respectively, 0.1% of hydroquinone, 0.1% catechol, 0.1% ammonium carbonate, 1% water, 0.05% sulfuric acid (gave a precipitate of amine sulfate), a strip of mild steel, 1 and 10% of concentrated aqua ammonia (28% NH_3) and carbon dioxide added as a gas (amine carbonate precipitated). No additive was beneficial and only carbonates were detrimental. The samples containing carbon dioxide and ammonium carbonate decomposed after one month while all others lasted two to two and one-half months.

Tri-(β-cyanoethyl)-amine was recovered by hot water extraction of the residues from the vacuum distillation of the primary and secondary amines. On cooling the hot water extract, the amine frequently separated as an oil. The recovery of crystalline material was facilitated by stirring the hot extract with Darco, filtering, and cooling slowly, and also by adding seed crystals of the triamine just as the aqueous solution became turbid on cooling. Recrystallization from alcohol gave similar results.

Preparation of γ-Aminopropylamines.—A portion of the mixture of β-cyanoethylamines produced in run 3, after removal of water, was hydrogenated without further treatment. In addition, portions of the purified primary and secondary β-cyanoethylamines were hydrogenated individually. The reductions were carried out at pressures of 50–250 atmospheres for five to ten hours at 90–125°. The apparatus used was the Adkins[4] type of rocking autoclave

TABLE III

PREPARATION OF γ-AMINOPROPYLAMINES FROM β-CYANO-ETHYLAMINES

Charge (β-cyanoethylamines)	1 Primary	2 Secondary	3 Mixture: 30% primary 65% secondary 4% tertiary
% by wt. of cyanoamine charge recovered as:			
Mono-(γ-aminopropyl)-amine	54	14	28
Di-(γ-aminopropyl)-amine	12	58	42
Tri-(γ-aminopropyl)-amine	3	13	13
	69	85	83

built by the American Instrument Company. Batches of 5–10 moles were reduced in the presence of 1.1 moles of anhydrous ammonia per mole of amine and 2–3 g. of Raney nickel catalyst per mole.

Hydrogenation of Di-(β-cyanoethyl) Ether.—A sample of di-(β-cyanoethyl) ether, prepared by reaction of ethylene cyanohydrin with acrylonitrile, was freshly redistilled at 140° at 2–3 mm. It was hydrogenated at pressures of 50–150 atm. and at temperatures between 80 and 125° for periods of two to ten hours. About 3–4 g. of Raney nickel catalyst was added per mole. The presence of 1.2 moles of anhydrous ammonia per mole of ether was found to reduce the percentage of low boiling products while increasing the amount of γ-aminopropanol formed and raising the yield of di-(γ-aminopropyl) ether. The best run was carried out in the presence of ammonia at 110–115° and 100 atm. for two hours, yielding 25–30% by weight of low boiling impurities (from which some propylamine was isolated), 35–40% of γ-aminopropanol, 20% of di-(γ-aminopropyl) ether and 15% residue.

We have recently obtained a copy of a French patent (879,788) which describes the preparation of di-(γ-aminopropyl) ether by a similar procedure. There is no mention of by-products and no yield is given, but the boiling point, 167° at 8 mm., is in fair agreement with our value of 135° at 3 mm.

Summary

Tri-(β-cyanoethyl)-amine (γ,γ',γ''-nitrilotripropionitrile) has been prepared from acrylonitrile and ammonia as a crystalline solid melting at 59°.

Di-(γ-aminopropyl)-amine and tri-(γ-aminopropyl)-amine have been prepared by hydrogenation of β-cyanoethylamines. Physical properties are given.

Hydrogenation of di-(β-cyanoethyl) ether yields some di-(γ-aminopropyl) ether but also forms γ-aminopropanol and propylamine by hydrogenolysis.

N-Substituted α-Aminoisobutyronitriles from Acetone Cyanohydrin

BY RALPH A. JACOBSON

α-Aminonitriles can be prepared by treating α-hydroxynitriles with ammonia,[1] or by one of the many modifications of the Strecker synthesis.[2] In connection with some work on another problem, a number of substituted α-aminoisobutyronitriles were required as intermediates. We found that they can be obtained conveniently under mild conditions by the reaction of acetone cyanohydrin and the proper amine, a procedure utilized by Bucherer and Grolee[3] for the preparation of α-phenylaminoisobutyronitrile. The results of our experience with this reaction are briefly discussed in the present paper.

One instance will illustrate the advantage of this procedure for the preparation of certain nitrogen-substituted α-aminoisobutyronitriles. Stew-

art and Cook,[4] for example, had much difficulty in preparing α-diethylaminoisobutyronitrile from acetone, sodium bisulfite, diethylamine and potassium cyanide by Knoevenagel's method.[5] The authors reported that the yield was very poor (not stated) and that the preparation could not be duplicated. More recent attempts to prepare this compound by the same method were also unsuccessful.[6] In contrast, we obtained α-diethylaminoisobutyronitrile in 58% yield merely by warming acetone cyanohydrin with diethylamine.[7] The preparation was one of a series, and no attempt was made to improve the yield. In some

(1) (a) Dubsky and Wensink, Ber., **49**, 1134 (1916); (b) Bucherer and Steiner, J. prakt. Chem., **140**, 308 (1934).

(2) For instance, Zelinsky and Stadnikoff, Ber., **39**, 1726 (1906).

(3) Bucherer and Grolee, ibid., **39**, 986 (1906).

(4) Stewart and Cook, THIS JOURNAL, **50**, 1980 (1928).

(5) Knoevenagel and Mercklin, Ber., **37**, 4087 (1904).

(6) Luten, J. Org. Chem., **3**, 588 (1939).

(7) The specific reaction rates of this reaction have been measured in acetone and in alcohol by a titration procedure, and the corresponding rate laws and reaction mechanism discussed by Stewart and Li, THIS JOURNAL, **60**, 2782 (1938). However, the reaction was not employed as a preparative method.

<div align="center">

Table I

N-Substituted α-Aminoisobutyronitriles from Acetone Cyanohydrin and Amines

</div>

Compound	Amine employed	M. p., °C.	B. p. °C.	Mm.	$n^{20}D$	Yield, %
$HN_2C(CH_3)_2CN$[a]	NH_3		68	24	1.4198	80
$(CH_3)_2NC(CH_3)_2CN$[b]	$(CH_3)_2NH$		50	20	1.4215	87.6
$(C_2H_5)_2NC(CH_3)_2CN$[c]	$(C_2H_5)_2NH$		66–68	14	1.4312	58.6
$HOCH_2CH_2NHC(CH_3)_2CN$[d]	$HOCH_2CH_2NH_2$		80	4	1.4550	58
$(NCC(CH_3)_2NHCH_2{-})_2$[e]	$NH_2CH_2CH_2NH_2$	56				40+
$\left(CH\!\!\begin{smallmatrix}/CH_2CH_2\\ \\ \backslash CH_2CH_2\end{smallmatrix}\!\!CH\right)_2 NC(CH_3)_2CN$[f]	$\left(CH\!\!\begin{smallmatrix}/CH_2CH_2\\ \\ \backslash CH_2CH_2\end{smallmatrix}\!\!CH\right)_2 NH$	92–94				36+
$C_6H_5NHC(CH_3)_2CN$[g]	$C_6H_5NH_2$	94				92.5
$p\text{-}HOC_6H_4NHC(CH_3)_2CN$[h]	$p\text{-}NH_2C_6H_4OH$	140–142				68
$CH_2\!\!\begin{smallmatrix}/CH_2CH_2\\ \\ \backslash CH_2CH_2\end{smallmatrix}\!\!NC(CH_3)_2CN$[i]	$CH_2\!\!\begin{smallmatrix}/CH_2CH_2\\ \\ \backslash CH_2CH_2\end{smallmatrix}\!\!NH$	44–46	93–94	14		70.7

[a] Prepared by allowing acetone cyanohydrin and liquid ammonia to stand in an iron cylinder, ref. 1. [b] Obtained from a commercial mixture containing 60% dimethylamine and 40% trimethylamine. The procedure incidentally serves as a method for separating the two amines. The compound was previously reported by Henry[12] from acetone, dimethylamine and hydrogen cyanide and by Luten (ref. 6) from acetone, potassium cyanide and dimethylamine hydrochloride. *Anal.* Calcd. for $C_6H_{12}N_2$: N, 25.00. Found: N, 25.09. [c] Previously prepared with great difficulty by Stewart and Cook (ref. 4) from acetone, sodium sulfite, diethylamine and potassium cyanide. *Anal.* Calcd. for $C_8H_{16}N_2$: N, 20.00. Found: N, 20.13. [d] *Anal.* Calcd. for $C_6H_{12}N_2O$: N, 21.87. Found: N, 21.98. [e] Schlesinger,[13] m. p. 55–56, from ethylenediamine hydrochloride, acetone and potassium cyanide. Both methods were employed in the present study. [f] *Anal.* Calcd. for $C_{16}H_{28}N_2$: N, 11.29. Found: N, 11.95. [g] Easily prepared in 25-lb. lots at room temperature. Previously prepared by Bucherer and Grolee (ref. 3) in ether solution. [h] Bucherer and Grolee (ref. 3) reported m. p. 137°. *Anal.* Calcd. for $C_{10}H_{12}N_2O$: N, 15.91. Found: N, 15.89. [i] Previously prepared by Velghe[14] and Walter and McElvain[15] from piperidine hydrochloride, acetone and potassium cyanide. The melting point and boiling point are not stated. *Anal.* Calcd. for $C_9H_{16}N_2$: N, 18.41. Found: N, 18.27.

instances the yields of α-amino-isobutyronitriles were considerably higher. Ammonia, dimethylamine and aniline, for example, reacted with acetone cyanohydrin at room temperature to give α-aminoisobutyronitrile, α-dimethylaminoisobutyronitrile and α-phenylaminoisobutyronitrile, in yields of 80, 87, and 92.8%, respectively. Dicyclohexylamine and acetone cyanohydrin reacted at room temperature to yield the new α-dicyclohexylaminoisobutyronitrile. A new amino-nitrile, *i. e.*, α-(β-hydroxyethylamino)-isobutyronitrile, was also prepared from acetone cyanohydrin and monoethanolamine. Table I summarizes the α-aminonitriles obtained by this procedure. Acetone cyanohydrin did not react either with urea or with formamide under the conditions employed.

α-Aminoisobutyronitrile reacted with carbon disulfide to yield 5,5-dimethyl-2,4-dithiohydantoin.[8] This reaction is of interest in being analogous to the preparation of 5,5-dimethylhydantoin from α-aminoisobutyronitrile and carbon dioxide.[9] Its structure was established (Dr. N. E. Searle) by converting the compound to 5,5-dimethylhydantoin with ammoniacal hydrogen peroxide. Recently, Henze and Smith[10] have gone in the reverse direction, *i. e.*, from 5,5-dimethylhydantoin to 5,5-dimethyl-2,4-dithiohydantoin, by treating the former with phosphorus trisulfide.

α-Aminoisobutyronitrile also reacted readily

(8) Detailed directions for its preparation are given in Jacobson, U. S. Patent 2,143,816.
(9) Ref. 1b.
(10) Henze and Smith, This Journal, **65**, 1090 (1943).

with acetic anhydride to give the acetyl derivative, with methacrylyl chloride to give the methacrylyl derivative, $CH_2{=}C(CH_3)CONHC(CH_3)_2$-CN, with phenyl isocyanate to yield N-(α-cyanoisopropyl)-N'-phenylurea, $C_6H_5NHCONHC$-$(CH_3)_2CN$ and with phosgene to give 1,3-bis-(α-cyanoisopropyl)-urea. The three latter compounds have not been previously described.

Experimental

Derivatives from α-Aminoisobutyronitrile

α-**Acetamidoisobutyronitrile** was prepared by treating α-aminoisobutyronitrile with acetic anhydride, m. p. 105–106° (literature 106°).[11]

α-**Methacrylamidoisobutyronitrile,** $(CH_2{=}C(CH_3)$-$CONHC(CH_3)_2CN)$.—The methacrylyl derivative was prepared by the reaction of α-methacrylyl chloride with α-aminoisobutyronitrile. Crystallization from water gave needles melting at 103–104°.

Anal. Calcd. for $C_8H_{12}N_2O$: N, 18.42. Found: N, 18.21.

N-(α-**Cyanoisopropyl**)-N'-**phenylurea** $(C_6H_5NHCON$-$HC(CH_3)_2CN)$ was prepared from α-aminoisobutyronitrile and phenyl isocyanate. Crystallization from alcohol yielded beautiful white crystals melting at 135–135.5°.

Anal. Calcd. for $C_{11}H_{13}N_3O$: N, 20.69. Found: N, 20.54.

1,3-**Bis**-(α-**cyanoisopropyl**)-**urea** $(NCC(CH_3)_2NHCON$-$HC(CH_3)_2CN)$.—This urea derivative was obtained by passing phosgene into a toluene solution of α-aminoisobutyronitrile. Crystallization from alcohol yielded white crystals melting at 238°.

(11) Hellsing, *Ber.*, **37**, 1921 (1904).
(12) Henry, *Bull. acad. roy. Belg.*, 741 (1904).
(13) Schlesinger, *Ber.*, **47**, 2416 (1914); **44**, 1136 (1911).
(14) Velghe, *Bull. sci. acad. roy. Belg.*, (5) **11**, 301 (1925).
(15) Walter and McElvain, This Journal, **56**, 1614 (1934).

Anal. Calcd. for $C_9H_{14}N_4O$: N, 28.86. Found: N, 28.40.

5,5-Dimethyl-2,4-dithiohydantoin.—A yield of 535 g. of 5,5-dimethyl-2,4-dithiohydantoin (m. p. 143°) was obtained from 420 g. of carbon disulfide and 925 g. of α-aminoisobutyronitrile (see ref. 8). *Anal.* Calcd. for $C_5H_8N_2S_2$: C, 37.50; H, 5.00; S, 40.00. Found: C, 37.44; H, 5.00; S, 40.16.

Acknowledgment.—The author wishes to express his indebtedness to Dr. N. E. Searle of the Chemical Department of E. I. du Pont de Nemours & Company for proving that the compound derived from carbon disulfide and α-aminoisobutyronitrile is 5,5-dimethyl-2,4-dithiohydantoin.

Summary

1. A number of N-substituted α-aminoiso-butyronitriles have been conveniently prepared from acetone cyanohydrin and amines, usually in good yields. α-Dicyclohexylaminoisobutyronitrile and α-(β-hydroxyethylamino)-isobutyronitrile have not been previously described.

2. Several new derivatives have been prepared from α-aminoisobutyronitrile. These include the methacrylyl derivative $(CH_2=C(CH_3)CONHC-(CH_3)_2CN)$, N-(α-cyanoisopropyl)-N'-phenyl-urea, $(C_6H_5NHCONHC(CH_3)_2CN)$, and 1,3-bis-(α-cy-anoisopropyl)-urea $(NCC(CH_3)_2NHCONHC-(CH_3)_2CN)$.

3. 5,5-Dimethyl-2,4-dithiohydantoin has been prepared from α-aminoisobutyronitrile and carbon disulfide.

Methacrylylurea and N-Phenyl-N'-methacrylylurea

BY RALPH A. JACOBSON

The preparation of monosodium urea and its reactions with esters to obtain acyl ureas were described in a preceding paper.[1] Methacrylyl-urea has now been prepared from monosodium urea and methyl methacrylate. The methacrylyl derivatives of phenylurea, aniline and phenyl-hydrazine have also been obtained by reaction of their respective sodium derivatives with methyl methacrylate.[2]

At 5 to 10° methyl methacrylate reacts with monosodium urea in the presence of acetone to yield methacrylylurea, $CH_2=C(CH_3)CONHCO-NH_2$. N-Phenyl-N'-methacrylylurea is obtained in an analogous manner from methyl methacrylate and N-sodium-N'-phenylurea. The monosodium urea and sodium phenylurea required as intermediates are easily obtained by the reaction of metallic sodium upon urea and phenylurea in liquid ammonia. In fact, the sodium derivatives need not be isolated since the subsequent reaction with methyl methacrylate goes well in liquid ammonia.

Methacrylylurea is soluble in water, alcohol and other organic solvents. It readily polymerizes when heated in alcohol solution in the presence of benzoyl peroxide. The polymeric form of methacrylylurea is an amorphous white powder, insoluble in water, alcohol and in the common organic solvents but soluble in dilute alkali. Since methacrylylurea polymerizes rather easily even in the absence of catalysts, any method of preparation involving high temperatures is unsuitable. The method here described has the advantage that only the mildest of experimental conditions are required. N-Phenyl-N'-methacrylylurea does not polymerize so readily as methacrylylurea.

The preparation of the methacrylyl derivatives of aromatic amines through their sodium derivatives is also feasible. Methyl methacrylate reacts, for example, with sodium aniline and with sodium phenylhydrazine to yield methacrylyl-aniline and N-methacrylyl-N'-phenylhydrazine, respectively. These compounds also polymerize, although less readily than methacrylylurea.

Experimental

N-Sodium-N'-phenylurea.—To a solution of 45 g. of phenylurea (0.33 mole) dissolved in 1 liter of liquid ammonia was slowly added 7.66 g. (0.33 mole) of sodium. Reaction proceeded smoothly and after each addition of sodium, the blue color was quickly discharged. The ammonia was allowed to evaporate overnight and the product was obtained as a white reactive powder; yield 51 g. (96%). The following analytical data were obtained on this crude product.

Anal. Calcd. for $C_7H_7N_2ONa$: N, 17.72; Na, 14.55. Found: N, 16.76; Na, 13.75.

Methacrylylurea.—A mixture of 2400 g. (24 moles) of methyl methacrylate, 656 g. (8 moles) of monosodium urea,[1] and 600 cc. of acetone was mechanically stirred for three hours at 5–10°. The thick yellow mixture was stirred, and 1520 cc. of 18% hydrochloric acid added at such a rate that the temperature of the mixture did not exceed 25°. The mixture was cooled to 2°, filtered with suction, and the excess methyl methacrylate recovered as the upper layer (1980 g.) of the filtrate. Crystallization of the solid material from alcohol yielded 384 g. (38%) of methacrylylurea, m. p. 133–134°.

Anal. Calcd. for $C_5H_8N_2O_2$: N, 21.87. Found: N, 21.39.

Methacrylylurea was also prepared by treating a solution of 200 g. (2 moles) of methyl methacrylate and 120 g. (2 moles) of urea in 1 liter of liquid ammonia with 46 g. (2 moles) of sodium; yield 112 g. (43.7%).

N-(α,β-Dichloroisobutyryl)-urea.—Chlorine was passed into a suspension of 32 g. (0.25 mole) of methacrylylurea in 150 cc. of carbon tetrachloride. The heat of reaction caused the carbon tetrachloride to boil. The reaction product at first dissolved in the solvent but in half an hour it separated as a crystalline mass. The mixture was diluted

(1) Jacobson, THIS JOURNAL, **58**, 1984 (1936).

(2) Jacobson, U. S. Patents 2,090,592, 2,090,594 and 2,090,596.