

NITROLYSIS OF 1,3,5-TRIS(β -CYANOETHYL)HEXAHYDRO-*s*-TRIAZINE*

V. KADĚŘÁBEK and J. DENKSTEIN

Department of Technology of Organic Compounds,
Institute of Chemical Technology, 532 10 Pardubice

Received May 16th, 1975

Nitrolysis of 1,3,5-tris(β -cyanoethyl)hexahydro-*s*-triazine (*I*) has been studied in nitric acid-acetic anhydride medium, when a mixture of N-acetoxymethyl-3-nitraminopropionitrile (*III*) and 4,6-dinitro-4,6-diazanonanedioic acid dinitrile (*IX*) is formed predominantly. Ratio of the both main reaction products *III* and *IX* is markedly affected especially by acidity of the reaction medium. Yields of the dinitrile *IX* can positively be influenced by the presence of nitrate of 3-aminopropionitrile in the nitrolysis course. Structure of the compound *III* was proved by its transformation into 3-nitraminopropionitrile (*IV*) which was independently synthesized by nitration of 3-acylamino propionitriles and decylation of the corresponding nitroamides. For preparation of the nitrile *IV* the method of decyanoethylation of 4-nitro-4-azaheptanedioic acid dinitrile has been found useful, too.

In our previous communication¹ we described the nitrolysis of 1,3,5-tris(cyanomethyl)-hexahydro-*s*-triazine (*II*) which, under appropriate conditions, can serve for preparation of N,N'-disubstituted methylenedinitramines, in the given case 3,5-dinitro-3,5-diazaheptanedioic acid dinitrile. This paper presents a summary of results of our study of structurally analogous 1,3,5-tris(β -cyanoethyl)hexahydro-*s*-triazine (*I*). At the same time various methods were investigated for preparation of 3-nitraminopropionitrile (*IV*) and 3-nitraminopropionic acid (*XII*) for the sake of identification of nitrolysis products of the triazine *I* under various conditions, because the compounds *IV* and *XII* are structural skeletons of the nitrolysis products.

The nitrolysis of the compound *I* proceeds similarly as that of the N-cyanomethyl analogue¹; predominant product of the nitrolytic splitting is N-acetoxymethyl-3-nitraminopropionitrile (*III*) accompanied by 4,6-dinitro-4,6-diazanonanedioic acid dinitrile (*IX*). The both compounds are formed in varying ratio which is sensitive to the reaction conditions, especially to the acidity of medium which, in the binary system acetic anhydride-nitric acid, is given by the molar excess of nitric acid in the reaction mixture or by addition of strong acids as *e.g.* sulphuric acid. Partial yields of the both main nitrolysis products (*III* and *IX*) reach a marked maximum; however, at higher acidity the partial yield of the dinitrile *IX* is suppressed more markedly (Table 1). However, even at the optimum conditions found for this case the

* Part VII in the series Syntheses in Nitramine Series; Part VI: This Journal 31, 2928 (1966).

yield of the dinitrile *IX* does not exceed 10 to 11%, which stands in contrast to analogous nitrolyses of the cyanomethyl substituted triazine *II*.

Thus from the preparative viewpoint the nitrolysis of the compound *I* is not very advantageous for obtaining the dinitrile *IX*. Yields of *IX* can, however, be increased markedly by the presence of 3-aminopropionitrile nitrate in the reaction mixture. This type of reaction, which can be called nitrolysis under modified Bachman conditions (nitrolysis of polymethyleneamines in the presence of ammonium nitrate²), will be described more generally within another context³.

Easy deacetylmethylation of the compound *III* in alkaline medium giving ammonium salt of 3-nitraminopropionitrile can be used for isolation of the dinitrile *IX*. The latter compound can be isolated from aqueous solution as crystalline solid. In this procedure, 3-nitraminopropionitrile (*IV*) was isolated from the aqueous filtrate by acidification and extraction in the yields 27 to 28%.

Structure of the dinitrile *IX* was proved by its transformation in 4,6-dinitro-4,6-diazanonanedioic acid (*X*) and the corresponding dimethyl ester *XI*.

Analogous nitrolysis experiments with the condensation product of formaldehyde and β -aminopropionic acid⁴ (whose structure has not yet been fully confirmed) led to a complex reaction product the composition of which could not be completely identified.

Further 3-nitraminopropionitrile (*IV*) was prepared by nitration of 3-acylamino-propionitriles and deacylation (Eq. (A)),

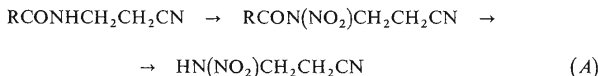


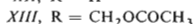
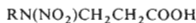
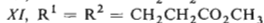
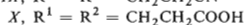
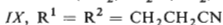
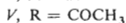
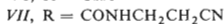
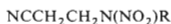
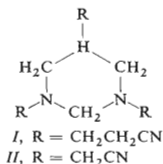
TABLE I

Nitrolysis of the Compound *I* in Acetic Anhydride-Nitric Acid Medium

Starting amount of the compound *I* 6.0 g (0.024 mol); acetic anhydride 12.5 ml (0.131 mol).

Experiment No	99.5% HNO ₃ , ml	Overall yield of the liquid portion g	Yield of the compound <i>IX</i>		M.p., °C (raw product)
			g	%	
1	3.2	4.70	0.33	3.43	95–105
2	4.0	7.50	0.62	10.50	105–110
3	5.5	8.90	0.57	9.65	105–110
4	6.6	8.80	0.44	7.45	105–109

R = H, CH₃, by N-nitration of N,N'-bis(β -cyanoethyl)urea and hydrolysis, and by partial decyanoethylation of 4-nitro-4-azaheptanedioic acid dinitrile. The last procedure is most advantageous, giving about 50% yields of the compound IV. This procedure gives comparable yields also in the preparation of the acid XII whose preparation procedures given in literature so far^{5,6} are lengthy and difficult.



EXPERIMENTAL

Melting points were determined with the use of a microscopic melting point apparatus and are not corrected. Infrared spectra of the compounds in KBr discs, solutions or Nujol were recorded with a UR-20 (Zeiss, Jena) spectrophotometer. Chromatography and detection of the compounds were carried out as in the previous work¹ (Whatman No 3 paper impregnated with formamide, eluent systems saturated with formamide: 1,2-dichloroethane (S₁), 1,2-dichloroethane-chloroform 1 : 1 (S₂), chloroform (S₃), tetrachloromethane-chloroform 1 : 1 (S₄); detection with the Franchimont test¹) or on the plates Silufol UV 254 with benzene-acetone 2 : 1 (S₅) as eluent and with detection by spraying with 2% ethanolic diphenylamine and irradiation with UV light.

1,3,5-Tris(β -cyanoethyl)hexahydro-*s*-triazine (I)

Aqueous formaldehyde (37%, 97.4 g, 1.2 mol) was added drop by drop to β -aminopropionitrile⁷ (70.1 g, 1.0 mol) at 10–15°C with stirring, and the obtained solution was stirred at 20–25°C 30 minutes. If not any solid precipitated, the solution was saturated with sodium chloride, the separated liquid was removed and cooled to 0–10°C for crystallization. Filtration and washing

with ethanol and ether gave 75.0 g (90%) of the product *I*, m.p. 66–68°C after recrystallization from water. For $C_{12}H_{18}N_6$ (246.3) calculated: 58.51% C, 7.35% H, 34.12% N; found: 58.66% C, 7.65% H, 34.41% N. Neutralization equivalent 99.80%.

4,6-Dinitro-4,6-diazanonanedioic Acid Dinitrile (*IX*)

A. Nitration of the compound I with nitric acid–acetic anhydride mixture. The compound *I* (6.0 g, 0.024 mol) was added portionwise to a stirred mixture of 99.5% nitric acid and acetic anhydride at 10–15°C during 3–5 minutes; the reaction mixture was stirred at 20–25°C 2 h, poured in 60 ml water, neutralized with $NaHCO_3$, and the separated liquid was removed and dried *in vacuo* (20–25°C/1–2 Torr). A further portion of the product was obtained by extraction of the reaction liquid with methylene chloride (3. 10 ml) and distillation off of the solvent. The compounds *IX* and *III* were separated by heating the obtained liquid with ammonium hydroxide until dissolution (4 ml 25% aqueous ammonia per 1 g of the liquid); after cooling to 20°C the precipitated crystalline product *IX* was filtered off. Influence of varying molar ratio of the compound *I* and 99.5% nitric acid on the yield of the reaction (compound *IX* and the liquid portion) is given⁸ in Table I. Dinitrile *IX*, m.p. 105–110°C; after recrystallization from ethanol and acetone m.p. 109–112°C. For $C_7H_{10}N_6O_4$ (242.2) calculated: 34.71% C, 4.16% H, 34.70% N; found: 34.74% C, 4.32% H, 34.42% N. IR spectrum (KBr): $\nu(NO_2)$ 1274, 1285, 1548 cm^{-1} ; $\nu(C\equiv N)$ 2258 cm^{-1} . R_F 0.39 (S_1).

B. Nitration of the compound I with nitric acid–acetic anhydride mixture in the presence of β -aminopropionitrile. The compound *I*, β -aminopropionitrile nitrate, and 99% nitric acid were added successively into stirred acetic anhydride at 55–60°C. Each of the reaction components was divided into 7 parts, and every component was added in acetic anhydride first after dissolution of the foregoing portion in the reaction mixture. After the dosing the reaction solution was stirred at 60°C 30 minutes, cooled to 20°C, and diluted by pouring in 60 ml water. The separated liquid was removed and further worked up as in the procedure *A*. Table II gives the dependence of the yields of the product *IX* on the reaction conditions.

4,6-Dinitro-4,6-diazanonanedioic Acid (*X*)

The dinitrile *IX* (1.0 g) was heated on a water bath under reflux with 5.0 ml 37% hydrochloric acid for 15 minutes. After cooling the solution to 15°C the precipitated acid *X* (0.5 g, 43%) was filtered off, m.p. 178–185°C; after recrystallization (water) m.p. 187–189°C. For $C_7H_{12}N_4O_8$ (280.2) calculated: 30.01% C, 4.32% H, 20.00% N; found: 30.31% C, 4.60% H, 20.09% N. IR spectrum (KBr): $\nu(NO_2)$ 1282, 1544 cm^{-1} ; $\nu(C=O)$ 1718 cm^{-1} . R_F 0.53 (S_5).

Dimethyl ester: The diacid *X* (1.0 g) was heated to boiling in 50 ml methanol with addition of 96% sulphuric acid (0.2 ml) for 1 h. After distilling off methanol the compound *XI* obtained melted at 60–62°C; after recrystallization (methanol) m.p. 64–65°C. For $C_9H_{16}N_4O_8$ (308.2) calculated: 35.07% C, 5.23% H, 18.18% N; found: 35.18% C, 5.39% H, 18.29% N. IR spectrum (Nujol): $\nu(NO_2)$ 1283, 1541 cm^{-1} ; $\nu(C=O)$ 1713, 1729 cm^{-1} . R_F 0.46 (S_5), 0.64 (S_4).

3-Nitraminopropionitrile (*IV*)

A. Hydrolysis of N-formyl-N-(β -cyanoethyl)nitramine (VI). N-(β -cyanoethyl)formamide⁹ (10 g, 0.119 mol) was dissolved in acetic anhydride (14.0 ml, 0.147 mol) at 15°C and 99.5% nitric acid (15.5 ml, 0.37 mol) was added to the solution. After raising the temperature to 25°C the solution was stirred 3 hours, and poured into a mixture of ice and water (32 g per 40 ml) so that the temperature did not exceed 0°C. Filtration of the precipitated product gave 4.0 g (27.6%) of the com-

pound VI; m.p. 31–33°C; after recrystallization (ether) m.p. 38–40°C. For $C_4H_5O_3N_3$ (143.1) calculated: 33.57% C, 3.52% H, 29.36% N; found: 33.84% C, 3.77% H, 29.17% N.

The compound VI was dried and dissolved in 85% formic acid (10 ml), and the obtained solution was left to stand overnight. Distilling off formic acid (35–40°C/7–10 Torr) gave the product IV (2.5 g 81.0%), m.p. 40–45°C; after recrystallization (ether) m.p. 51–53°C. For $C_3H_5N_3O_2$ (115.1) calculated: 31.30% C, 4.38% H, 36.51% N; found: 31.08% C, 4.66% H, 36.61% N. IR spectrum (dichloromethane): $\nu(NO_2)$ 1283, 1581 cm^{-1} ; $\nu(C\equiv N)$ 2256 cm^{-1} ; $\nu(N-H)$ 3384 cm^{-1} ; $\nu(N-D)$ 2528 cm^{-1} . R_F 0.07 (S_1), 0.03 (S_3).

B. *Deacetylation of N-acetyl-N-(β -cyanoethyl)nitramine (V)*. N-(β -cyanoethyl)acetamide¹⁰ (10 g, 0.089 mol) was nitrated in the same way as given in preparation of the compound VI. The reaction mixture was poured onto crushed ice (70 g) and the mixture of oily liquid and water was neutralized with potassium hydrogen carbonate; the separated liquid was removed, washed with water (2 . 10 ml) and dried *in vacuo*. Yield 4.4 g (31%) liquid n_D^{20} 1.4907. Attempts of distillation under reduced pressure led to decompositions. The raw nitramide V was submitted to alkaline hydrolysis in aqueous ammonium hydroxide (4.0 g in 8.0 ml 25%), and after acidification and extraction it gave an evaporation residue (2.1 g) which crystallized on standing. Yield 1.5 g (10.0%) compound V, m.p. 40–45°C. R_F 0.07 (S_1).

C. *Decyanoethylation of 4-nitro-4-azaheptanedioic acid dinitrile (VIII)*. The dinitrile¹¹ VIII (42.0 g, 0.25 mol) was heated with potassium hydroxide solution (14.0 g, 0.25 mol in 180 ml water) with stirring on a water bath under reflux for 1 hour. After cooling to 20°C the solution was neutralized with 37% hydrochloric acid and extracted with ether (8 . 30 ml). Yield 14.2 g (48.9%) compound IV, m.p. 44–49°C; after recrystallization (water) m.p. 49–50°C. R_F 0.07 (S_1), 0.03 (S_3).

TABLE II

Nitrolysis of the Compound I (3.5 g, 0.014 mol) in Acetic Anhydride–Nitric Acid Medium in the Presence of Nitrate of 3-Aminopropionitrile; Acetic Anhydride (13.0 ml, 0.136 mol)

Experiment	Nitrate of 3-amino- propionitrile, g	99.5% HNO_3 , ml	Yield of the compound IX		M.p., °C
			g	%	
1	2.1	2.8	0.60	17.7	104–107
2	2.1	3.5	0.55	16.2	98–103
3	2.8	2.8	0.45	13.2	102–106
4	2.8	3.5	0.25	7.4	98–104
5	3.5	1.4	0.35	10.3	100–104
6	3.5	2.1	0.40	11.8	102–106
7	3.5	3.5	0.30	8.8	103–106
8 ^a	3.5	3.5	0.15	4.4	103–106
9	5.6	3.5	0.25	7.4	100–104

^a Acetic anhydride amount 18 ml.

D. *Hydrolysis of N-nitro-N,N'-bis(β-cyanoethyl)urea* (VII). Nitric acid 99.5% (0.6 ml, 0.0145 mol) was added drop by drop to a stirred mixture of N,N'-bis(β-cyanoethyl)urea¹² (0.8 g, 0.0048 mol) and acetic anhydride (2.0 ml, 0.021 mol) at 0–5°C; after 2 hours stirring at 5–10°C the reaction mixture was diluted with ice water (0–5°C), and the precipitated crystalline product VII was filtered off after 5 minutes. The substance was washed with ice water (3 . 3 ml) and dried on a sintered glass by suction until constant weight. Yield 0.85 g (84%), m.p. 52–61.5°C. The compound VII is very unstable in boiling water. Not more than 2 to 3 minutes boiling in water (0.7 g VII, 0.0033 mol in 5 ml) brings about decomposition with crystallization of a compound m.p. 140–149°C (0.15 g) and formation of the original N,N'-bis(β-cyanoethyl)urea. Evaporation residue of the aqueous filtrate was chromatographically identified as the compound IV. R_F 0.07 (S₁), 0.03 (S₂).

Attempts to nitrate the compound VII to a higher degree failed, the starting mononitro derivative being regenerated in all cases. For C₇H₉N₅O₃ (211.2) calculated: 39.81% C, 4.30% H, 33.17% N; found: 40.09% C, 4.48% H, 33.11% N.

N-(Acetoxymethyl)-3-nitraminopropionitrile (III)

A. *Acetoxymethylation of the compound IV*. Mixture of acetic anhydride (12.0 ml, 0.126 mol) and anhydrous sodium acetate (2.0 g, 0.024 mol) was added to the compound V (4.5 g, 0.039 mol) in 37% formaldehyde (4.5 ml, 0.064 mol) with stirring at 50°C. Cooling was required to maintain the temperature of the reaction mixture within 40–50°C, and after the main reaction ceased the solution was maintained at 60–70°C for 1 hour. Cooling to 20°C, dilution with water (30 ml) and neutralization with potassium hydrogen carbonate resulted in separation of oily liquid (2.2 g); the liquid was removed, and the mother liquor extracted with chloroform (3 . 20 ml). The overall yield 3.1 g (52.7%). Repeated distillation at 152–154°C/2–3 Torr gave the compound III, n_D^{20} 1.4970. For C₆H₉N₃O₄ (187.1) calculated: 38.50% C, 4.85% H, 22.45% N; found: 38.38% C, 5.20% H, 22.57% N. IR spectrum (dichloromethane): $\nu(\text{NO}_2)$ 1289, 1555 cm⁻¹; $\nu(\text{C}=\text{O})$ 1740 cm⁻¹; $\nu(\text{C}\equiv\text{N})$ 2257 cm⁻¹. R_F 0.73 (S₂).

B. *Nitration of the compound I* by the procedure described with preparation of the dinitrile IX and vacuum distillation (152–154°C/2–3 Torr) of the separated liquid combined with the liquid obtained by extraction of the mother liquor gave a product having identical properties with the compound III prepared by the above procedure A. R_F 0.73 (S₂).

3-Nitraminopropionic Acid (XII)

3-Nitraminopropionitrile (IV) (5.97 g, 0.052 mol) and sodium hydroxide (4.15 g in 38 ml water) were heated to boiling for 75 hours, then neutralized with 96% sulphuric acid (5.1 g, 0.052 mol), and the solution was concentrated *in vacuo* (25–30°C/20 Torr) to crystallization of sodium sulphate. The suspension was diluted with ethanol, the undissolved portions were filtered off, and the filtrate was evaporated *in vacuo*. Yield of the compound XII 4.2 g (60.4%), m.p. 64–72°C; after recrystallization (ether) m.p. 69–72°C; ref.⁶ gives m.p. 70.5–72°C. IR spectrum (Nujol): $\nu(\text{NO}_2)$ 1296, 1580 cm⁻¹; $\nu(\text{C}=\text{O})$ 1712 cm⁻¹. R_F 0.35 (S₅).

The elemental analyses were carried out in Analytical Chemistry Department, Institute of Chemical Technology, Pardubice. The authors are indebted to Mrs M. Nováková for technical assistance.

REFERENCES

1. Denkstein J., Kadeřábek V.: This Journal 31, 2928 (1966).
2. Bachman I. W. E., Sheenan J. C.: J. Amer. Chem. Soc. 71, 1842 (1949).
3. Denkstein J., Kadeřábek V.: This Journal, in press.
4. Franzen H., Fellmer E.: J. Prakt. Chem. 2, 95, 307 (1917).
5. Franchimont A. P. N., Friedman R.: Rec. Trav. Chim. Pays-Bas 26, 220 (1906).
6. Hardy J., Spratt D. A., Meer G. C. (I. C. I. Ltd.): Brit. 1005860; Chem. Abstr. 63, 17911 (1965).
7. *Organic Syntheses*, Coll. Vol. 3, p. 93. Wiley-Interscience, New York 1955.
8. Sobotka M.: *Thesis*. Institute of Chemical Technology, Pardubice 1968.
9. Badische Anilin und Soda Fabrik: Fr. 976959; Chem. Abstr. 47, 9348 (1953).
10. Olin J. F.: U.S. 2461842; Chem. Abstr. 43, 3841 (1949).
11. Frankel M. B., Vanneman C. R.: J. Org. Chem. 23, 1810 (1958).
12. Bayer O.: Ann. N. Y. Acad. Sci. 59, 257 (1947).

Translated by J. Panchartek.