArCOO^- \longrightarrow \underset{VI}{ArCOOCH_2COOCH_3}$$

In simplest terms, Chart I depicts an oxonium ion-catalyzed reaction of 3,5-dinitrobenzoic acid with methyl diazoacetate. The irreversible formation of hydronium ion in Step (1) would be important, since 3,5-dinitrobenzoic acid alone in reaction with I gave a low yield of VI. The dissociation of the acid in Step (2) may be of great importance or none, depending on the importance of the ion in Step (4). The reaction of diazoacetic esters with

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(6) This statement is based on analytical data and on the absence of a band in the infrared absorption spectrum in the region 2000–2200 cm.$^{-1}$ For detailed infrared spectral data, see ref. (3), footnotes (13), (14), (15), and (16).

(7) The possibility of halogen being present was considered, in view of the ready reaction of diazoketones with hydrogen chloride liberated in the course of the reaction. However, aroyldiazo esters are unusually stable toward acid, a possibility which has been previously discussed by F. Arndt and J. Amende [*Ber.* **61**, 1123 (1928)]. See also ref. (4).

(8) A. Einhorn and R. Seuffert, *Ber.* **43**, 3000 (1910).

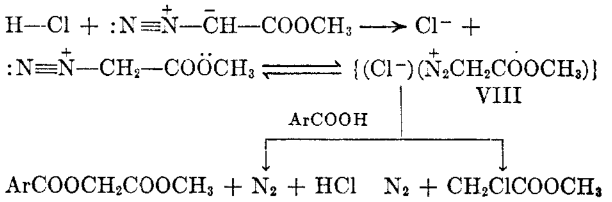
(9) F. Miller in *Organic Chemistry*, Vol. III, edited by H. Gilman, John Wiley and Sons, Inc., New York, N. Y., 1953, pp. 140–141, 143–150.

(10) Of several important review articles over the chemistry of aliphatic diazo compounds, three can be cited for their coverage of the theoretical area: (a) B. Eistert (translated and revised by F. W. Spangler) in *Newer Methods of Preparative Organic Chemistry*, Interscience, New York, N. Y., 1948, p. 513; (b) R. Huisgen, *Österr. Chem. Ztg.*, **55**, 237 (1954); (c) R. Huisgen, *Angew. Chem.*, **67**, 439 (1955). Recent papers of interest include (d) J. D. Roberts, C. M. Regan, and I. Allen, *J. Am. Chem. Soc.*, **74**, 3679 (1952) and preceding papers; (e) D. Y. Curtin and S. M. Gerber, *J. Am. Chem. Soc.*, **74**, 4052 (1952); (f) R. W. Taft, Jr., and D. J. Smith, *J. Am. Chem. Soc.*, **76**, 305–7 (1954).

(11) B. Eistert, *Ber.*, **68**, 208 (1935).

hydronium ion in Step (3) is well known.[12] The formation of VI could involve either a displacement of nitrogen from the diazonium ion VII as in step (4)(a), or a dissociation to carbonium ion and subsequent coupling as in step (4)(b).[13] Utilization of carboxylate anion is largely a matter of convenience. Attack of diazonium or carbonium ion on the undissociated acid also could give VI [alternative Step (4)]. Inasmuch as the solvent system employed cannot be clearly defined, it is difficult to determine the extent to which it would support ionization. If the mechanism is indeed ionic, it is obvious that other molecules in addition to water could carry the proton: *e.g.*, methanol or acetic acid in the methyl acetate used. The fate of chloride ion is not indicated. Presumably it reacts with diazonium ion [from regenerated hydronium ion in Step (2) or alternative Step (4) and excess I] to give methyl chloroacetate and nitrogen.

A somewhat different approach to the problem of mechanism would assume that methyl diazoacetate effects proton transfer without any intermediate formation of appreciable quantities of hydronium ion, or even in the absence of water. Such a mechanism could be important if the solvent system is aprotic or becomes aprotic during the course of the reaction. The key step in such a mechanism would be reaction of molecular hydrogen chloride (from hydrolysis of the acid chloride) with I to give initially diazonium and chloride ions. It is conceivable that the latter would be associated in the ion-pair VIII, of limited but finite stability. Reaction of VIII with undissociated acid would give VI, nitrogen and hydrogen chloride, while the competing decomposition of VIII would give methyl chloroacetate and nitrogen. The whole problem of mechanism in the present study is intimately associated with the larger problem of specific and general acid catalysis of reactions of diazoacetic ester,[14] and is regarded as incompletely solved.



$$\mathrm{H{-}Cl} + :\mathrm{N{\equiv}\overset{+}{N}{-}\overset{-}{C}H{-}COOCH_3} \longrightarrow \mathrm{Cl^-} +$$

$$:\mathrm{N{\equiv}\overset{+}{N}{-}CH_2{-}CO\ddot{O}CH_3} \rightleftharpoons \{(\mathrm{Cl^-})(\overset{+}{\mathrm{N}}_2\mathrm{CH_2C\dot{O}OCH_3})\}\ \mathrm{VIII}$$

$$\mathrm{VIII} \xrightarrow{\mathrm{ArCOOH}} \underset{\mathrm{VI}}{\mathrm{ArCOOCH_2COOCH_3}} + \mathrm{N_2} + \mathrm{HCl} \qquad \mathrm{VIII} \longrightarrow \mathrm{N_2} + \mathrm{CH_2ClCOOCH_3}$$

In explaining the formation of carboxylic anhydrides, the discussion will be restricted to the sequence in Chart I. Rates appear important. In formation of VI it appears likely that Step (1) is fast to give a large number of hydronium ions, which react rapidly to give a correspondingly large number of diazonium ions. The latter would react readily with carboxylic acid molecules or carboxylate ions to give the glycollate VI. If, however, the rate of hydrolysis of the acid chloride is slow, reaction of carboxylic acid molecules or carboxylate ions with unreacted acid chloride, in presence of the base methyl diazoacetate, would be statistically favored. A more detailed analysis is not obvious from data in the present study. The practical problem of purity of the acid chlorides may have a profound effect on the reaction course and also must be considered.[15]

The reactivity of methyl diazoacetate can be correlated to some extent with that of diazomethane. The catalytic activity of water, alcohols, and certain salts in reactions of the latter compound has long been recognized as important.[16] Very recently, interesting accounts of the basic activity of diazomethane in promoting ester interchange have been recorded.[17] It is apparent from the present study that methyl diazoacetate also is capable of acting as a useful base, and may prove important in synthesis of other reactive intermediates.

EXPERIMENTAL[18]

Source and purity of reagents. All acid chlorides except β-naphthoyl chloride were of the purest grade (White Label) available from the Eastman Kodak Co., and were used without additional purification. β-Naphthoyl chloride was practical grade, and also was used without purification. Glycine methyl ester hydrochloride was obtained from the Dow Chemical Co. Methyl acetate was obtained from several different companies, none of whom offered the reagent grade solvent, and was used as received.

Methyl diazoacetate. This substance was prepared from glycine methyl ester hydrochloride by the method of Womack and Nelson.[19] The residual ester from ether removal was used without further purification, and was stored in a refrigerator between runs.

Methyl 0-(3,5-dinitrobenzoyl)glycollate. A. From reaction of 3,5-dinitrobenzoyl chloride with methyl diazoacetate. A 5-g. quantity of 3,5-dinitrobenzoyl chloride was dissolved in *ca.* 30 ml. of methyl acetate and the resulting solution added slowly to 4.5 ml. of methyl diazoacetate. Gas evolution commenced immediately. After standing at room temperature

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[12] See ref. (10), especially b, c, and d; also L. P. Hammett, *Physical Organic Chemistry*, McGraw-Hill Book Co., New York, N. Y., 1940, p. 288.

[13] An interesting recent discussion of this general problem is presented by A. Streitwieser, Jr., and W. D. Schaeffer, *J. Am. Chem. Soc.*, **79**, 2888 (1957).

[14] For a detailed discussion of this rather difficult problem, see ref. (10) (d).

[15] Recent studies in this laboratory indicate that interaction of very pure I and freshly recrystallized II and V affords the aroyldiazo ester in satisfactory yield (J. H. Looker and C. H. Hayes, unpublished observations).

[16] H. Meerwein and W. Burneleit, *Ber.*, **61B**, 1840 (1928). These authors cite several studies by other workers indicating the importance of catalysts of various types.

[17] T. Wieland and R. K. Rothhaupt, *Chem. Ber.*, **89**, 1176 (1956); H. Bredereck, R. Sieber, L. Kamphenkel, and R. Bamberger, *Chem. Ber.*, **89**, 1169 (1956).

[18] All melting points are uncorrected, and are expressed in °C. Infrared spectra of Nujol mulls were recorded with a Perkin-Elmer Model 21 spectrophotometer, using sodium chloride prisms. Analyses for nitrogen content were performed by D. N. T. by the Dumas Method. Carbon-hydrogen analyses and molecular weight determinations were run by either Clark Microanalytical Laboratories, Urbana, Ill., or by Micro-Tech Laboratories, Skokie, Ill.

[19] E. B. Womack and A. B. Nelson, *Org. Syntheses*, **24**, 56 (1944).

for 24 hr., the reaction mixture was placed in a refrigerator for one week. The crystalline material present was collected by filtration and recrystallized twice from methanol-methyl acetate; yield 4.2 g. (68%), m.p. 131–132°.

Anal. Calcd. for $C_{10}H_8N_2O_8$: C, 42.26; H, 2.84; N, 9.86; mol. wt., 284. Found: C, 42.00; H, 2.83; N, 9.66; mol. wt. (Rast), 272, 286.

B. From reaction of sodium 3,5-dinitrobenzoate with methyl chloroacetate. Reaction of methyl chloroacetate and sodium 3,5-dinitrobenzoate in aqueous methanol containing sodium iodide according to the general method of Einhorn and Seuffert[8] gave an 82% yield of methyl *O*-(3,5-dinitrobenzoyl)-glycollate, m.p. 131–132°, no depression upon admixture with the compound prepared as in *A*. The infrared spectra of the products prepared by the two methods were identical, and possessed absorption bands at 1745 (ester carbonyl), 1725 (ester carbonyl), 1535, 1350, 1225, 1160, and 719 cm.$^{-1}$

C. From reaction of 3,5-dinitrobenzoic acid with methyl diazoacetate. 3,5-Dinitrobenzoic acid (5 g., 0.024 mole) was dissolved in 30 ml. of methyl acetate and added to 10 ml. of methyl diazoacetate (0.11 mole) at 5°. No immediate evolution of gas was noticed. The reaction mixture was allowed to stand for 24 hr. at room temperature, then for two weeks at 0°. At the end of this time a crystalline product was collected and recrystallized from methanol-methyl acetate; yield, 1.2 g. (18%), m.p. and mixed m.p., 131–132°.

α-Naphthoic anhydride. To 5.6 g. (0.056 mole) of methyl diazoacetate at 5° was added a 5-g. quantity (0.026 mole) of α-naphthoyl chloride. Gas evolution commenced immediately. After standing at 0–5° for one week, the crystalline product then present was collected by filtration and recrystallized twice from methanol-methyl acetate; yield 2.8 g. (66%), m.p. 147–148° [lit.[20] m.p., 148°]. The infrared absorption spectrum showed a prominent band at 1762 cm.$^{-1}$, attributed to the anhydride carbonyl group.[9]

Anal. Calcd. for $C_{22}H_{14}O_3$: C, 80.96; H, 4.32. Found: C, 80.67; H, 4.33.

β-Naphthoic anhydride. To 5.6 g. (0.056 mole) of methyl diazoacetate at 5° was added a 5-g. quantity (0.026 mole) of β-naphthoyl chloride, dissolved in *ca.* 30 ml. of methyl acetate. After standing at 0–5° for three weeks, the crystalline product then present was collected by filtration and recrystallized from methanol-methyl acetate; yield, 2.0 g. (48%), m.p. 137–138° [lit.[21] m.p. 134°]. The infrared spectrum displayed a prominent absorption maximum at 1775 cm.$^{-1}$, due to the carboxylic anhydride carbonyl group.[9]

Anal. Calcd. for $C_{22}H_{14}O_3$: C, 80.96; H, 4.32. Found: C, 80.67; H, 4.31.

o-Iodobenzoic anhydride. To 4 ml. (0.045 mole) of methyl diazoacetate at 5° was added a 5-g. quantity (0.019 mole) of liquid *o*-iodobenzoyl chloride (warmed if necessary). Gas evolution commenced immediately. After standing at room temperature one day and at 0° for one week, the crystalline product then present was collected by filtration and recrystallized from methanol-methyl acetate; yield, 3.0 g., (66%), m.p. 76–77°. The infrared absorption spectrum showed a strong maximum at 1790 cm.$^{-1}$

Anal. Calcd. for $C_{14}H_8O_3I_2$: C, 35.20; H, 1.69. Found: C, 35.50; H, 1.75.

Acknowledgment. The support of this investigation by the Research Corporation of New York through a Frederick Gardner Cottrell Grant to The University of Nebraska is gratefully acknowledged.

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(20) W. F. Bruce, *J. Am. Chem. Soc.*, 60, 2277 (1938).

(21) I. Heilbron, *Dictionary of Organic Compounds*, Vol. III, Oxford University Press, New York, N. Y., 1953, p. 559.

[CONTRIBUTION NO. 1016 FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF PITTSBURGH]

Chemistry of Pyrazine and its Derivatives. I. The Hypohalite Oxidation of Acetonyl- and Phenacylpyrazine[1]

JOHN D. BEHUN[2] AND ROBERT LEVINE

Received August 5, 1957

Acetonylpyrazine has been oxidized with potassium hypochlorite solution to give a mixture of what is believed to be dichloromethylpyrazine (III) (78%) and acetic acid (36%). Similarly, phenacylpyrazine gives a mixture of III (37%) and benzoic acid (56%). The reaction of III with methanolic sodium methoxide gave a 79% yield of the dimethyl acetal of pyrazinealdehyde.

As part of an extensive study of the chemistry of pyrazine and its derivatives, we have prepared a series of ketones in high yields by acylating the side chain of methylpyrazine with a variety of esters using sodium amide in liquid ammonia as the condensing agent.[3] Acetonylpyrazine and phenacylpyrazine are two of the ketones which were prepared by this method.

It was of interest to treat acetonylpyrazine, I, with potassium hypochlorite as a possible route to the previously unreported pyrazineacetic acid (II). However, none of the desired acid was obtained. Instead, what is believed to be dichloromethylpyrazine (III) (78%) and acetic acid (36%) were isolated. When phenacylpyrazine was treated similarly, a mixture of III (37%) and benzoic acid

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(1) This work was performed under Contract No. AT(30-1)-670 between the U. S. Atomic Energy Commission and the University of Pittsburgh.

(2) This paper is based on part of the thesis to be presented by John D. Behun to the Graduate Faculty of the University of Pittsburgh in partial fulfillment of the requirements of the Ph.D. degree.

(3) J. D. Behun and R. Levine, page 9N of the Abstracts of the 130th meeting of the American Chemical Society, Atlantic City, N. J., September 16–21, 1956; the details of these acylations will be published shortly.