

b. p. 179–180°, with thionyl chloride as described by Fourneau, Montaigne and Puyal.⁷ Hexahydrobenzamide, m. p. 183–185°, was prepared from the acid chloride and ammonia. The nitrile, b. p. 185–187°, obtained by distilling the amide with phosphorus pentoxide, upon reduction yielded hexahydrobenzylamine.

β -Cyclohexylethylamine, b. p. 80–85° (20–25 mm.), was prepared as described by Wallach⁸ from cyclohexylacetic acid. Cyclohexyl bromide with the sodio derivative of malonic ester gave cyclohexylmalonic ester, b. p. 157–158° (19 mm.). Saponification of the ester yielded cyclohexylmalonic acid, m. p. 178–181° (with evolution of carbon dioxide). Decarboxylation of this acid at 200° as described by Eykman⁹ gave cyclohexylacetic acid, b. p. 145–146° (28–30 mm.). This was converted into cyclohexylacetyl chloride, b. p. 195–200°, with thionyl chloride. The acid chloride and ammonia gave cyclohexylacetamide, m. p. 185–186°, which upon distillation with phosphorus pentoxide, yielded cyclohexyl acetoneitrile, b. p. 200–205°. (Wallach reported a b. p. of 215–217° for this nitrile.) Reduction of the nitrile gave the amine.

Phenylbenzylamine hydrochloride, m. p. 210–212°, and dibenzylamine hydrochloride, m. p. 256–258°, were prepared by passing dry hydrogen chloride into cold ethereal solutions of the respective amines (Eastman).

Symmetrical dibenzylthiourea, m. p. 142–145°, and benzylthiourea, m. p. 155–157°, were prepared from benzylamine (Eastman) as described by Dixon.¹⁰

S-Methyl benzylisothiourea hydroiodide was prepared as follows: 8.0 g. (0.0481 mole) of benzylthiourea and 7.0 g. (0.0493 mole) of methyl iodide, b. p. 42–43°, in 45 cc. of absolute alcohol were heated under reflux on a water-bath for half an hour. Dry ether was added to the cooled solution to permanent turbidity. Vigorous

stirring at 0° gave a crystalline precipitate which was filtered off and washed with dry ether. The crude salt, 14 g., was dissolved in 25 cc. of hot absolute alcohol, bone blacked, filtered and ether added to permanent turbidity. The crystalline precipitate which formed was filtered off, washed with dry ether and air dried. The purified S-methyl benzylisothiourea hydroiodide was white, readily soluble in cold water and alcohol but insoluble in ether. It melted at 103–104°. The yield (purified salt) was 11.5 g. or 78.2%.

Anal. Calcd. for $C_9H_{13}N_2SI$: I, 41.19. Found: I, 41.19.

The isomer of this compound, N,N'-methylbenzylthiourea, was prepared by Dixon¹¹ from methyl mustard oil and benzylamine. It is erroneously listed in Richter's "Lexikon" as S-methylbenzylisothiourea.

General Methods of Preparation of Guanidines.—The monoguanidines reported here were made by either of two methods: (a) from a 1° or 2° amine hydrochloride and cyanamide, or (b), from a 1° or 2° amine and S-methylisothiourea sulfate. (In the preparation of α,γ -dibenzylguanidine hydrochloride S-methylbenzylisothiourea hydroiodide was used.) The experimental details, physical constants, properties and analytical data are recorded in Table I.

The major part of this investigation was supported by a Sigma Xi Research Grant.

Summary

1. The preparation and properties of salts of seven new monoguanidines are described.
2. The preparation and properties of S-methyl benzylisothiourea hydroiodide and its application in a new synthesis of α,γ -dibenzylguanidine hydrochloride are reported.

(11) A. E. Dixon, *J. Chem. Soc.*, **55**, 619 (1889).

BURLINGTON, VERMONT

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[CONTRIBUTION FROM THE WALKER CHEMICAL LABORATORY OF THE RENSSELAER POLYTECHNIC INSTITUTE]

The Synthesis of Alpha-alkyl-alpha-phenyl-gamma-chlorobutyronitriles¹

BY RANDALL HASTINGS AND JOHN B. CLOKE

The synthesis of a series of α -alkyl- α -phenyl- γ -chlorobutyronitriles, $ClCH_2CH_2C(R)(C_6H_5)CN$, was undertaken in order to supply intermediates for some work on pyrroline structure now under way in this Laboratory. The present paper is an extension of previous work by Knowles and Cloke.² In their work a method was described for the synthesis of α -phenyl- γ -chlorobutyroni-

trile by the action of thionyl chloride on α -phenyl- γ -hydroxybutyronitrile, which, in turn, was prepared by the action of ethylene chlorohydrin on sodium phenylacetoneitrile.

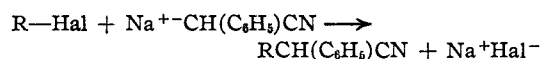
The first step in the present work on the synthesis of our α -alkyl- α -phenyl- γ -chlorobutyronitriles was the preparation of the proper alkyl-phenylacetoneitriles by the method of Bodroux and Taboury.³ In this work benzyl cyanide in ether solution was treated with an equimolar

(1) This paper has been prepared from a thesis presented by Randall Hastings to the Rensselaer Polytechnic Institute in June, 1933, in partial fulfillment of the requirements for the degree of Master of Science.

(2) Knowles and Cloke, *THIS JOURNAL*, **54**, 2028 (1932).

(3) Bodroux and Taboury, *Bull. soc. chim.*, **7**, 666 (1910); *Compt. rend.*, **150**, 531, 1241 (1910).

quantity of sodium amide in order to form the monosodium salt, which was then allowed to react with an equimolar amount of an alkyl halide or sulfate to form the alkylphenylacetone nitrile as follows



Two methods have been studied for the transformation of the alkylphenylacetone nitriles into the α -alkyl- α -phenyl- γ -chlorobutyronitriles. In the first of these, sodium alkylphenylacetone nitrile, $\text{Na}^+\text{-C}(\text{R})(\text{C}_6\text{H}_5)\text{CN}$, was treated with ethylene chlorohydrin to give a mixture containing α -alkyl- α -phenyl- γ -hydroxybutyronitrile, $\text{HOCH}_2\text{-CH}_2\text{C}(\text{R})(\text{C}_6\text{H}_5)\text{CN}$, which was then treated with thionyl chloride, as in the work of Knowles and Cloke, to give a rather small yield of the required α -alkyl- α -phenyl- γ -chlorobutyronitrile, which, however, proved to be quite difficult to purify. In the second method, which proved to be successful, the sodium alkylphenylacetone nitrile was treated directly with ethylene chloride to give the α -alkyl- α -phenyl- γ -chlorobutyronitrile and other products. In future work an attempt will be made to isolate the dialkyldiphenyladiponitriles which are doubtless present in such by-products.

In passing it may be added that our α -alkyl- α -phenyl- γ -chlorobutyronitriles form pyrrolines by the method of Cloke.⁴ Since there is little doubt of the Δ^1 structure of these new pyrrolines, the properties of these compounds are being studied in order to throw more light on the position of the double bond in some of the older pyrrolines, whose structures in many cases seem to have been assigned rather arbitrarily.

Experimental Part

Preparation of Methylphenylacetone nitrile.—Two moles (240 g.) of benzyl cyanide⁵ and twice its volume of dry ether were placed in a two-liter, three-necked, round-bottomed flask, which was attached to a dropping funnel, reflux condenser and a mercury sealed mechanical stirrer arrangement. The stirrer was set in motion, and to the solution a two molar quantity (80 g.) of sodium amide, which had been finely ground under ether, was added slowly in the form of an ether suspension through the dropping funnel. The mixture in the flask was then refluxed on the water-bath for eight hours, when it was thoroughly cooled in an ice-bath. At this point a two molar quantity (252 g.) of dimethyl sulfate was slowly added to the constantly stirred mixture over the course of

about four hours. The long period of addition was necessitated by the vigor of the reaction. At the end of this period the mixture was allowed to warm up to room temperature and the stirring was continued for eight hours thereafter. Water was then added to the mixture and when the precipitate had dissolved, the ether layer was removed, dried over anhydrous sodium sulfate and distilled. A yield of 181 g. of methylphenylacetone nitrile (α -phenylpropionitrile), b. p. 80–85° at 3 to 4 mm., was obtained.

The ethyl-, *n*-propyl- and *n*-butylphenylacetone nitriles were prepared as outlined above with the exception that diethyl sulfate and propyl and butyl bromides were substituted for the dimethyl sulfate and the reaction mixture was refluxed after the first vigorous reaction had subsided.

The Preparation of the α -Alkyl- α -phenyl- γ -chlorobutyronitriles.—The following description of the preparation of α -ethyl- α -phenyl- γ -chlorobutyronitrile by the second method is typical of all four preparations. In the synthesis of this compound 368 g. (2.53 moles) of ethylphenylacetone nitrile and twice its volume of dry benzene were placed in the two-liter flask which was fitted up as described above. The stirrer was started and 101.4 g. (2.53 moles) of finely ground sodium amide in benzene suspension was added slowly through the separatory funnel. After this addition the temperature of the water-bath was raised to 70–75°, where it was maintained for eight hours. The flask was then cooled in an ice-bath and 251 g. (2.53 moles) of ethylene chloride was added during the course of about two and a half hours, when the mixture was allowed to warm up to room temperature. At the end of a ten-hour period of stirring, water was added, which dissolved the heavy precipitate which had formed, and the supernatant benzene solution was separated, dried over anhydrous sodium sulfate and distilled. The first distillation gave 82 g. of a compound, b. p. 115–116.5° at 3–4 mm. Redistillation of this fraction gave 77 g. of product having the same boiling range. It possessed a density, d_4^{20} , of 1.0784 and a refractive index, n_D^{20} , of 1.52252, which correspond to a molecular refractivity, MR_D^{20} (n^2) of 58.76 as compared with the calculated value of 58.86.⁶

A second sample, which was prepared in essentially the same way, gave the following constants: b. p. 114–114.5° (3–4 mm.); d_4^{20} , 1.0807; n_D^{20} , 1.52256.

TABLE I
 α -ALKYL- α -PHENYL- γ -CHLOROBUTYRONITRILES

No.	α -Alkyl	B. p., °C. (3–4 mm.)	Yield, %	d_4^{20}	n_D^{20}	MR_D^{20}	
						Calcd.	Found
1	Methyl	109–111	20.1	1.0941	1.52626	53.96	54.35
2	Ethyl	115–116.5		1.0784	1.52252	58.86	58.76
3	<i>n</i> -Propyl	121–123	23.6	1.0518	1.51734	63.19	63.78
4	<i>n</i> -Butyl	133–135		1.0390	1.51389	67.80	68.26

No.	Formula	Analyses, %					
		Nitrogen		Chlorine			
		Calcd.	Found	Calcd.	Found		
1	C ₁₁ H ₁₂ NCI	7.23	7.02	7.26	18.34	18.15	18.63
2	C ₁₂ H ₁₄ NCI	6.75	6.68	6.82	17.15	17.00	17.18
3	C ₁₃ H ₁₆ NCI	6.32	6.03	6.22	16.04	17.03	16.82
4	C ₁₄ H ₁₈ NCI	5.94	6.29	5.76			

(4) Cloke, THIS JOURNAL, 51, 1174 (1929); Krebs, "Thesis," Rensselaer Polytechnic Institute, 1933; Murray, "Thesis," 1934.

(5) Adams and Thal, "Organic Syntheses," John Wiley and Sons, Inc., New York, 1922, Vol. II, p. 9.

(6) Von Auwers' value for nitrile nitrogen has been employed in the calculation of the molecular refractivities reported in this paper [Ber., 60, 2126 (1927)].

Since the foregoing procedure has given rather low yields (about 22%), an effort will be made in subsequent work to ascertain the conditions for the optimum results. The use of a larger quantity of the dihalogen derivative would doubtless be of great importance.

Summary

A method has been described for the synthesis of the α -methyl-, α -ethyl-, α -*n*-propyl- and α -*n*-butyl- α -phenyl- γ -chlorobutyronitriles. These compounds are being used in the synthesis of Δ^1 -pyrrolines and other derivatives.

TROY, N. Y.

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The Hydration of Unsaturated Compounds. III. The Hydration Rate of Trimethylethylene in Aqueous Solutions of Acids¹

BY HOWARD J. LUCAS AND YUN-PU LIU²

The studies on the hydration of unsaturated compounds which started with isobutene³ have been extended to trimethylethylene.

Actual hydration of this hydrocarbon by aqueous solutions of formic, acetic and oxalic acids was first observed by Miklaschewsky.⁴ Later Michael and Brunel⁵ found that in the presence of hydrobromic acid less than 5 *N* the hydrocarbon was converted to the alcohol only.

In the present investigation the rate of hydration of trimethylethylene has been measured at 25 and 35° in the presence of nitric acid and potassium nitrate and at 25° only in the presence of a number of other acids alone.

Experimental

Materials.—The acids used were mostly the ordinary *c. p.* acids, except the dithionic and *p*-toluenesulfonic acids. The former was prepared by treatment of a known amount of very pure barium dithionate⁶ in aqueous solution with the calculated quantity of sulfuric acid, filtering through asbestos with suction and evaporating the filtrate to the desired concentration. Eastman *p*-toluenesulfonic acid was crystallized three times from 6 *N* hydrochloric acid, filtering through sintered glass after decolorizing with norite. The final, colorless crop was allowed to remain in a vacuum desiccator over caustic soda until all hydrogen chloride was gone.

The trimethylethylene was obtained by fractionation of the mixed pentenes resulting from the decomposition of tertiary amyl alcohol when heated with oxalic acid.⁷ After four fractionations through an 85-cm. column of glass rings under a reflux, there was obtained a 27% yield

of trimethylethylene boiling at 38.2–38.3° (corr.) under 745 mm.

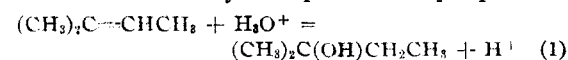
Solutions and Apparatus.—An aqueous solution of trimethylethylene was prepared by shaking 600 ml. of water and 0.5 ml. of the olefin in a tube closed at both ends with stopcocks. The tube remained in the thermostat at 25° until the aqueous phase became clear, a part of the air was removed by suction and the calculated amount of acid added. The contents were thoroughly mixed by gentle agitation and allowed to stand until the aqueous phase became clear, a matter of several minutes only if the agitation had not been violent. The aqueous solution was then run from the bottom of the container into the reaction apparatus, which was similar to the one previously described³ except it was larger and had a greater capacity. This previously had been swept out with air saturated with the pentene vapor.

Sampling and Analysis.—These operations were performed as previously described except that a larger sample (18.59 ml.) was taken because the pentene has a lower solubility in water than *i*-butene.

Reaction Product.—This was shown to be the tertiary alcohol as follows: 600 ml. of water saturated with pentene was made 1 *N* in nitric acid and allowed to stand at 25° for three days. The acid was neutralized with sodium hydroxide and the solution was distilled through a fractionating column until the temperature became constant, yielding 10 ml. of a two-phase distillate. The upper phase, after drying with anhydrous potassium carbonate, measured 2 ml. and distilled at 101.5°. On the addition of 10 ml. of concentrated hydrochloric acid a second phase of approximately 2 ml. separated. This distilled at 86°. These boiling points check those of tertiary amyl alcohol and chloride, respectively.

Discussion of the Data

Since it is shown later on that the hydration rate is first order with respect to nitric acid, the hydration of trimethylethylene resembles that of isobutene³ and may be represented by equation 1.



(1) Presented at the Berkeley meeting of the American Association for the Advancement of Science, June 20, 1934.

(2) Fellow of the Rockefeller Foundation.

(3) Lucas and Eberz, *THIS JOURNAL*, **56**, 460 (1934).

(4) Miklaschewsky, *Ber.*, **24**, ref. 269 (1891).

(5) Michael and Brunel, *Am. Chem. J.*, **48**, 270 (1912).

(6) Kindly supplied by Prof. D. M. Yost of this Laboratory.

(7) Norris and Thomson, *THIS JOURNAL*, **53**, 3114 (1931).