

The Action of Phenylmagnesium Bromide (One Mole) on N-Phenyl-1,2-cyclobutanedicarboximide (V).—Five grams (0.025 mole) of V, prepared according to Perkin's directions,⁶ was dissolved in 75 cc. of absolute ether. Fourteen cubic centimeters (0.025 mole) of 2.1 *N* phenylmagnesium bromide was then added, and the mixture was refluxed and stirred for three hours. A white precipitate was formed, and when the reaction mixture was decomposed with ice and hydrochloric acid and the ether extract evaporated, a mass of colorless, leafy needles was obtained. After three recrystallizations from alcohol the compound melted at 149.5–150.5°. That it was *cis*-2-benzoylcyclobutanecarboxanilide (VII) was demonstrated by its quantitative conversion into the known *trans* isomer IV when it was allowed to stand a short time in alcohol solution containing a few drops of dilute sodium hydroxide.

Anal. Calcd. for C₁₈H₁₇O₂N: C, 77.4; H, 6.09. Found: C, 77.1; H, 6.11.

The Action of Phenylmagnesium Bromide (Two Moles) on N-Phenyl-1,2-cyclobutanedicarboximide (V).—Four grams (0.02 mole) of V was dissolved in 75 cc. of absolute ether and treated with 20 cc. (0.04 mole) of 2.1 *N* phenylmagnesium bromide. The mixture was stirred and refluxed for four hours, during which time a heavy white precipitate appeared. The reaction mixture was decomposed with ice and hydrochloric acid to yield a crystalline solid which was only slightly soluble in the ether layer. After three recrystallizations from alcohol the product melted at 193.5–194.5°. The analysis and properties of the compound indicated that it was the anilide (VIII) of 2-(α -hydroxybenzohydryl)-cyclobutanecarboxylic acid.

Anal. Calcd. for C₂₄H₂₃O₂N: C, 80.7; H, 6.44. Found: C, 80.4; H, 6.55.

The properties of the anilide which contribute toward a knowledge of its structure are as follows: (1) It was transformed into III by boiling with acetic anhydride or by boiling with alcohol containing a small amount of either sulfuric acid or sodium hydroxide. (2) Dehydration by boiling for two hours in xylene with a small quantity of anhydrous potassium acid sulfate yielded VI. (3) It was unaffected by permanganate, or by dilute aqueous sodium hydroxide after two hours of boiling. Four hours of boiling with 4 *M* sulfuric acid changed it only partially into VI.

Summary

Phenylmagnesium bromide has been shown to react with 1,2-cyclobutanedicarboxylic anhydride (II) in a fashion analogous to its reaction with phthalic anhydride. One mole of the Grignard reagent produces the keto acid, 2-benzoylcyclobutanecarboxylic acid (I); and two moles give the lactone (III) of 2-(α -hydroxybenzohydryl)-cyclobutanecarboxylic acid.

The phenylimide (V) of 1,2-cyclobutanedicarboxylic acid reacts in a manner similar to the anhydride when treated with phenylmagnesium bromide. The products obtained with one and two moles, respectively, of the Grignard reagent are *cis*-2-benzoylcyclobutanecarboxanilide (VII) and the anilide (VIII) of 2-(α -hydroxybenzohydryl)-cyclobutanecarboxylic acid.

URBANA, ILLINOIS

RECEIVED MAY 14, 1934

[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT OF THE UNIVERSITY OF NEBRASKA]

The Reactivity of Nuclear Chlorine in 2-Chloro-5-nitrophenylarsonic Acid

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In this investigation the reactivity of the chlorine in 2-chloro-5-nitrophenylarsonic acid was found to be less than that in 3-nitro-4-chlorophenylarsonic acid,¹ and the introduction of a nitro group into *o*-chlorophenylarsonic acid para to the halogen increased the reactivity of the chlorine as shown, in general, by a comparison of the ease of condensation and yields obtained.²

In order to determine the most favorable experimental conditions for the reaction studied, variations were made in the solvent, temperature, catalyst, proportion of reactants, and the reaction time. Amyl alcohol proved to be an excellent solvent and the optimum reaction temperature was approximately 135°, which permitted active

refluxing of the solvent. The reaction time varied with the type of reactant. A small piece of carefully cleaned sheet copper, when used as a catalyst, produced better results than either cuprous iodide or finely divided copper obtained by precipitation from copper sulfate.

The aliphatic amines (isobutyl, iso- and *n*-amyl, ethylenediamine and ethanolamine) condensed quite readily with 2-chloro-5-nitrophenylarsonic acid, and these were reduced to the corresponding amino derivatives. Condensations between 2-chloro-5-nitrophenylarsonic acid and several substituted phenols resulted in a number of phenyl ether derivatives. Phenol, *p*-chlorophenol, *o*- and *p*-cresol were found to condense under the same conditions employed with the amines.

When 2-chloro-5-nitrophenylarsonic acid was

(1) Maclay and Hamilton, *THIS JOURNAL*, **54**, 3310 (1932).

(2) Etzelmler and Hamilton, *ibid.*, **53**, 3085 (1931).

condensed with *o*-chlorophenol, a product was obtained which gave a negative test for chlorine. The analysis corresponded to a heterocyclic compound which would result from the elimination of hydrochloric acid between the two benzene rings, ortho to the ether linkage. The resulting compound, 1-arsono-3-nitrodibenzofuran, was reduced to the corresponding amino derivative with alkaline ferrous hydroxide solution. The analysis and negative chlorine test of this compound furnished additional evidence in support of the structure assigned to it. A review of the methods previously used in the synthesis of dibenzofuran derivatives failed to show a procedure involving elimination of hydrogen chloride in this manner. It is possible that hydrolysis preceded ring formation and that the final step involved elimination of water instead of hydrogen chloride.

Experimental

2-Chloro-5-nitrophenylarsonic Acid.—A slight modification of the general directions of Barber³ for the nitration of halogenophenylarsonic acids was used in the preparation of this compound. A large excess of fuming nitric acid was used in the cold and when the initial reaction had subsided the reaction mixture was heated at 100° on a water-bath for one hour. The crude product was purified by reprecipitating from dilute alkali and recrystallizing from hot water. The arsonic acid separated as hexagonal plates which melted at 229–230°; yield, 85%.⁴

Anal. Calcd. for C₆H₄O₆NClAs: As, 26.63. Found: As, 26.61, 26.65.⁵

condenser, and the flask and contents were heated in an oil-bath at 185° for twenty-five hours. The mixture was then steam distilled to remove the amyl alcohol and in most cases the excess alkylamine, and the resultant dark solution treated with activated charcoal. Upon acidification to Congo red paper with concentrated hydrochloric acid, a yellow crystalline product separated. The dried product was then dissolved in acetone at the boiling point, cooled, filtered, and the filtrate diluted with water until precipitation was complete. The crude products were purified by reprecipitation from dilute alkali and recrystallization from dilute acetic acid.

Bis-2-arsono-4-nitrophenylaminoethane.—Ten grams of 2-chloro-5-nitrophenylarsonic acid was condensed with 3 cc. of ethylenediamine in the presence of 10 g. of anhydrous potassium carbonate and a small piece of sheet copper. Fifty cc. of amyl alcohol was employed as solvent, and the mixture was heated under reflux with mechanical stirring for fifteen hours at 140°. The amyl alcohol was then removed by steam distillation and the dark solution treated with activated charcoal. Upon acidification to Congo red paper with hydrochloric acid, a light brown crystalline mass separated. The product was reprecipitated twice from dilute alkali and recrystallized from glacial acetic acid. It separated as small diamond-shaped plates which darkened at 225° and decomposed at 228–229°, yield 46%. The compound was found to be insoluble in most organic solvents but quite soluble in glacial acetic acid.

Anal. Calcd. for C₁₄H₁₆O₁₀N₄As₂: As, 27.25. Found: As, 27.16, 27.20.

Preparation of 5-Amino-2-alkylaminophenylarsonic Acids.—The method employed for the preparation of these compounds was that described by Jacobs, Heidelberger and Rolf.⁶ It consisted of the reduction of nitroaryl-sonic acids by means of freshly prepared ferrous hydroxide.

TABLE I

5-NITRO-2-ALKYLAMINOPHENYLARSONIC ACIDS

-Aminophenylarsonic acid	Yield, %	M. p., °C.	Formula	Arsenic analyses, %		
				Calcd.	Found	
5-Nitro-2-phenyl-	70	182–184	C ₁₂ H ₁₁ O ₆ N ₂ As	22.17	22.28	22.24
5-Nitro-2-isobutyl-	62	189–190 dec.	C ₁₀ H ₁₅ O ₆ N ₂ As	23.56	23.64	23.62
5-Nitro-2- <i>n</i> -amyl-	80	135–137	C ₁₁ H ₁₇ O ₆ N ₂ As	22.57	22.68	22.73
5-Nitro-2-isoamyl-	81	186 dec.	C ₁₁ H ₁₇ O ₆ N ₂ As	22.57	22.77	22.75
5-Nitro-2-β-hydroxyethyl-	75	146–147	C ₈ H ₁₁ O ₆ N ₂ As	24.49	24.53	24.66
5-Nitro-2-β-aminoethyl-	43	250–251 dec.	C ₈ H ₁₂ O ₆ N ₃ As	24.56	24.45	24.52

Secondary Amine Derivatives

General Procedure.—A mixture of 10 g. of 2-chloro-5-nitrophenylarsonic acid, 8 cc. of the alkylamine, 10 g. of anhydrous potassium carbonate, 50 cc. of amyl alcohol, and a small piece of bright sheet copper was introduced into a 200-cc. Erlenmeyer flask fitted with ground glass connections. The reaction mixture was agitated by means a mechanical stirrer which extended down through the

The products were purified by reprecipitation from dilute hydrochloric acid and recrystallization from dilute acetic acid or acetone. The majority of these reduction products were subject to slight discoloration in air or when dried in an oven.

Bis-2-arsono-4-aminophenylaminoethane.—This compound was prepared from the corresponding nitro derivative by reduction with alkaline ferrous hydroxide solution. The product was purified by reprecipitation from dilute alkali containing a small amount of sodium sulfite. The free acid separated as pink needles which darkened rapidly in air and melted with decomposition at 200–201°; yield, 48%.

Anal. Calcd. for C₁₄H₂₀O₆N₄As₂: As, 30.58. Found: As, 30.48, 30.41.

(3) Barber, *J. Chem. Soc.*, 471 (1929).

(4) The structure of this compound was proved by comparison with the product prepared by Lucile Hac (Master's thesis, University of Nebraska (1931)) by nitrating *o*-chloroaniline and then arsonating this compound.

(5) The potentiometric method of Cislak and Hamilton, *THIS JOURNAL*, 52, 638 (1930), was used for the quantitative determination of arsenic in all of the compounds prepared.

(6) Jacobs, Heidelberger and Rolf, *ibid.*, 40, 1581 (1918).

TABLE II
5-AMINO-2-ALKYLAMINOPHENYLARSONIC ACIDS

-Aminophenylarsonic acid	Yield, %	M. p., °C.	Formula	Arsenic analyses, %		
				Calcd.	Found	
5-Amino-2-phenyl-	71	195 dec.	C ₁₂ H ₁₃ O ₄ N ₂ As	24.32	24.14	24.19
5-Amino-2-isobutyl-	65	192 dec.	C ₁₀ H ₁₇ O ₄ N ₂ As	26.01	25.95	26.09
5-Amino-2- <i>n</i> -amyl-	64	178-179 dec.	C ₁₁ H ₁₉ O ₄ N ₂ As	24.81	24.81	24.82
5-Amino-2-isoamyl-	65	186 dec.	C ₁₁ H ₁₉ O ₄ N ₂ As	24.81	24.75	24.77
5-Amino-2-β-hydroxyethyl-	70	154-155 dec.	C ₈ H ₁₃ O ₄ N ₂ As	27.14	26.97	26.98

Phenyl Ether Derivatives

General Procedure.—Fifteen grams of 2-chloro-5-nitrophenylarsonic acid, 15 g. of anhydrous potassium carbonate, 6 g. of the substituted phenol, 50 cc. of amyl alcohol, and a small piece of sheet copper were heated under reflux with rapid stirring at 130-135° for eight hours. The reaction mixture was then steam distilled, cooled and acidified to Congo red paper with hydrochloric acid. The dark brown oil which separated soon solidified to a granular mass. The products were purified by extraction with ether to remove the excess phenol and reprecipitation from dilute alkali. Most of these compounds could be recrystallized from dilute acetic acid.

The carboxy derivatives of the products resulting from condensations with *o*- and *p*-cresols were prepared by oxidation with alkaline permanganate.

1-Arsono-3-nitrodibenzofuran.—Fifteen grams of 2-chloro-5-nitrophenylarsonic acid, 15 g. of anhydrous po-

colored solution was then diluted with water until crystals began to separate, and cooled. The product was found to contain considerable 2-chloro-5-nitrophenylarsonic acid which was removed by recrystallization from glacial acetic acid. The 1-arsono-3-nitrodibenzofuran crystallized in the form of long slender needles, m. p. 203-205°; yield, 32%.

Anal. Calcd. for C₁₂H₉O₄NAs: As, 22.23. Found: As, 22.20, 22.28.

1-Arsono-3-aminodibenzofuran.—This compound was prepared by reduction of the corresponding nitro derivative with alkaline ferrous hydroxide solution. The product was purified by repeated precipitation from dilute hydrochloric acid solution, from which it separated as short colorless rods. The compound darkened at 210° and decomposed at 218°; yield, 50%.

Anal. Calcd. for C₁₂H₁₀O₄NAs: As, 24.40. Found: As, 24.30, 24.36.

TABLE III
2-ARSONO-4-NITROPHENYL ETHER DERIVATIVES

2-Arsono-4-nitro-	Yield, %	M. p., °C.	Formula	Arsenic analyses, %		
				Calcd.	Found	
-Phenyl ether	60	231-232	C ₁₂ H ₁₀ O ₄ NAs	22.10	22.11	22.12
-4'-Chloro-phenyl ether	60	225-230	C ₁₂ H ₉ O ₄ NClAs	20.06	20.16	20.19
-4'-Methyl-phenyl ether	32	245-246	C ₁₃ H ₁₂ O ₄ NAs	21.23	21.33	21.37
-4'-Carboxy-phenyl ether	81	>250	C ₁₃ H ₁₀ O ₆ NAs	19.56	19.61	19.66
-2'-Methyl-phenyl ether	21.3	>250	C ₁₃ H ₁₂ O ₄ NAs	21.23	21.55	21.51
-2'-Carboxy-phenyl ether	65	229 dec.	C ₁₃ H ₁₀ O ₆ NAs	19.56	19.58	19.53

TABLE IV
2-ARSONO-4-AMINOPHENYL ETHER DERIVATIVES

2-Arsono-4-amino-	Yield, %	M. p., °C.	Formula	Arsenic analyses, %		
				Calcd.	Found	
-Phenyl ether	56	203	C ₁₂ H ₁₂ O ₄ NAs	24.25	24.17	24.22
-4'-Chloro-phenyl ether	74	>250	C ₁₂ H ₁₁ O ₄ NClAs	21.81	21.78	21.81
-4'-Methyl-phenyl ether	60	224 dec.	C ₁₃ H ₁₄ O ₄ NAs	23.22	23.23	23.30
-4'-Carboxy-phenyl ether	80	>250	C ₁₃ H ₁₂ O ₆ NAs	21.22	21.20	21.26
-2'-Carboxy-phenyl ether	61	227 dec.	C ₁₃ H ₁₂ O ₆ NAs	21.22	21.18	21.25
-2'-Methyl-phenyl ether	65	>250	C ₁₃ H ₁₄ O ₄ NAs	23.22	23.20	23.24

The compounds in Table IV were prepared by reduction of the corresponding nitro derivatives with alkaline ferrous hydroxide solution.

tassium carbonate, 15 cc. of *o*-chlorophenol, 50 cc. of amyl alcohol and a piece of sheet copper were heated under reflux with rapid stirring at 135° for eight hours. The reaction mixture was steam distilled to remove the amyl alcohol and the dark solution treated with decolorizing charcoal. Upon acidification to Congo red paper with hydrochloric acid a dark brown oil separated which solidified on cooling. The solid material was treated with several portions of ether to remove the excess *o*-chlorophenol, and the residue was dissolved in hot glacial acetic acid and treated with activated charcoal. The resulting amber-

Summary

1. 2-Chloro-5-nitrophenylarsonic acid has been condensed with aniline and with a series of aliphatic amines, namely, isobutyl, iso- and *n*-amyl, ethanolamine and ethylenediamine. The ethylenediamine gave rise to the formation of two derivatives involving one or both of the amino groups. The corresponding amino derivatives of the above condensation products have been prepared.

2. A new series of phenyl ether derivatives has been prepared by the condensation of 2-chloro-5-nitrophenylarsonic acid with various substituted phenols. Condensations were carried out with phenol, *o*- and *p*-chlorophenol, and *o*- and *p*-cresol. *o*-Chlorophenol condensed with 2-chloro-5-nitrophenylarsonic acid to form 1-arsono-3-nitrodibenzofuran. The carboxyl derivatives of the

cresol condensation products were also prepared. The amino derivatives have been prepared for all of the above phenyl ether arsenicals.

3. Halogen in 2-chloro-5-nitrophenylarsonic acid was found less active toward primary amines and phenols than halogen in 3-nitro-4-chlorophenylarsonic acid.

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RECEIVED MAY 16, 1934

[CONTRIBUTION FROM THE GEORGE HERBERT JONES LABORATORY OF THE UNIVERSITY OF CHICAGO]

The Peroxide Effect in the Addition of Reagents to Unsaturated Compounds. VIII. The Addition of Hydrogen Iodide to Ethylene Compounds

BY M. S. KHARASCH AND CHESTER HANNUM

Introduction

Previous studies in this Laboratory on the addition of hydrogen bromide to ethylene compounds under carefully controlled conditions have indicated that the controlling factor guiding the addition to the double bond was the peroxide content of the reaction mixture.¹ However, simple experiments with peroxide containing unsaturated compounds demonstrated that hydrogen iodide is an excellent reagent for decomposing organic peroxides. It appeared very likely, therefore, that the addition of hydrogen iodide to ethylene compounds should not be affected by peroxides, and that under all conditions the "normal" addition product should be formed.

Previous Work.—Very little work has been recorded on the addition of anhydrous hydrogen iodide to ethylene compounds studied by us. The earlier investigators² are in agreement that isopropyl iodide is the only product of reaction between propylene and hydrogen iodide. Butene-1 has been treated with aqueous hydrogen iodide³ and found to form secondary butyl iodide. Whitmore and Homeyer⁴ report that neopentylethylene did not add hydrogen iodide to the double bond at 0°, when the olefin was saturated with hydrogen iodide, although hydrogen bromide under those conditions gave practically quantitative yields of 1-bromo-4,4-dimethylpentane.⁵

(1) Kharasch and Mayo, *THIS JOURNAL*, **55**, 2469 (1933); Kharasch, McNab and Mayo, *ibid.*, **55**, 2521 (1933); Kharasch, Hannum and Gladstone, *ibid.*, **56**, 244 (1934); Kharasch and Hannum, *ibid.*, **56**, 712 (1934); Kharasch and Hinckley, *ibid.*, **56**, 1212, 1243 (1934).

(2) Berthelot, *Ann.*, **104**, 184 (1857); Erlenmeyer, *ibid.*, **139**, 228 (1866); Butlerow, *ibid.*, **145**, 275 (1867); cf. Michael, *Ber.*, **39**, 2138 (1906).

(3) Wurtz, *Ann.*, **152**, 23 (1869).

(4) Whitmore and Homeyer, *THIS JOURNAL*, **55**, 4555 (1933).

(5) Cf. Kharasch, Hannum and Gladstone, *Ref. 1*.

The addition of hydrogen iodide to allyl bromide has never been described. Simpson⁶ reports having prepared the 1-bromo-2-iodopropane by the addition of an aqueous solution of bromiodine to propylene. His product boiled at 160–168° with decomposition. It is quite evident that the structure of Simpson's compound has not been definitely established.

General Procedure of this Work

In this work anhydrous hydrogen iodide was added in equal molar quantities to the olefin in order to minimize any reduction of the iodide thus formed. The general technique of addition was the same as described in previous papers.² When bombs were run with peroxides such as terpene peroxide, ascaridole, etc., these substances were added to the olefin at least thirty minutes before the addition of the hydrogen iodide.

The reaction of olefins with hydrogen iodide is quite vigorous at room and even at low temperatures. The hydrogen iodide used by us was purified very carefully and, when cooled in liquid air, was always obtained in an absolutely white form entirely free of iodine. Table I summarizes briefly the results of our addition of hydrogen iodide to a number of unsaturated compounds. As stated, the only product of the reaction under peroxide and antioxidant conditions was the "normal product," the product analogous to that obtained under antioxidant conditions with hydrogen bromide. Under our method of addition there was not the slightest difficulty in adding the hydrogen iodide to neopentylethylene. The addition of hydrogen iodide to that molecule is ex-

(6) Simpson, *J. Chem. Soc.*, **27**, 564 (1874).