Organic Chemistry

Dinitramide and its salts
7.* Alkylation of dinitramide and its salts

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The dinitramide anion shows ambident properties. Its reactions with alkylating reagents give rise to *N*- or *O*-alkylated products or their mixtures. The reactions of alkylated products with bases were studied.

Key words: dinitramide, dinitramide salts, *N*-alkyl-*N*,*N*-dinitroamines, *N*-alkoxy-*N'*-nitrodiazene *N*-oxides.

It has been shown previously[1] that treatment of the dinitramide (DNA) silver salt with methyl iodide (**1**) gives satisfactory yields of *N*-methyl-*N*,*N*-dinitroamine (**2**), the first member of an insufficiently studied class of organic compounds, namely, *N*-alkyl-*N*,*N*-dinitroamines (ADA).

In the present work we studied the regularities of the alkylation of DNA salts. This reaction can also be useful for synthesizing other compounds belonging to this class, including the unknown α-substituted ADAs. This reaction is even more interesting because the DNA anion should display ambident properties, which opens up the possibility of obtaining the hitherto unknown *N*-alkoxy-*N'*-nitrodiazene *N*-oxides (ANDOs). In addition to their purely scientific interest, compounds of this class are interesting as energy-rich materials.

Primary, secondary, and tertiary alkyl halides, alkyl chlorides containing heteroatoms with an unshared electron pair (UEP) at the α-position to the chlorine atom, diazo compounds, and trialkyloxonium salts were studied as alkylating reagents.

It was shown that the reaction and its direction depend significantly on the nature of both reagents. For example, iodide **1** does not react with $KN(NO_2)_2$ in acetonitrile at ~20 °C, whereas the reaction with $AgN(NO_2)_2$ under these conditions takes 2 to 3 days to give ADA **2** in 50 % yield. Similarly, alkylation with allyl iodide (**3**) gives product **4** in 16 % yield. No other alkylation products were found to result from the reactions with **1** and **3**. Conversely, the reaction with ethyl iodide resulted in a mixture of products of *N*- and *O*-ethylation (**5**) and (**6**) in a ratio of ~3 : 2 in 26 % overall yield (Scheme 1).

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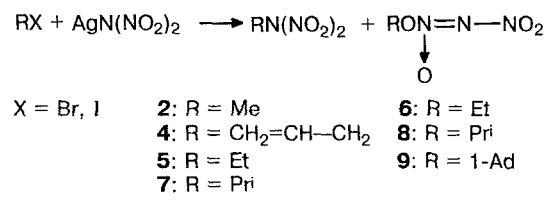
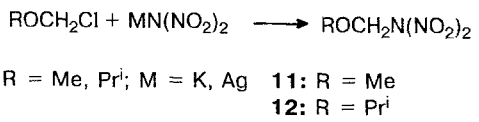
Scheme 1



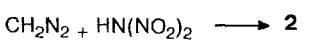
The reaction involving isopropyl iodide mostly gives the *O*-alkylation product (ratio of compounds **7** : **8** ~1 : 5). In the case of isopropyl bromide and 1-bromoadamantane, only products of *O*-alkylation (**8**) and (**9**) were found.

It is well known that alkyl halides, which contain atoms bearing an UEP in the α-position relative to the halogen atom, have much greater reactivity; furthermore, alkylation of ambident ions frequently takes a significantly different direction. In view of this, we studied the alkylation of DNA salts with chloromethyl ethers, *N*-chloromethylamides, and *N*-chloromethylimides. It was found that, unlike aklyl iodides and aklyl bromides, chloromethyl ethers can be used for alkylating alkaline salts of DNA. However, the reaction proceeds slowly: for example, treatment of chlorodimethyl ethers (**10**) with $KN(NO_2)_2$ in acetonitrile for four days gives *N*-methoxymethyl-*N*,*N*-dinitroamine (**11**) in only 7 % yield. Chloromethyl isopropyl ether reacts more readily, even in a heterogeneous medium; this reaction also gives a product of *N*-alkylation (**12**) in 28 % yield. The reaction of ether **10** with $AgN(NO_2)_2$ occurs almost two orders of magnitude more quickly, while product **11** is formed in a several times greater yield.



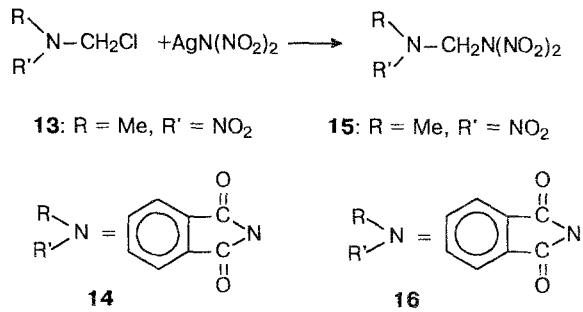
The reaction of *N*-methyl-*N*-chloromethyl-*N*-nitroamine (**13**) with $KN(NO_2)_2$ results in a complex mixture of compounds, which, according to the IR spectra, does not contain alkylation products. When compound **13** is treated with $AgN(NO_2)_2$, the IR spectrum of the reaction mixture contains bands typical of alkyldinitroamines (1650, 1620, and 1260 cm^{-1}), which indicates that product **15** is formed. However, the latter quickly decomposes after removal of the solvent. The reaction of *N*-chloromethylphthalimide (**14**) with $AgN(NO_2)_2$ gave an *N*-alkylation product (**16**) (Scheme 2).

Treatment of DNA with diazomethane (**17**) in ether gives ADA **2** (yield 30 %).

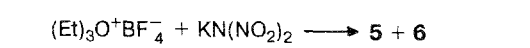


The *N*-alkylation product (**5**) is also the main product of the reaction of triethyloxonium tetrafluoroborate

Scheme 2



(**18**) with $KN(NO_2)_2$ in CH_2Cl_2. Judging by the IR spectrum, the reaction also gives a minor amount of an *O*-alkylation product **6**.



Thus, the reactions of alkylating agents with DNA and its salts can result in *N*- and *O*-alkylation products or their mixtures. In these reactions the DNA anion displays dual reactivity.

The resulting ADAs and ANDOs are unstable oily compounds.* For example, compound **8** partially decomposes during distillation at 30—40 °C (6 Torr) and even at ~20 °C.

The yields of the products obtained on alkylation of DNA and its salts do not exceed 25—50 %. This can be explained by the fact that, in many cases, the reactions proceed slowly (in several days), and the products partially decompose after they are formed (one should be careful when using the above ratios of the *N*- and *O*-alkylation products formed). On the other hand, the high volatility of some of the products results in their partial loss when the solvents are distilled off.

The structures of the products were confirmed by spectroscopic methods and by chemical transformations.

The IR spectra of all individual ADAs and their mixtures contain intense bands characteristic of the *N*,*N*-dinitroamine group (ν 1600—1650 and 1250 cm^{-1}). The spectra of the ANDOs contain strong bands attributable to the *N*-oxydiazene-*N*-oxide moiety (ν = 1550—1555 and 1220—1235 cm^{-1}) along with intense bands of the nitro groups (ν 1620 and 1290—1295 cm^{-1}). Similar bands are also observed in the IR spectra of the products of *O*-alkylation of *N*-nitrosulfamides[2] and *N*-nitrourethanes.[3]

The ^1H NMR spectra of mixtures of *N*- and *O*-alkylation products display signals of the alkyl substituents, in which the signals of the protons located at the α-position relative to the nitrogen atom (*N*-alkylation products) are shifted ~0.4 ppm upfield compared to

* In all cases studied, the *N*- and *O*-alkylation products had almost equal R_f values when chromatographed on silica gel.

those for the α-protons at the oxygen atom in the *O*-alkylation products.

The hydrolysis of compound **9**, which results in adamantanol and DNA, provides conclusive evidence of the location of the heteroatoms in the *O*-alkylation products:

$$\mathbf{9} + H_2O \longrightarrow \text{1-AdOH} + HN(NO_2)_2,$$

Alkaline hydrolysis follows another route to give, for example, potassium nitrate instead of a DNA salt in the case of ANDO:

$$\mathbf{8} + KOH \longrightarrow KNO_3$$

Similarly, the closely related *N*-isopropyloxy-*N'*-tolyldiazene *N*-oxide (**19**) and *N*-cyclohexyloxy-*N'*-tolyldiazene *N*-oxide (**20**) undergo nucleophilic attack at the acid residue bonded to the diazene oxide group:

$$n\text{MeC}_6\text{H}_4\text{SO}_2\text{N}{=}\overset{\displaystyle\text{O}}{\overset{\downarrow}{\text{N}}}{-}\text{OR} + KOH \longrightarrow n\text{MeC}_6\text{H}_4\text{SO}_3K$$

19: R = Pr^i
20: R = C_6H_{11}

It was of interest to study the behavior of certain *N*-alkylation products toward bases.

The method elaborated by us previously[1] for synthesizing DNA salts was implemented according to Scheme 3.

Scheme 3

$$NCCH_2CH_2N(NO_2)_2 \xrightarrow{KOH} [\bar{N}CCHCH_2N(NO_2)_2] \longrightarrow$$

$$\longrightarrow NCCH{=}CH_2 + N(NO_2)_2^-$$

These transformations do not occur with the simplest ADAs, probably due to the competitive attack on the nitro group by the nucleophile.[4] One can increase the probability of attack at the α-position in the case of ADAs prone to the formation of relatively stable α-carbocations. Indeed, alkaline hydrolysis of ADAs **11** or **12** makes it possible to obtain $KN(NO_2)_2$ in 50—80 % yields.

$$\mathbf{11} \text{ or } \mathbf{12} + KOH \longrightarrow KN(NO_2)_2$$

A DNA salt is formed in a good yield when ADA **16** is treated with ammonia.

$$\mathbf{16} + NH_3 \longrightarrow NH_4N(NO_2)_2$$

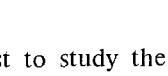
Thus, not only β- but also α-substituted ADA can serve as starting reagents for synthesizing DNA salts.

Experimental

^{1}H NMR spectra were recorded on a Perkin-Elmer R-12 spectrometer (60 Hz); IR spectra were obtained on a UR-10 spectrophotometer.

The reaction of $AgN(NO_2)_2$ with alkyl halides. A fourfold excess of an alkyl halide in a solvent (10 mL) was added to a solution or a suspension of AgN_3O_4 (3 g) in the same solvent (40 mL). The reaction mixture was stirred for 2—3 days, the precipitate was filtered off, the filtrate was concentrated *in vacuo*, and the residue was distilled or chromatographed on silica gel. **A.** The reaction of AgN_3O_4 (2 g) with compound **3** in dry MeCN gave 0.24 g (16 %) of allyldinitroamine **4**, b.p. 58 °C (18 Torr). IR, ν/cm^{-1}: 1600—1650 s, 1440 w, 1370 w, 1310 w, 1250 s, 1000 m, 950 m, 830 s.

B. The reaction of AgN_3O_4 (3.09 g) and Pr^{i}Br in dry ether gave 0.87 g of *N*-isopropyloxy-*N'*-nitrodiazene *N*-oxide **8**. IR, ν/cm^{-1}: 2990(3), 2940(2), 1620(9), 1550(8), 1450—1470(4), 1380(10), 1296(7), 1220(8), 1180(5), 1145(5), 995(6), 880(4), 830(6), 770(6). ^{1}H NMR, δ: 1.35 (d, CH_3C), 5.05 (m, CH).

C. A solution of 1-bromoadamantane (1 g) in dry ether (15 mL) was added to a suspension of AgN_3O_4 (1.47 g) in dry ether (25 mL). The mixture was stirred for 2 h and the filtrate was concentrated to give *N*-adamantyloxy-*N'*-nitrodiazene *N*-oxide **9**. IR, ν/cm^{-1}: 1620, 1310, 1290 (N—NO_2), 1550, 1235  .

***N*-Methoxymethyl-*N,N*-dinitroamine (11).** A solution of compound **10** (1.7 mL) in MeCN was added to a solution of AgN_3O_4 (obtained from 2 g KN_3O_4 and 2.34 g $AgNO_3$) in MeCN. The mixture was stirred for 1 h and the filtrate was concentrated *in vacuo* to a volume of ~15 mL. Benzene was added to the mixture, which was then washed twice with water and dried. Removal of the solvents gave 0.53 g (25.5 %) of compound **11**. IR, ν/cm^{-1}: 1650, 1605, 1290, 1250 ($N(NO_2)_2$).

***N*-Isopropyloxymethyl-*N,N*-dinitroamine (12).** A solution of chloromethyl isopropyl ether (1.1 mL) in dry ether (10 mL) was added to a suspension of KN_3O_4 (1 g) in dry ether (30 mL). The mixture was stirred for 6 h and left overnight, the filtrate was concentrated, and the residue was distilled to give 0.35 g (28 %) of compound **12**, b.p. 34 °C (2 Torr). IR, ν/cm^{-1}: 1650, 1605, 1250 ($N(NO_2)_2$).

The reaction of $AgN(NO_2)_2$ with compound 13. A solution of compound **13** (0.23 g) in 10 mL dry ether (10 mL) was added to a suspension of AgN_3O_4 (0.73 g) in dry ether (20 mL). The mixture was stirred for 2 h and the filtrate was concentrated *in vacuo* to give 1,1,3-trinitro-1,3-diazabutane **15** as an unstable oil. IR, ν/cm^{-1}: 1650, 1620, 1250 ($N(NO_2)_2$), 1560, 1310 (N—NO_2).

The reaction of AgN_3O_4 with compound 14. A solution of compound **14** (0.92 g) in dry MeCN (20 mL) was added to a solution of AgN_3O_4 (1.47 g) in dry MeCN (20 mL). The mixture was kept for three days at 20 °C and the filtrate was concentrated *in vacuo*. The residue was worked-up with ether to isolate *N*-phthalimidomethyl-*N,N'*-dinitroamine **16** (an oil which does not undergo crystallization). IR, ν/cm^{-1}: 1655, 1610, 1250 ($N(NO_2)_2$), 1740 (CO).

The reaction of diazomethane with DNA. A solution of diazomethane in dry ether was added dropwise at 0—4 °C to a solution of DNA (obtained from 2 g of KN_3O_4) in dry ether

and the mixture was stirred for 30 min. Distillation gave 0.43 g (29 %) of compound **2**, b.p. 20 °C (7 Torr).

The reaction of KN_3O_4 with compound 18. Compound **18** (2.6 g) was added at −60 °C to a suspension of KN_3O_4 (2.54 g) in dry CH_2Cl_2 (35 mL) and the mixture was stirred for 3 h at 0 °C. Distillation of the filtrate gave 0.44 g (23.5 %) of a mixture of *N*-ethyl-*N*,*N*-dinitroamine **5** with *N*-ethoxy-*N'*-nitrodiazene *N*-oxide **6** in a ~4 : 1 ratio. ^1H NMR, δ: for **5**, 1.3 (t, MeC); for **6**, 1.37 (t, MeC); 4.08 (q, CH_2N); 4.45 (q, CH_2O).

The reaction of 8 with KOH. A solution of KOH (0.28 g) in ethanol was added to a solution of compound **8** (0.37 g) in ethanol. One day later, a precipitate (0.2 g) was filtered off. Its IR spectrum was similar to that of KNO_3.

The reaction of compounds 19 and 20 with KOH. A solution of KOH (0.12 g) in ethanol was added to a solution of compound **19** (0.27 g) in ethanol. One day later, a precipitate was filtered off. The IR spectrum of the precipitate was similar to that of the authentic potassium *p*-toluenesulfonate. A similar result was obtained starting from compound **20**.

The reaction of 11 and 12 with KOH. A solution of KOH (0.23 g) in ethanol was added to a solution of compound **11** (0.53 g) in a minimum amount of ethanol. The formation of a precipitate was observed immediately. After 30 min, 0.31 g (80 %) of KN_3O_4 was filtered off, m.p. 123—126 °C. Under similar conditions, 0.13 g (50 %) of KN_3O_4 was obtained from compound **12** (0.32 g) and KOH (0.1 g).

The reaction of 16 with ammonia. NH_3 was passed through a solution of compound **16** (0.165 g) in dry ether. The ether and excess NH_3 were evaporated *in vacuo*. The residue was dissolved in water, washed with ether, and partially concentrated *in vacuo*. The formation of the DNA salt (yield 51.5 %) was established by UV spectroscopy.

References

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