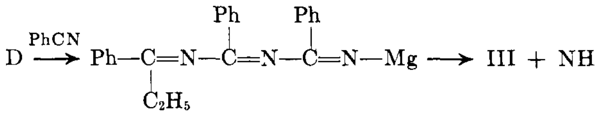
III may be visualized as an addition of D to a third molecule of benzonitrile followed by cyclization, with the loss of ammonia.[12]



$$D \xrightarrow{PhCN} Ph-\underset{C_2H_5}{C}=N-\overset{Ph}{C}=N-\overset{Ph}{C}=N-Mg \longrightarrow III + NH_3$$

Experimental

1,3-Diphenyl-2-methyl-1,3-propanedione (I).—Diethylmagnesium (5.8 mmoles) and benzonitrile (27.0 mmoles) in 32 ml. of tetrahydrofuran were allowed to react in a closed reaction vessel for 1 week at room temperature, followed by heating on a steam bath for 40 hr. The brick red solution was decomposed in saturated ammonium chloride and extracted with ether. The ether solution was then extracted with 10% sodium bisulfite. After decomposition of the bisulfite solution, extraction with ether, and evaporation of the ether, a solid residue was obtained, which was recrystallized from 1:1 hexane–pentane to give 0.22 g. (18.3% based on benzonitrile) of colorless product melting at 81.0–82.3°. An analytical sample prepared by recrystallization from ethanol melted at 83.4–84.7° (lit.[13] m.p. 82.5–84°).

Anal. Calcd. for $C_{16}H_{14}O_2$: C, 80.65; H, 5.92. Found: C, 80.88, 80.86; H, 5.99, 5.73.

The infrared absorption spectrum contained a doublet at 1689 and 1667 cm.$^{-1}$. The n.m.r. spectrum contained a quartet at τ 5.74–5.76 (J = 5.9 c.p.s.) and a doublet at 8.45–8.56 (J = 5.9 c.p.s.). The aromatic proton absorption appeared as two multiplets at τ 2.15–2.38 and 2.66–2.85. The relative areas of the quartet, doublet, and two aromatic multiplets were 1:3:4:6, respectively. The melting point of I was not depressed when admixed with an authentic sample of I prepared by the alkylation of dibenzoylmethane with methyl iodide.

5-Methyl-2,4,6-triphenylpyrimidine (III).—The ether layer which remained after the extraction with sodium bisulfite in the preparation of I was concentrated to 30 ml. and, upon addition of 50 ml. of methanol, the crude solid precipitated, m.p. 167–175°. Recrystallization from ether afforded 0.98 g. (34.4% based on benzonitrile) of colorless crystals, m.p. 179.0–180.3°. An additional recrystallization from ether gave the analytical sample, m.p. 180.0–181.4° (lit.[12] m.p. 182°).

Anal. Calcd. for $C_{23}H_{18}N_2$: C, 85.68; H, 5.63; N, 8.69. Found: C, 85.85; H, 5.72; N, 8.27.

The n.m.r. spectrum contained a singlet at τ 7.70 as well as multiplets in the aromatic region at 1.68–1.76, 2.42–2.63, and 2.66–2.90. The relative areas of these peaks were 3:2:4:9, respectively. The infrared absorption spectrum contained a strong peak at 1538 cm.$^{-1}$.

A gas which was evolved when the reaction vessel above was opened was isolated on a vacuum manifold and identified as ethane by vapor phase chromatography on a Perkin-Elmer Vapor Fraktometer Model 154 using a J column. The retention time was identical with that of authentic ethane at 25°.

N-(α-Ethylbenzal)benzamidine (II). A.—To the diethylmagnesium[14,15] prepared from 14.2 g. (0.130 mole) of ethyl bromide and 1.6 g. (0.065 g.-atom) of magnesium in 200 ml. of ethyl ether, there was added 6.7 g. (0.065 mole) of benzonitrile. The solution turned yellow and a slight precipitate developed. After stirring the reaction mixture for 2 days at room temperature, 20 ml. of water was added and the mixture was filtered. The combined organic layers were evaporated to dryness. Distillation of the residue afforded 8.2 g. (0.062 mole, 95%) of propiophenone ketimine, b.p. 92–96° (7.3 mm.), n^{22}_D 1.5475 [lit.[16] b.p. 101.5–102.5° (13.5 mm.), n^{22}_D 1.5476].

B.—The above reaction was run with 0.085 mole of diethylmagnesium and 0.17 mole of benzonitrile (1 ethyl group/benzonitrile). After decomposition of the reaction mixture in water, it was extracted with ether. Upon evaporation of the ether, crystals were obtained which were white after washing with ether. The white solid weighed 3.6 g. (18%) and melted at 139–140°. An analytical sample obtained by recrystallization from aqueous methanol melted at 140.0–140.4°. The infrared spectrum showed bands at 3310 and 3470 (N–H) and at 1575–1650 cm.$^{-1}$ (C=N—Ph).

Anal. Calcd. for $C_{16}H_{16}N_2$: C, 81.32; H, 6.83; N, 11.86. Found: C, 80.89, 81.32, 80.88; H, 6.97, 7.11, 6.88; N, 11.54, 11.69, 11.62.

Attempts to prepare this compound from benzamidine and propiophenone failed. When the mother liquor from the above preparation was distilled *in vacuo*, 2.9 g. (13%) of propiophenone, b.p. 35–36° (8 mm.), n^{25}_D 1.6293, was isolated. The nondistillable residue was a thick, orange oil which hardened to a glass upon standing. The glass was insoluble in water, 5% sodium bicarbonate, 5% sodium hydroxide, 6 *N* NaOH, and 2 *N* HCl, but it did dissolve in concentrated hydrochloric acid.

Trituration of the "glass" with methanol dissolved the orange material leaving white crystals, m.p. 182–183°. The infrared spectrum of this material was identical with that of III.

1-(2,4-Dinitrophenyl)-3,5-diphenyl-4-methylpyrazole.—A solution of I, 0.886 g. (3.72 mmoles), in 50 ml. of ethanol was combined with a hot solution of 0.737 g. (3.68 mmoles) of 2,4-dinitrophenylhydrazine in 150 ml. of ethanol containing 10 ml. of concentrated hydrochloric acid. After cooling, 1.21 g. of yellow solid, m.p. 180–182°, was obtained by filtration. Recrystallization from 175 ml. of ethanol afforded 1.09 g. (67.0%) of yellow crystals, m.p. 183.2–185.0°. An analytical sample, prepared by recrystallization from ethanol, melted at 183.3–185.1°.

Anal. Calcd. for $C_{22}H_{16}N_4O_4$: C, 65.99; H, 4.03; N, 13.99. Found: C, 65.91; H, 3.65; N, 13.76.

Acknowledgment.—We acknowledge the generous support of part of this work by the National Science Foundation under its Grant G-14558 (A. A. S.) and by the American Cyanamid Company (N. M. B.). We also acknowledge the synthesis of 1,3-diphenyl-2-methyl-1,3-propanedione by Mr. William Greenberg.

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[12] R. M. Anker and A. H. Cook [*J. Chem. Soc.*, 323 (1941)] isolated 2-ethyl-2,4,6-triphenyl-1,2-dihydrotriazine from the reaction between ethyllithium and benzonitrile. When they heated the heterocycle at 250–300°, it was converted to III.

[13] R. D. Abell, *ibid.*, 928 (1901).

[14] S. J. Stofer and E. I. Becker, *J. Org. Chem.*, **27**, 1868 (1962).

[15] R. Kullmann, *Compt. rend.*, **231**, 866 (1950).

[16] C. Moureu and G. Mignonac, *ibid.*, **156**, 1801 (1913).

Halogenation of Aromatic Compounds by N-Bromo- and N-Chlorosuccinimide under Ionic Conditions

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In the extensive literature involving N-halosuccinimides and related N-halo compounds, there appears to have been only one investigation of ring substitution by N-haloimides or -amides in aromatic compounds not containing highly active groups.[1] Schmid[2] found that benzene and toluene gave fair yields of their respective monobromo derivatives with N-bromosuccinimide (NBS) and aluminum chloride, but poor yields (together with polysubstituted products) following long reflux with NBS and zinc or iron(III) chlorides, or with NBS and concentrated sulfuric acid.

Our work in which *t*-butyl hypochlorite was used in aqueous sulfuric acid to attack aromatic compounds resulted in excellent yields of ring-chlorinated products,[3] but announcement of the results was anticipated

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[1] *I.e.*, aromatic compounds without hydroxy or amino groups or their derivatives.

[2] H. Schmid, *Helv. Chim. Acta*, **29**, 1144 (1946).

[3] We thank Paul J. Shlicta, Ted W. Reid, David A. Keefer, and Jerry D. Albert for extensive experimental work in developing this area, and the National Science Foundation for its support under G-2386 and under the Undergraduate Research Participation Program (G-1226).

by the publication of parallel findings by Harvey and Norman.[4] However, this experience with *t*-butyl hypochlorite led us to consider the potentially analogous behavior of the more readily available N-bromo- (NBS) and N-chlorosuccinimides (NBS).

We have found that rapid aromatic substitution resulting in excellent yields of product takes place under easily attainable experimental conditions. Polyhalogenation is nil or very low and no benzylic substitution occurs when toluene is the substrate. The results are presented in Table I.

TABLE I

AROMATIC HALOGENATION BY N-BROMO- AND N-CHLOROSUCCINIMIDE IN AQUEOUS SULFURIC ACID

Aromatic compd.	Halogenating agent	Reaction condn. Temp., °C.	H_2SO_4[a]	Time,[b] hr.	Yield of product,[c] %
Benzene	NBS	45–55	1:4	3.75	81[d]
	NBS	50–55	1:1	2	90[d]
	NBS	50–55	1:1	0.42	83[d]
	Br_2	50–55	1:1	0.42	2
	NCS	65–70	1:1	2.5	64[e]
Toluene	NBS	65–70	1:4	2.5	95[f]
	NCS	70–80	1:1	1	93[f]
Chlorobenzene	NBS	50–55	1:1	2.25	94[f]
	NCS	60–65	2:1	4	59[f]
	NCS	80–85	2:1	2.25	80[f]
Nitrobenzene	NBS	85–90	1:1	3	70[g]

[a] Ratio of concentrated H_2SO_4 to water by volume. [b] Time that the reaction mixture was stirred. Actual reaction may have been completed within 30 min. in all, except for nitrobenzene; *cf.* Experimental section. [c] Per cent of theoretical. [d] Dihalo derivative less than 1% yield. [e] Dihalo derivative less than 0.6% yield. [f] No dihalo product (from toluene) or polyhalo (from chlorobenzene) detected in v.p.c. analysis. [g] Determined by v.p.c. on a 6 ft. × 0.25 in. column of Apiezon L on 60–80-mesh Chromosorb regular. No dihalo product.

Although modest attempts were made to obtain adequate product yields, no exhaustive investigation of optimum conditions was carried out because of the generally excellent results noted in Table I. More dilute acid usually resulted in lower quantities of product. Portionwise addition of the NBS or NCS to the reaction mixture over a period of hours gave equal or better yields but was obviously less convenient than the simple mixing of all reagents at one time. The bleach test described in the Experimental section afforded a convenient indication of the progress of the reaction.

The isomer distribution of the products of reactions involving toluene and chlorobenzene is given in Table II.

Although the isomer distributions are consistent with halogenation at 25° by $(H_2OX)^+$ or Cl^+,[5] it is patently fallacious to draw strong mechanistic conclusions from this correlation. Certainly, the actual halogenating moiety is not free halogen; the experiments using bromine in sulfuric acid gave very small amounts of product (Table I). The active agent could possibly be the protonated N-halo compound as has been suggested for N-chloromorpholine.[6] Further study is necessary to establish the mechanism of the reaction.

TABLE II

ISOMER DISTRIBUTION IN THE HALOGENATION OF AROMATIC COMPOUNDS BY N-HALOSUCCINIMIDES IN AQUEOUS SULFURIC ACID

Compd.	Halogenating agent	Isomer ratio *ortho*	*meta*	*para*	Analytical method
Toluene	NBS	67	2	31	*a*
	NCS	65	1	34	*a*
Chlorobenzene	NBS	39.4	1.5	59.1	*b*
	NCS	41.3	1.4	57.3	*b*

[a] Determined by v.p.c. on a 12 ft. × 0.25 in. column of approximately 10% tricresyl phosphate on 60–80-mesh Chromosorb regular. *meta* and *para* isomers were not resolved. *m*-Chlorotoluene was determined by infrared analysis using the 860-cm.$^{-1}$ band, and *m*-bromotoluene by using the 830-, 765-, and 679-cm.$^{-1}$ bands. [b] Determined by v.p.c. on a 12 ft. × 0.25 in. column of 5% diisodecyl phthalate and 5% Bentone on 60–80-mesh Chromosorb W.

Because of the ready availability and convenience of use of the halogenating agents, simple reaction conditions, short reaction time, absence of large amounts of free bromine or chlorine, and generally excellent yields of monohalo derivatives, this process of ring substitution with N-haloimides (and presumably N-haloamides) under ionic conditions recommends itself for a wide variety of aromatic halogenations.

Experimental

General Procedure.—In a 500-ml. three-necked Morton flask, which was heated by a water bath and fitted with thermometer, condenser, and Teflon blade stirrer, was placed 200 ml. of sulfuric acid, diluted as noted in Table I. After 100 ml. of the aromatic compound had been poured in and the temperature adjusted as desired, 0.16 mole of NBS or NCS was added to the vigorously stirred reaction mixture.[7] The temperature usually rose 2–10° above that of the water bath for a few minutes.

The progress of the reaction could be followed more accurately by use of potassium iodide–starch paper. When a drop of the reaction mixture was placed on the paper, a blue-black spot immediately appeared. Within a few seconds to a minute, the center of the blackened area bleached toward white. When this effect was no longer observed (after 15 min. for toluene, 2 hr. for nitrobenzene), the reaction was assumed to be nearly complete.[8] However, in all cases except those noted in Table I, stirring was continued for at least 1 hr. longer. The 25-min. reaction time (with benzene) was based on the results of the bleach test; the yield of product obtained in this experiment compared with those wherein longer reaction times were used indicates that the test is of adequate utility in following the progress of the reaction.

Work-up of the reaction mixture was by obvious methods: separation of layers, washing of the organic layer with base and water,[9] and finally distillation through a simple 2-ft. tantalum helix column at atmospheric pressure.

Isomer distribution analyses were made by v.p.c. analysis of the solvent-stripped product in a Research Specialties instrument fitted with katharometer detector and employing the columns noted in Table II. Because the *m*- and *p*-halotoluenes were not resolved on the columns available, a solvent-free fraction of the product was analyzed for concentration of the *meta* isomer using a neat sample in a Perkin-Elmer 237 infrared spectrophotometer at the band positions stated in Table II. Infrared

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(4) D. R. Harvey and R. O. C. Norman, *J. Chem. Soc.*, 3604 (1961).

(5) Leading references are given by L. M. Stock and H. C. Brown, *Advan. Phys. Org. Chem.*, **1**, 34 (1963).

(6) M. D. Carr and B. D. England, *Proc. Chem. Soc.*, 350 (1958).

(7) Vigorous agitation was essential. Slow stirring, even in a Morton flask, decreased yields of product by a third or more.

(8) The bleaching of the blue-black starch–iodine complex may be caused by the N-halosuccinimides themselves in dilute sulfuric acid or by the halogenating agents derived from them. Whichever is the case, when bleaching no longer occurs, little (if any) potential or free halogenating agent remains in the reaction mixture and, thus, little or no further halogenation can be expected.

(9) In one experiment involving nitrobenzene and NBS, bromine vapors were noted during the final distillation despite supposedly adequate washing. A subsequent preparation was shaken with ammonium hydroxide after the sodium hydroxide wash and no such difficulties were experienced.

and v.p.c. results were corroborated by examining mixtures of known composition of the pure halo aromatics involved.

Chemicals.—Practical N-bromosuccinimide (Arapahoe) or purified NBS (Matheson Coleman and Bell) gave equivalent yields of product as did practical or purified N-chlorosuccinimide (Matheson Coleman and Bell) after allowance for inert content. Of the substances used as standards in the v.p.c. or infrared analyses, o-bromochlorobenzene was synthesized by the standard procedure[10]; all other chemicals were White Label Eastman or reagent grade Matheson Coleman and Bell products whose purity was established by v.p.c. and/or infrared examination.

Acknowledgment.—We thank Mr. James P. Hardy for preliminary experimental work and the National Science Foundation for its support by Grants G-12126 (J. P. H.), GE-987 (R. J. P.), and GE-2797 (W. D. E.) for Undergraduate Science Education.

(10) J. L. Hartwell, "Organic Syntheses," Coll. Vol. III, E. C. Horning, Ed., John Wiley and Sons, Inc., New York, N. Y., 1955, p. 185.

Reaction of Benzil with Cyanide Ion in Dimethyl Sulfoxide

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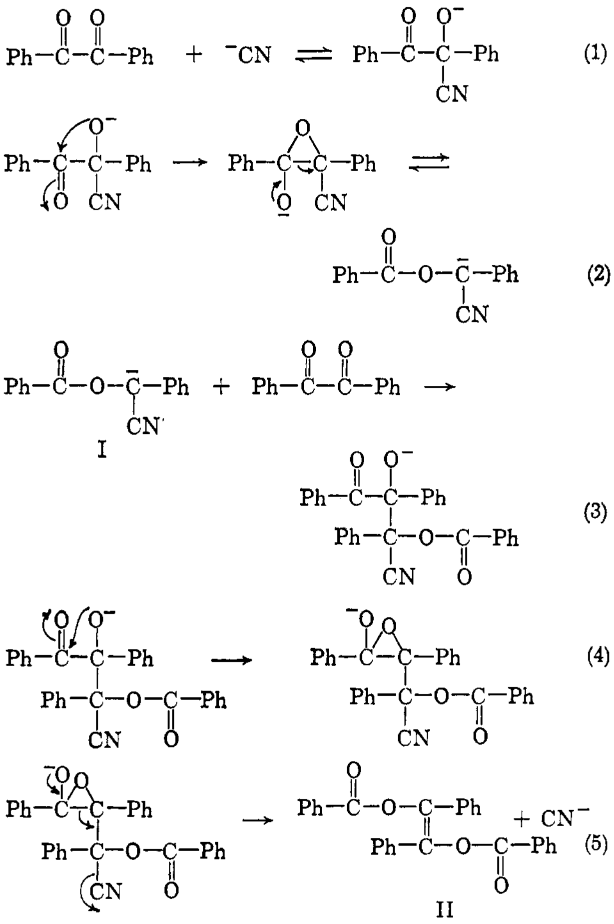
A number of reports concerning the cleavage of benzil by cyanide ion has appeared in the literature. Jourdan[2] and more recently Kwart and Baevsky[3] reported that cleavage products in alcoholic solution are benzaldehyde and the corresponding benzoic ester.

$$(PhCO)_2 + ROH \xrightarrow{^-CN} PhCHO + PhCO_2R$$

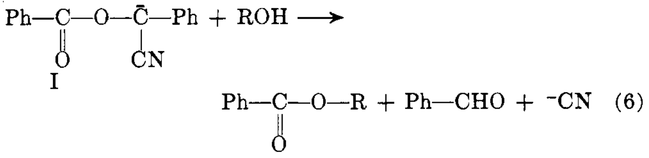
Dilthey and Scheidt[4] observed that the benzilic acid rearrangement is inhibited by cyanide ion and that cleavage products, benzoic acid and benzaldehyde, are obtained. Dakin and Harington[5] found that benzil is converted to benzamide and benzaldehyde by alcoholic ammonium cyanide. Other aromatic α-diketones were observed to exhibit similar behavior. Weiss[6] has shown that a mixture of benzoin and benzil can be separated by taking advantage of the facile cleavage of benzil by cyanide ion in aqueous ethanol at room temperature. Benzoin is also cleaved by cyanide ion, but under more vigorous conditions[7]; the reaction is carried out in refluxing aqueous ethanol and for a longer period of time than that required for benzil cleavage.

Although cleavage of benzil by cyanide ion in protic solvents has been extensively studied, to our knowledge an investigation of the reaction in an aprotic solvent has not been made. With this thought in mind benzil was treated with sodium cyanide in dimethyl sulfoxide and *trans*-α,α′-stilbenediol dibenzoate (II) was obtained as the cleavage product. Thus, it is seen that a change from protic to aprotic solvent causes a change in the type of product obtained. The reaction is quite rapid at room temperature, being complete in less than 1 min.

The following mechanism is suggested to account for the formation of the observed product.



Reaction steps 1 and 2 in alcoholic solution have been established by the work of Kwart and Baevsky.[3] These investigators proposed that step 2 is followed by neutralization of anion I with subsequent cleavage to benzoic ester and benzaldehyde as shown in eq. 6.



$$\underset{\text{I}}{Ph\text{—}\overset{}{\underset{\|}{C}}(=O)\text{—}O\text{—}\bar{C}(CN)\text{—}Ph} + ROH \longrightarrow Ph\text{—}C(=O)\text{—}O\text{—}R + Ph\text{—}CHO + {}^-CN \qquad (6)$$

It is seen that in an aprotic solvent reaction step 6 is not likely to occur. In dimethyl sulfoxide a proton is not readily available and, since this solvent has a tendency to greatly enhance nucleophilic activity,[8] anion I would be expected to attack the available electrophile which is another molecule of benzil. Actually steps 4 and 5 are quite similar to step 2 with the exception that cleavage is accompanied by the loss of cyanide ion and formation of the stable compound II. In addition to accounting for the observed product in a logical manner, the suggested mechanism tends to further support the mechanism proposed by Kwart and Baevsky[3] for the cleavage reaction in alcoholic solution.

Reports concerning α,α′-stilbenediol dibenzoate usually refer to the isomer melting at 159°, "isobenzil",

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[1] Taken in part from the M.S. Thesis of J. L. F.

[2] F. Jourdan, *Ber.*, **16**, 659 (1883).

[3] H. Kwart and M. Baevsky, *J. Am. Chem. Soc.*, **80**, 580 (1958).

[4] W. Dilthey and P. Scheidt, *J. prakt. Chem.*, **142**, 125 (1935).

[5] H. D. Dakin and C. R. Harington, *J. Biol. Chem.*, **55**, 487 (1923).

[6] M. Weiss and M. Appel, *J. Am. Chem. Soc.*, **70**, 3666 (1948).

[7] J. S. Buck and W. S. Ide, *ibid.*, **53**, 2784 (1931).

[8] A. J. Parker, *Quart. Rev.* (London), **16**, 163 (1962).