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Synthesis of Nitro Compounds Starting with Dialkyl Aminomalonates

M. A. Ishchenko, V. D. Nikolaev, A. A. Sokolov, and S. V. Nikolaeva

St. Petersburg Technological Institute, St.Petersburg, 198013 Russia

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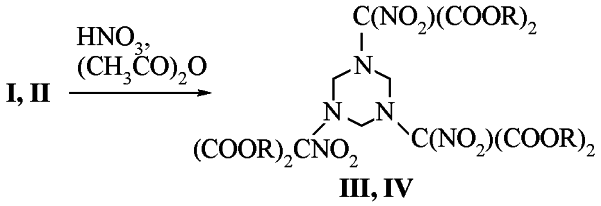
Abstract—By reaction of dialkyl aminomalonates with formaldehyde were prepared 1,3,5-tris(dialkoxycarbonylmethyl)hexahydro-1,3,5-triazines that on nitration under mild conditions yielded the corresponding nitromethyl derivatives. The reaction of dialkyl aminomalonates with formaldehyde and polynitroalkanes operating as C—H acids results in Mannich bases. The latter were subjected to nitration with mixtures of sulfuric and nitric acids to afford dimethyl and diethyl 2,2,2-polynitroalkylnitroaminonitromalonates.

Dialkyl aminomalonates as polyfunctional compounds are prone to participate in versatile chemical reactions yielding new useful substances [1, 2]. The presence of an amino group in the molecule enables it to react with aldehydes, and also with aldehydes and compounds possessing active hydrogen atoms (Mannich type reaction) [3, 4]. Two ester groups in the molecule of dialkyl aminomalonate and its N-substituted derivatives are attached to the central carbon atom and possess electron-withdrawing properties (*–I*-effect). This fact and also high electronegativity of the nitrogen atom linked to the carbon activate the C–H σ-bond and allow to expect that these compounds can be nitrated into new nitro compounds. Yet the presence in the molecule of dialkyl aminomalonate of antagonistic groups, an amino and two ester groups, requires special caution: It should be stored as hydrochloride, and the conditions of chemical reactions therewith should be carefully selected.

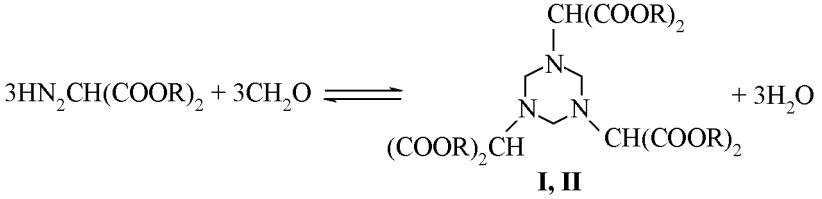
The condensation of primary aliphatic amines with formaldehyde is known to afford 1,3,5-trialkylhexahydro-1,3,5-triazines [5] and more seldom monomeric azomethines [6]. We presumed that the dialkyl aminomalonates (dimethyl and diethyl aminomalonates) would provide by reaction with formaldehyde 1,3,5-tris(dialkoxycarbonylmethyl)hexahydro-1,3,5-triazines

Actually, when to the water solution of dialkyl aminomalonate and formaldehyde at 0–25°C was added sodium acetate to pH 4–4.5 a second light-yellow oily phase separated that was easily extracted into dichloromethane. On drying and removing the solvent we obtained compounds **I** and **II** in 70–80% yield that were subjected to nitration with a mixture of concentrated nitric acid and acetic anhydride without further purification.



R = CH_3 (**III**), C_2H_5 (**IV**).

In both cases as a result of nitration after usual workup were separated thick oily yellow substances that according to IR spectra contained a mixture of nitro compounds. It was found that efficient purification of the target 1,3,5-tris(dialkoxycarbonylnitromethyl)hexahydro-1,3,5-triazines (**III, IV**) occurred



R = CH_3 (**I**), C_2H_5 (**II**).

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by treating the obtained mixture with a solution of concentrated sulfuric acid in trifluoroacetic acid. This mixture catalyzed the decomposition of impurities. Compounds **III** and **IV** are colorless crystalline substances sufficiently stable for storage under common conditions.

Let us assume that the first stage of 1,3,5-tris(dialkoxycarbonylmethyl)hexahydro-1,3,5-triazines (**I, II**) formation consists in reaction of dialkyl aminomalonate with formaldehyde yielding the corresponding N-oxymethyl derivative of the amine. The protonation and dehydration of the latter should afford mesomerically stabilized aminocarbenium ion. Then the addition into the reaction system of nucleophilic reagents, e.g. polynitroalkanes, should provide the necessary and favorable conditions for Mannich reaction [7–10]. As C–H acids to serve acidic components in Mannich reaction we chose readily available trinitromethane (nitroform) and 1,1-dinitroethane that were used in reaction in the form of the corresponding β-polynitroalcohols, 2,2,2-trinitroethanol and 2,2-dinitropropanol. Condensation of the dimethyl and diethyl aminomalonates with the mentioned polynitroalcohols furnished the corresponding Mannich bases **V–VII**.

$$R'C(N_2O)_2CH_2OH + H_2NCH(COOR)_2$$

$$\rightleftharpoons R'C(N_2O)_2CH_2NHCH(COOR)_2 + H_2O$$

V–VII

R' = NO_2, R = CH_3 (**V**), C_2H_5 (**VI**);
R = R' = CH_3 (**VII**).

Compounds **V–VII** possess to two neighboring reactive centers capable of electrophilic substitution. It was presumable that the nitration of these compounds would occur both at amino group and at the carbon bonded to the labile hydrogen in the malonic ester moiety. Actually at low-temperature nitration we obtained dimethyl and diethyl 2,2,2-trinitroethylnitraminonitromalonates and 2,2-dinitropropylnitraminonitromalonates (**VIII–X**).

V–VII

$$\xrightarrow{HNO_3/H_2SO_4} R'C(N_2O)_2CH_2N(NO_2)C(NO_2)(COOR)_2$$

VIII–X

R' = NO_2, R = CH_3 (**VIII**), C_2H_5 (**IX**); R = R' = CH_3 (**X**).

The polynitroalkylnitraminonitromalonic acids esters obtained are sufficiently thermally stable disregarding the presence in α-position to the nitramino group of three electron-withdrawing substituents, one nitro and two ester groups. Some nitromethylamine derivatives, for instance, nitromethyl isocyanate [11] and nitromethylimides [12] were formerly described; however isolation of nitromethylamine failed. Kissinger and Ungnade [11] presumed that nitromethylamines containing hydrogen atom attached to nitrogen were prone to eliminate nitrous acid.

Thus we demonstrated that starting with dialkyl aminomalonate it was possible to prepare new interesting nitro compounds useful for the study of interconnection of the structure and both physical and chemical characteristics of a substance.

The polynitro compounds obtained here are explosives that require special precautions in handling.

EXPERIMENTAL

IR spectra were measured on spectrometer UR-20 from mulls in mineral oil. ^1H NMR spectra were recorded on spectrometer Perkin-Elmer R-12 (60 MHz), internal reference HMDS. Elemental analyses were carried out on Hewlett-Packard 185B instrument. The homogeneity of compounds was checked by TLC on Silufol UV-254 plates.

Hexamethyl 1,3,5-triazinane-1,3,5-trimalonate (I). To a solution of 5.5 g (0.03 mol) of dimethyl aminomalonate hydrochloride and 2.2 ml (0.03 mol) of 37% formalin in 50 ml of water at 20°C while vigorous stirring was added by small portions sodium acetate till pH 4. The reaction mixture was stirred at the same temperature for 50 min, the separated thick oily substance was extracted into dichloromethane (3–25 ml). The combined extracts were dried with anhydrous $MgSO_4$. The solvent was distilled off. We obtained 3.3 g (70%) of triazine I that was subjected to nitration without purification.

Hexaethyl 1,3,5-triazinane-1,3,5-trimalonate (II). To a solution of 6.35 g (0.03 mol) of diethyl aminomalonate hydrochloride and 2.2 ml (0.03 mol) of 37% formalin in 20 ml of water at 20°C while vigorous stirring was added by small portions sodium acetate till pH 4.5. The reaction mixture was stirred at the same temperature for 10 min, the separated thick oily substance was extracted into dichloromethane (3–25 ml). The combined extracts were dried with anhydrous $MgSO_4$. The solvent was distilled off. We obtained 4.5 g (80%) of triazine **II** that was subjected to nitration without purification.

Hexamethyl α,α′,α″-trinitro-1,3,5-triazinane-1,3,5-trimalonate (III). To a solution of 9.5 g (0.02 mol) of compound **I** in 30 ml of acetic anhydride with stirring at −10°C was added 30 ml of 98% HNO_3. The mixture was stirred for 2 h at the same temperature, and then was poured into 150 ml of water on 150 g of ice. The appeared 5 g (40%) of thick oily substance was separated from the water phase and was added at stirring to a solution of 5 ml of 95% sulfuric acid in 15 ml of trifluoroacetic acid maintaining the mixture temperature at −5–0°C. After 50 min the solution obtained was poured into water with ice, and the separated colorless crystals were filtered off. On recrystallization first from ethanol and then from carbon tetrachloride we obtained 2.5 g (20%) of colorless crystals, mp 167–168°C. IR spectrum, ν, cm^{-1}: 1730 (C=O), 1520, 1285 (NO_2). ^1H NMR spectrum (acetone-d_6), δ, ppm: 3.90 s (18 H, CH_3), 4.70 s (6H, CH_2). Found, %: C 35.11; H 3.87; N 13.84;
$C_{18}H_{24}N_6O_{18}$. Calculated, %: C 35.29; H 3.92; N 13.72.

Hexaethyl-α,α′,α″-trinitro-1,3,5-triazinane-1,3,5-trimalonate (IV) was prepared in a similar way as compound **III**. Yield 30%, mp 54–55°C (from CCl_4). IR spectrum, ν, cm^{-1}: 1725 (C=O), 1510, 1280 (NO_2). ^1H NMR spectrum (acetone-d_6), δ, ppm: 1.30 t (18 H, CH_3), 4.40 q (12H, CH_2), 4.70 s (6H, CH_2).Found, %: C 41.35; H 5.01; N 12.13. $C_{24}H_{36}N_6O_{18}$. Calculated, %: C 41.38; H 5.17; N 12.07.

Dimethyl 2-[(2,2,2-trinitroethyl)amino]malonate (V). To a solution of 7.5 g (0.04 mol) of 2,2,2-trinitroethanol in 90 ml of water at 20°C was added with stirring a solution of 5.5 g (0.03 mol) of dimethyl aminomalonate hydrochloride in 20 ml of water. To the obtained mixture at 20°C while stirring was added dropwise a saturated water solution of sodium acetate till pH 4. The mixture was stirred for another 30 min, the precipitated oily light-yellow substance was separated and dissolved in 100 ml of ethyl ether. The ether solution was washed with water (2–30 ml), dried with anhydrous $MgSO_4$, and concentrated in a vacuum. We obtained 6.5 (70%) of light-yellow oily compound. IR spectrum, ν, cm^{-1}: 1770 (C=O), 1615, 1320 (NO_2). ^1H NMR spectrum ($CDCl_3$), δ, ppm: 3.79 s (6H, CH_3), 3.86 s (2H, CH_2), 5.00 s (1H, CH), 8.70 br.s (1H, NH). The reaction product **V** was also identified by further nitration into compound **VIII**.

Diethyl 2-[(2,2,2-trinitroethyl)amino]malonate (VI) was similarly obtained from diethyl aminomalonate. Light-yellow oily substance, yield 82%. IR spectrum, ν, cm^{-1}: 1770 (C=O), 1615, 1320 (NO_2). ^1H NMR spectrum ($CDCl_3$), δ, ppm: 1.30 t (6H, CH_3), 3.85 s (2H, CH_2), 4.40 m (4H, CH_2), 5.00 s (1H, CH), 8.65 br.s (1H, NH). The reaction product **VI** was identified by nitration into compound **IX**.

Dimethyl 2-[(2,2-dinitropropyl)amino]malonate (VII). A mixture of 18.3 g (0.1 mol) of dimethyl aminomalonate hydrochloride, 6.5 ml of water, 15 g (0.1 mol) of 2,2-dinitropropanol, and 8.2 g (0.1 mol) of sodium acetate was heated to 80°C while stirring, and then was kept at ±5°C for 1 h. The reaction mixture was cooled to 20°C, the formed light-yellow oily substance was separated from the water layer and dissolved in 100 ml of ethyl ether. The ether solution was washed with water (2–30 ml). dried with anhydrous $MgSO_4$, and concentrated in a vacuum. We obtained 23.2 g (83%) of light-yellow oily compound. IR spectrum, ν, cm^{-1}: 1770 (C=O), 1590, 1340 (NO_2). ^1H NMR spectrum ($CDCl_3$), δ, ppm: 2.10 s (3H, CH_3), 2.30 s (6H, CH_3), 3.50 s (2H, CH_2), 4.80 s (1H, CH), 8.55 br.s (1H, NH). The reaction product **VII** was identified by nitration into compound **X**.

Dimethyl 2-nitro-2-[*N*-nitro-*N*-(2,2,2-trinitroethyl)amino]malonate (VIII). To the nitrating mixture prepared from 7 ml of 98% nitric acid and 12 ml of 96% sulfuric acid cooled to 0–5°C was added while vigorous stirring 1.9 g (0.006 mol) of compound **V**. The reaction mixture was stirred for 1 h at 0–5°C and then poured on crushed ice. The separated crystals were filtered off, washed with water, and dried in air. We obtained 2.1 g (86%) of colorless crystalline compounds that was recrystallized from hexane–CCl_4 mixture, 1:1, mp 119.5°C (decomp.). IR spectrum, ν, cm^{-1}: 1775 (C=O), 1600,1300 (NO_2). ^1H NMR spectrum ($CDCl_3$), δ, ppm: 2.00 s (6H, CH_3), 6.30 s (2H, CH_2). Found, %: C 21.03; H 1.85; N 21.01. $C_7H_8N_6O_{14}$. Calculated, %: C 21.00; H 2.00; N 21.00.

Diethyl 2-nitro-2-[*N*-nitro-*N*-(2,2,2-trinitroethyl)amino]malonate (IX) was obtained similarly to compound **VIII**. Colorless crystalline compound, Yield 80%, mp 85°C (hexane–CCl_4, 1:1). IR spectrum, ν, cm^{-1}: 1770 (C=O), 1600, 1300 (NO_2). ^1H NMR spectrum ($CDCl_3$), δ, ppm: 1.40 s (6H, CH_3), 4.40 q (4H, CH_2), 5.90 s (2H, CH_2).Found, %: C 25.22; H 2.82; N 19.52. $C_9H_{12}N_6O_{14}$. Calculated, %: C 25.24; H 2.82; N 19.63.

Dimethyl 2-[*N*-(2,2-dinitropropyl)-*N*-nitroamino]-2-nitromalonate (X) was prepared similarly

to compound **VIII**. Yield 57%, mp 74°C (hexane–CCl_4, 1:1). IR spectrum, ν, cm^{-1}: 1780 (C=O), 1590, 1290 (NO_2). ^1H NMR spectrum ($CDCl_3$), δ, ppm: 2.10 s (3H, CH_3), 2.35 s (6H, CH_3), 5.60 s (2H, CH_2).Found, %: C 25.94; H 3.02; N 18.90. $C_8H_{11}N_5O_{12}$. Calculated, %: C 26.00; H 2.98; N 18.97.

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