Organic Chemistry

Alkylation of salts of *N*-(β-hydroxyalkyl)-*N'*-hydroxydiazene *N*-oxides with alkyl halides and dimethyl sulfate

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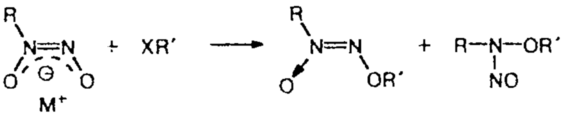
Salts of *N*-(β-hydroxyalkyl)-*N'*-hydroxydiazene *N*-oxides, $RCH(OH)CH_2N(O){=}NO^-$ M^+ (R = Me, Pr^i, or Bu^t; and M = Li, Na, K, Ag, NH_4, or Me_4N), were prepared. Their alkylation with alkyl halides R'X (X = Cl, Br, or I) and dimethyl sulfate was studied. Generally, alkylation afforded mixtures of *N*-(β-hydroxyalkyl)-*N'*-alkoxydiazene *N*-oxides $RCH(OH)CH_2N(O){=}NOR'$ and *O*-alkyl-*N*-(β-hydroxyalkyl)-*N*-nitrosohydroxylamines $RCH(OH)CH_2N(NO)OR'$.

Key words: *N*-(β-hydroxyalkyl)-*N'*-alkoxydiazene *N*-oxides, *O*-alkyl-*N*-(β-hydroxyalkyl)-*N*-nitrosohydroxylamines, *N*-(β-hydroxyalkyl)-*N'*-hydroxydiazene *N*-oxide salts, alkylation, nitrosation.

The major procedure for the synthesis of *N*-alkyl-*N'*-alkoxydiazene *N*-oxides is alkylation of salts of *N*-alkyl-*N'*-hydroxydiazene *N*-oxides.* Because of the ambident character of the anions of *N'*-hydroxydiazene *N*-oxides (HDOs), *N,O*-dialkyl-*N*-nitrosohydroxylamines are formed along with *N'*-alkoxydiazene *N*-oxides (ADOs). Because of their instability, *N,O*-dialkyl-*N*-nitrosohydroxylamines can be isolated only in specific cases.



ADOs were generally obtained in 15—60% yields. Only in exceptional cases were the yields as high as 80—85%.[1]

The aim of this work is to reveal the principal regularities of alkylation of salts of *N*-(β-hydroxyalkyl)-*N'*-hydroxydiazene *N*-oxides primarily with the simplest alkyl halides and, in specific cases, with dimethyl sulfate. To be more precise, our goal was to elucidate the structures of the major reaction products and to study the effects of various factors on their yields. The choice of *N*-β-hydroxyalkyl derivatives of HDOs was governed by two reasons. First, we intended to develop a rather simple method for the synthesis of previously unknown *N*-(β-hydroxyalkyl)-*N'*-alkoxydiazene *N*-oxides based on the above-mentioned derivatives. Second, it was of interest to find out whether the presence of the β-hydroxyl group in HDO salts is favorable for an increase in the yield of the target compounds. Because of the *cis* arrangement of the oxygen atoms in the anions of HDOs,[2] the β-hydroxyl group in the *N*-alkyl radical is located much closer to one of the oxygen atoms and can, in principle, form a hydrogen bond with this oxygen atom,

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* See Ref. 1 and references cited therein.

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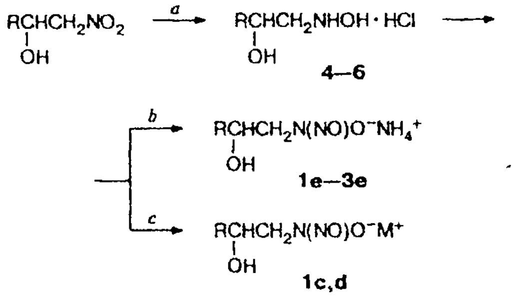
which may hinder the approach of the alkylating reagent to the above-mentioned oxygen atom and promote alkylation at the other oxygen atom, *i.e.*, can favor the formation of ADOs rather than *N*-nitrosohydroxylamines (NHAs).

We studied silver (**a**), lithium (**b**), sodium (**c**), potassium (**d**), ammonium (**e**), and tetramethylammonium (**f**) salts of *N*-(2-hydroxypropyl)- (**1a—f**), *N*-(2-hydroxy-3-methylbutyl)- (**2a,d**), and *N*-(2-hydroxy-3,3-dimethylbutyl)-*N*′-hydroxydiazene *N*-oxides (**3a,d**), which were subjected to alkylation. Primary, secondary, and tertiary alkyl halides and dimethyl sulfate were used as alkylating reagents.

Initial salts **1—3** were synthesized from β-nitroalcohols by electrochemical reduction according to the modified procedure[3] followed by nitrosation of hydroxylamine hydrochlorides **4—6** according to Scheme 1.

Scheme 1

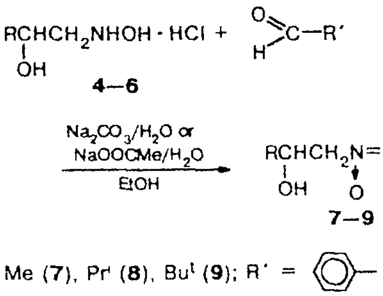


M = Li, Na, K

	1c	1d	1e	2e	3e	4	5	6
R	Me	Me	Me	Pr^i	Bu^t	Me	Pr^i	Bu^t

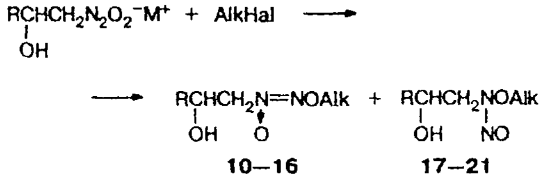
Reagents: *a*. 1) [$\bar{e}$]/H_2SO_4, 2) $CaCO_3$, 3) HCl;
b. 1) KOH/MeOH, 2) NH_3/THF, 3) BuONO/ether;
c. 1) MNO_2/H_2O, 2) M_2CO_3

Contrary to the data obtained previously,[4] hydrochloride **4** appeared to be a crystalline, relatively highly-melting compound. Therefore, its structure was confirmed not only by elemental analysis but also by conversion of **4** to the known nitrone **7** [4] by the reaction with benzaldehyde. The structures of hydrochlorides **5** and **6** were established by analogous transformations to nitrones **8** and **9**, respectively.



R = Me (**7**), Pr^i (**8**), Bu^t (**9**); R′ =

It was found that in most cases the reactions of salts of hydroxydiazene oxides **1—3** with the above-mentioned alkyl halides afforded mixtures of *N*-(β-hydroxyalkyl)-*N*′-alkoxydiazene *N*-oxides (**10—16**) and *O*-alkyl-*N*-(β-hydroxyalkyl)-*N*-nitrosohydroxylamines (**17—21**) (Table 1).



Hal = Cl, Br, I; Alk = Me, Et, CH_2Ph, Pr^i, 1-Ad

An inference about the structures of diazene oxides **10—16** was made based on the data of elemental analysis, NMR spectra (Table 2), and IR spectra, which have characteristic absorption bands of the —N(O)=N—O fragment (at 1500—1520 and 1300—1320 cm^{-1}).[5—8] The structures of the above-mentioned compounds were also confirmed by the absence of the qualitative color reaction to the N—NO group when **10—16** were treated with a mixture of diphenylamine and concentrated H_2SO_4. The resulting alkoxydiazene oxides **10—16** are quite stable colorless (generally crystalline) compounds. Unlike **10—16**, the corresponding *O*-alkyl-*N*-nitrosohydroxylamines **17—21** are generally slightly yellowish relatively unstable oils (Table 3) whose IR spectra have absorption bands in the region of 1445—1460 cm^{-1}, which is typical of the N(NO)O fragment.[5,9] When treated with a mixture of diphenylamine and concentrated H_2SO_4, all nitrosohydroxylamines immediately gave a bright-yellow reaction. The relative purity of compounds **17—21** can be judged from their ^{1}H NMR spectra. The integrated intensities of protons of admixtures were no more than 10—20%. There is no question that the errors of the determination of the yields of nitrosohydroxylamines by the above-mentioned method (together with the yields of ADOs) do not allow one to estimate precisely the relative activities of the oxygen centers in anions of **1—3**. However, the high total yields of both alkylation products (70—95%), which were obtained in half of the reactions under consideration, is evidence in favor of relatively small possible losses of NHAs due to decomposition. Therefore, in our opinion the principal regularities of the reactions can be reliably revealed.

The nature and the structure of the alkylating reagent (the nature of the halogen atom and the character of the alkyl group), the nature and the structure of the substrate subjected to alkylation (the nature of the cation and the steric requirements of the alkyl group), and the solvent substantially affect the yields of ADOs and NHAs and their ratio (see Table 1). The HDO salts exhibit rather low nucleophilicity. Alkylation proceeds

Table 1. Conditions of the formation and the yields of *N*-(β-hydroxyalkyl)-*N'*-hydroxydiazene *N*-oxides (ADO) $RCH(OH)CH_2N(O)=NOR'$ and *O*-alkyl-*N*-(β-hydroxyalkyl)-*N*-nitrosohydroxylamines (NHA) $RCH(OH)CH_2N(NO)OR'$ prepared by the reactions of the salts $RCH(OH)CH_2N(O)=NO^-M^+$ with R'X [a]

R	R'	M	X	Solvent	*T*/°C	*t*/h	Yield (%)	
							ADO	NHA
Me	Me	Ag	I	Ether	20	10	67	7.5
Me	Me	Ag	I	Methanol	20	10	78	13
Me	Me	Li	I	DMF	20	50	86	13
Me	Me	Li	I	DMSO	20	50	58	3
Me	Me	Li	I	Methanol	20	50	18	3
Me	Me	Li	I	Glyme	20	50	2	—
Me	Me	Na	I	DMF	20	50	62.5	7
Me	Me	Na	I	DMSO	20	50	66	3
Me	Me	Na	OSO_2OMe	Acetone/water	60	1.5	67.5	—
Me	Me	Na	OSO_2OMe	Acetone/water	60	2	74	—
Me	Me	K	I	DMF	20	50	82	9
Me	Me	K	I	DMSO	20	50	70	12.5
Me	Me	K	OSO_2OMe	Acetone/water	60	1.5	66	—
Me	Me	K	OSO_2OMe	Acetone/water	60	2	69	—
Me	Me	NH_4	OSO_2OMe	Acetone/water	60	2	75	—
Me	Me	NH_4	OSO_2OMe	DMF	20	30	20	—
Me	Me	Me_4N	I	Acetonitrile	20	40	50	13
Me	Et	Ag	I	Methanol	20	10	72	10
Me	Et	Me_4N	I	Acetonitrile	20	40	56	15
Me	Et	Ag	Br	Methanol	20	10	17	9
Me	Et	Me_4N	Br	Acetonitrile	20	40	50	14
Me	$PhCH_2$	Ag	Br	Ether	20	10	48	22
Me	Pr^i	Ag	I	Methanol	20	10	60	2.5
Me	Pr^i	K	I	DMF	20	70	72.5	5
Me	Pr^i	Me_4N	I	Acetonitrile	20	40	50	12
Me	Pr^i	Ag	Br	Methanol	20	10	12	7.5
Me	Pr^i	Me_4N	Br	Acetonitrile	20	40	34	11
Me	Pr^i	Me_4N	Cl	Acetonitrile	20	40	18.5	3
Me	1-Ad	Ag	Br	Methanol	20	10	<0.1	24
Me	1-Ad	Me_4N[b]	Br	Acetonitrile	20	40	4.5	41
Pr^i	Me	Ag	I	Methanol	20	10	70	<0.1
Pr^i	Me	K	I	DMF	20	70	75.5	<0.1
Pr^i	Me	K	OSO_2OMe	Acetone/water	60	2	69	—
Bu^t	Me	Ag	I	Methanol	20	10	41	<0.1
Bu^t	Me	K	I	DMF	20	70	47.5	<0.1
Bu^t	Me	K	OSO_2OMe	Acetone/water	60	2	86.5	—

[a] The salt : R'X ratio was 1 : 2. [b] The salt : R'X ratio was 1 : 1.

most rapidly in the case of the reactions of Ag salts with alkyl iodides. On going to alkyl bromides and alkyl chlorides, the yields of the alkylation products were no more than 20—40% even upon storage at 20 °C for several days. The use of alkyl iodides made it possible not only to accelerate alkylation and to increase the total yield of the alkylation products but, in some cases, to increase the contents of ADOs in these mixtures as well. Under optimum conditions with the use of Ag salts, the yields of ADOs were as high as 70—80%. For alkyl halides to interact with alkali-metal salts, it is necessary to increase the duration of storage by several times. However, when optimum solvents were used, the final yields of ADOs were as high as the yields of ADOs obtained from Ag salts. Therefore, the use of alkali-metal salts can be recommended for the synthesis of ADOs. To a first approximation, the radius of the metal cation (Li, Na, and K) has no effect on the yield of ADO. However, the reactions with onium salts afforded ADOs in lower yields. Nevertheless, the yields were still satisfactory (50—55% in the case of alkyl iodides).

The yields of ADOs and the ratio of the alkylation products are strongly affected by the character of the alkyl group in the alkylating reagent. The highest yields of ADOs were obtained with the use of primary alkyl halides. The content of ADO in the alkylation products was decreased in going to secondary alkyl halides. The reactions with tertiary halides gave ADOs only as minor products or these compounds were virtually unavailable.

The yields of ADOs also decrease as the volume of the alkyl substituent in the anions of HDOs increases, which is, apparently, attributable to the fact that alkylation on the whole slows down rather than leads to an increase in the contribution of the reaction that pro-

Table 2. Melting points, retention indices, and the data of ^{1}H NMR spectra and elemental analysis for diazene *N*-oxides RCH(OH)CH$_2$N(O)=NOR′

R	R′	M.p./°C (solvent)	R_f	NMR (CDCl$_3$), δ: ^{1}H	^{13}C*	^{14}N Δν$_{1/2}$/Hz	Found / Calculated (%): C	H	N	Molecular formula
Me	Me	Oil	0.15	1.18 (d, 3 H, CH$_3$); 3.58 (br.s, 1 H, OH); 3.8 (d, 2 H, CH$_2$); 4.0 (s, 3 H, CH$_3$); 4.3 (m, 1 H, CH)	19.6 (CH$_3$), 61.4 (CH$_3$O), 64.6 (CH$_2$), 68.6 ($\underline{C}$HOH)	−68.6 (217)	35.58 35.82	7.67 7.51		$C_4H_{10}N_2O_3$
Me	Et	29−31 (benzene—hexane)	0.26	1.1 (d, 3 H, CH$_3$); 1.22 (t, 3 H, CH$_3$); 3.72 (d, 1 H, OH); 3.85 (d, 2 H, CH$_2$N); 4.18 (q, 2 H, CH$_2$O); 4.21 (m, 1 H, CH)		−69.4 (217)	40.21 40.53	8.25 8.16	19.12 18.91	$C_5H_{12}N_2O_3$
Me	PhCH$_2$	52−54 (hexane)	0.54	1.2 (d, 3 H, CH$_3$); 3.3 (br.s, 1 H, OH); 3.95 (m, 2 H, CH$_2$N); 4.3 (m, 1 H, CH); 5.25 (s, 2 H, CH$_2$O); 7.45 (m, 5 H, Ph)		−67.2 (217)	57.32 57.13	6.74 6.71	13.26 13.32	$C_{10}H_{14}N_2O_3$
Me	Pr^i	37−40 (hexane)	0.38	0.9 (d, 3 H, CH$_3$); 1.0 (d, 6 H, CH$_3$); 3.65 (m, 2 H, CH$_2$); 3.85 (br.s, 1 H, OH); 4.05 (m, 1 H, CHO); 4.25 (m, 1 H, CH)		−71.3 (128)	44.23 44.43	8.67 8.70	17.28 17.27	$C_6H_{14}N_2O_3$
Me	1-Ad	98−101	0.56	1.23 (d, 3 H, CH$_3$); 1.65 (s, 6 H, Ad); 2.0 (s, 6 H, Ad); 2.23 (s, 3 H, Ad); 3.6 (br.s, 1 H, OH); 4.0 (m, 2 H, CH$_2$); 4.35 (m, 1 H, CH)		−70.0 (96)			10.81 11.01	$C_{13}H_{22}N_2O_3$
Pr^i	Me	95−97 (benzene—hexane)	0.45	0.75 (q, 6 H, CH$_3$); 1.65 (m, 1 H, CH); 3.5 (br.s, 1 H, OH); 3.87 (m, 1 H, C$\underline{H}$OH); 3.95 (m, 2 H, CH$_2$); 3.97 (s, 3 H, CH$_3$O)	17.1 (CH$_3$), 18.2 (CH$_3$), 31.5 ($\underline{C}$H(CH$_3$)$_2$), 61.1 (CH$_3$O), 66.05 (CH$_2$), 72.3 ($\underline{C}$HOH)	−68.0 (163)	44.77 44.43	7.94 8.70	18.85 17.27	$C_6H_{14}N_2O_3$
Bu^t	Me	86−88 (benzene)	0.56	0.95 (s, 9 H, CH$_3$); 3.85 (m, 1 H, CH); 3.95 (s, 3 H, CH$_3$) 4.05 (m, 2 H, CH$_2$) 4.35 (br.s, 1 H, OH)	26.2 (($\underline{C}$H$_3$)$_3$C), 35.0 ($\underline{C}$(CH$_3$)$_3$), 61.0 (CH$_3$O), 66.7 (CH$_2$), 75.5 ($\underline{C}$HOH)	−66.2 (83)	47.30 47.71	9.07 9.15	16.04 15.90	$C_7H_{16}N_2O_3$

* The spectra were interpreted with the use of the DEPT-135 program.

Table 3. Melting points, retention indices, and the data of ^{1}H NMR spectra of *O*-alkyl-*N*-nitrosohydroxylamines RCH(OH)CH$_2$N(NO)OR′

R	R′	M.p./°C (solvent)	R_f	δ (CDCl$_3$)
Me	Me	Oil	0.5	1.0 (d, 3 H, CH$_3$); 3.6 (br.s, 4 H, CH$_3$O+OH); 3.8 (m, 1 H, CH); 3.95 (m, 2 H, CH$_2$)
Me	Et	Oil	0.6	1.1 (br.s, 6 H, CH$_3$); 3.6 (br.s, 1 H, OH); 3.85 (br.s, 2 H, CH$_2$N); 4.05 (br.s, 2 H, CH$_2$O); 4.2 (br.s, 1 H, CH)
Me	CH$_2$Ph	Oil	0.79	1.2 (d, 3 H, CH$_3$); 2.4 (br.s, 1 H, OH); 3.8 (m, 1 H, CH); 4.1 (m, 2 H, CH$_2$N); 5.05 (s, 2 H, CH$_2$O); 7.4 (s, 5 H, Ph)
Me	Pr^i	Oil	0.69	1.2 (br.s, 6 H, CH$_3$); 1.35 (d, 3 H, CH$_3$); 3.45 (br.s, 1 H, OH); 4.0 (m, 1 H, CHO); 4.2 (br.s, 2 H, CH$_2$); 4.45 (m, 1 H, CHO)
Me	1-Ad*	75−77 (heptane)	0.75	1.2 (d, 3 H, CH$_3$); 1.5−1.8 (m, 15 H, Ad); 2.5 (br.s, 1 H, OH); 4.0 (m, 2 H, CH$_2$); 4.25 (m, 1 H, CH)

* Found (%): C, 59.90; H, 8.36; N, 10.50. $C_{13}H_{22}N_2O_3$. Calculated (%): C, 61.39; H, 8.72; N, 11.01.

ceeds at another center because in this case no noticeable amounts of NHAs were obtained as well.

The solvent or, more precisely, the "solvent—cation" pair, substantially affects the reaction. In this respect, the yield of ADO obtained by alkylation of salt **1b** with iodomethane is extremely significant. This yield ranged from 2 to 86% depending to the solvent used. When Ag salts **1—3** are used, methanol can be recommended as the solvent in spite of the fact that competitive solvolysis can in principle occur. In the case of alkali-metal salts, aprotic dipolar solvents (DMF and DMSO) should be used. In the case of tetralkylammonium salts, acetonitrile should be used.

Using dimethyl sulfate as an example, it was demonstrated that *N*-(β-hydroxyalkyl)-*N'*-alkoxydiazene *N*-oxides can be successfully prepared by alkylation of salts of the corresponding HDOs with dialkyl sulfates instead of alkyl iodides. At room temperature, the reactions of dimethyl sulfate with the salts under study proceeded at a low rate. Because of this, the reactions were carried out upon heating in aqueous acetone. In this case, the desired ADOs were obtained in 65—85% yields. It should be noted that under these conditions the corresponding NHAs were not formed. Apparently, this result is largely attributable to decomposition of NHAs under the action of H_2SO_4 that is formed due to partial hydrolysis of dimethyl sulfate.

Therefore, alkylation of salts of *N*-(β-hydroxyalkyl)-*N'*-hydroxydiazene *N*-oxides with primary and secondary alkyl iodides and alkyl bromides (and, apparently, with dialkyl sulfates) is a quite workable procedure for the synthesis of previously unknown *N*-(β-hydroxyalkyl)-*N'*-alkoxydiazene *N*-oxides. A comparison of the results of this work with the fragmentary published data on the reactions of salts of *N*-alkyl-*N'*-hydroxydiazene *N*-oxides[1] allows one to assume that, to a first approximation, the introduction of the hydroxyl group at the β position of the *N*-alkyl radical of HDOs has no noticeable effect on the course of alkylation with alkyl halides and dialkyl sulfates. In this respect, the hydroxyl group differs substantially from the carboxylate (or alkoxycarbonyl) group whose presence leads to a substantial decrease in the yields of ADOs.[6]

Experimental

The IR spectra were recorded on UR-20, Specord M-60, and Specord M-82M spectrophotometers as KBr pellets or in thin films on KBr glasses. The NMR spectra were obtained on Bruker AM-300, Bruker WM-250, and Bruker AC-200C instruments (at 300.13, 255.13, and 200.13 MHz for ^{1}H; at 21.69 MHz for ^{14}N; and at 62.9 and 50.32 MHz for ^{13}C). The ^{1}H and ^{13}C chemical shifts were measured relative to the solvent (δ 2.07 and 30.0 for acetone-d$_6$; δ 7.25 and 77.0 for chloroform-d$_1$). The ^{14}N chemical shifts were measured relative to the external standard ($MeNO_2$). The melting points were determined on a Böetius microtable between glasses.

Preparative TLC was carried out using Silpearl UV-254 and Silufol UV-254 silica gels; ether was used as the eluent.

Pivalic aldehyde was prepared according to the Bouveault method.[10] Nitro alcohols were prepared according to the Henry reaction by condensation of nitromethane with the corresponding aldehydes according to known procedures: $MeCH(OH)CH_2NO_2$,[11] $Me_2CHCH(OH)CH_2NO_2$,[12] and $Me_3CCH(OH)CH_2NO_2$.[13]

Preparation of *N*-(β-hydroxyalkyl)hydroxylamine hydrochlorides (4—6) (according to the modified procedure[3]). The corresponding β-nitroalcohol (95 mmol) and a 5% H_2SO_4 solution (200 mL) were placed in a 250-mL glass beaker equipped with a lead cathode, a lead anode (a cylinder and a rod, respectively, separated by a porous ceramic membrane), a thermometer, and a magnetic stirrer. A 5% H_2SO_4 solution was used as the anolyte. Electrochemical reduction was carried out with a current of 1.7 A and a voltage of 3.5—6.0 V; the current density was ~1 A dm^{-2} (the duration of the reaction was ~6 h). After completion of the reaction, the catholyte was neutralized with $BaCO_3$ or $CaCO_3$ to pH 8—9. The precipitate of barium and calcium salts was separated and washed with a small amount of water. The filtrate was acidified with a concentrated solution of HCl to pH ~3—4. Water and excess HCl were distilled off *in vacuo*. The residue was treated with Pr^{i}OH (~200 mL). The precipitate that formed was filtered off. The filtrate was concentrated *in vacuo*. The oily residue was triturated with Pr^{i}OH or dry THF (in the case of compounds **4** and **6**, respectively). The resulting white crystalline product was filtered off and dried on a filter. Compound **4** was obtained, m.p. 87—94 °C (from Pr^{i}OH) (*cf.* Ref. 4: oil). Found (%): N, 10.91; Cl, 27.84. $C_3H_9NO_2 \cdot HCl$. Calculated (%): N, 10.98; Cl, 27.79. Compound **4** was converted into nitrone **7** according to a known procedure,[4] m.p. 92—94 °C (*cf.* Ref. 4: m.p. 90—92 °C). IR, ν/cm^{-1}: 1610 (C=N). ^{1}H NMR ($(CD_3)_2CO$), δ: 1.2 (d, 3 H, CH_3); 3.9 (m, 2 H, CH_2); 4.35 (m, 1 H, CH); 4.9 (br.s, 1 H, OH); 7.72 (s, 1 H, CH=N); 7.45, 8.35 (m, 5 H, Ph). Compound **5** (oil) was converted to nitrone **8** by the reaction with PhCHO, m.p. 100—102 °C (from benzene). Found (%): N, 6.68. $C_{12}H_{17}NO_2$. Calculated (%): N, 6.76. IR, ν/cm^{-1}: 1596 (C=N). ^{1}H NMR ($CDCl_3$), δ: 0.95 (t, 6 H, 2 CH_3); 1.72 (m, 1 H, CHC); 3.8 (m, 1 H, CHO); 3.95 (m, 2 H, CH_2); 4.72 (br.s, 1 H, OH); 7.38 (br.s, 4 H, CH=N, Ph); 8.15 (m, 2 H, Ph). Compound **6**, m.p. 114—116 °C (from THF) was converted to nitrone **9** by the reaction with PhCHO, m.p. 84—88 °C (from a mixture of benzene and hexane). Found (%): C, 70.03; H, 8.57; N, 6.04. $C_{13}H_{19}NO_2$. Calculated (%): C, 70.56; H, 8.65; N, 6.33. IR, ν/cm^{-1}: 1598 (C=N). ^{1}H NMR ($CDCl_3$), δ: 1.0 (s, 9 H, 3 CH_3); 3.8 (m, 1 H, CH); 4.0 (d, 2 H, CH_2); 4.55 (br.s, 1 H, OH); 7.4 (m, 4 H, CH=N, Ph); 8.2 (m, 2 H, Ph).

General procedure for the preparation of salts 1—3

Ammonium salt 1e. A solution of KOH (1.23 g, 22 mmol) in ethanol (10 mL) was added to a solution of compound **4** (2.55 g, 20 mmol) in ethanol (60 mL). The precipitate that formed was filtered off and washed with ethanol (5 mL). The filtrate was concentrated at ≤40 °C *in vacuo*. The oily residue was mixed with anhydrous THF (100 mL). The precipitate that formed was filtered off. The filtrate was placed in a four-neck flask equipped with a stirrer, a thermometer, a bubbler, and a reflux condenser, cooled to ~0 °C, and saturated with dry ammonia for 30 min. A solution of dry BuONO (1.86 g, 20 mmol) in anhydrous ether (20 mL) was added with stirring to the resulting solution. The reaction mixture was kept at ≤0 °C for 5 h. The precipitate of salt **1e** that formed was filtered off, washed with dry ether, and dried on a filter for 1 h. The yield was 2.03 g (~80%); m.p. 203—209 °C (decomp., EtOH). Found (%): C, 26.31; H, 7.98; N, 30.86. $C_3H_{11}N_3O_3$.

Calculated (%): C, 26.27; H, 8.08; N, 30.64. IR, ν/cm^{-1}: 3210, 2870, 1400, 1280, 1230, 1190, 1135, 1095, 965, 940, 913, 850, 762.

Alkali-metal salts 1b,c,d, 2d, and 3d. ***A.*** A solution of the corresponding alkali-metal nitrite (10 mmol) in water (8 mL) was added dropwise with stirring to a solution of *N*-(β-hydroxyalkyl)hydroxylamine hydrochloride (10 mmol) in water (10 mL) at ≤0 °C. The reaction mixture was kept at 0 °C for 5 min. Then a solution of the corresponding carbonate (5 mmol) in water (5 mL) was added at the same temperature. The resulting solution was allowed to warm up to room temperature and kept for 10 min. Then water was evaporated *in vacuo*. The solid residue was suspended in methanol (50 mL) and filtered off. The filtrate was concentrated *in vacuo*. The resulting residue was recrystallized from the corresponding alcohol. The yields of the salts were 80—85%. Salt **1b**, m.p. 204—207 °C (decomp., Pr^{i}OH). Found (%): C, 28.38; H, 5.34; Li, 5.45; N, 22.38. $C_3H_7LiN_2O_3$. Calculated (%): C, 28.57; H, 5.56; Li, 5.56; N, 22.22. IR, ν/cm^{-1}: 3100, 2970, 1425, 1382, 1345, 1290, 1225, 1180, 1145, 1080, 982, 955, 925, 870, 763. Salt **1c**, m.p. 97—100 °C (decomp., EtOH). Found (%): C, 24.21; H, 5.48; N, 18.68; Na, 15.28; H_2O, 6.64. $C_3H_7N_2NaO_3 \cdot 0.5H_2O$. Calculated (%): C, 23.84; H, 5.28; N, 18.49; Na, 15.19; H_2O, 6.00. IR, ν/cm^{-1}: 3400, 2980, 1405, 1385, 1278, 1245, 1190, 1140, 1090, 965, 935, 915, 850, 830, 760. Salt **1d**, m.p. 203—209 °C (decomp., EtOH). Found (%): C, 22.80; K, 24.20; N, 17.80. $C_3H_7KN_2O_3$. Calculated (%): C, 22.80; K, 24.70; N, 17.70. IR, ν/cm^{-1}: 3150, 2970, 1435, 1395, 1370, 1273, 1217, 1185, 1145, 1100, 1070, 965, 935, 920, 855, 760. Salt **2d**, m.p. 180—184 °C (decomp., EtOH). IR, ν/cm^{-1}: 3200, 2980, 1410, 1370, 1280, 1240, 1170, 1105, 1070, 1050, 1015, 970, 920, 880, 840, 745. Salt **3d**, m.p. >310 °C (decomp., EtOH). Found (%): C, 35.49; H, 6.65; K, 19.32; N, 14.05. $C_6H_{13}KN_2O_3$. Calculated (%): C, 36.00; H, 6.50; K, 19.50; N, 14.00. IR, ν/cm^{-1}: 3200, 2960, 1420, 1365, 1280, 1245, 1165, 1090, 1060, 1013, 970, 930, 875, 805, 735.

B. A solution of the corresponding hydroxide (10 mmol) in methanol (10 mL) was added to a solution of salt **1e** (1.37 g, 10 mmol) in methanol (30 mL). The resulting solution was concentrated to dryness *in vacuo*. The solid residue was recrystallized from the corresponding solvent. The yield was ~80%. Salts **1b—d** prepared according to this procedure are identical to those prepared according to the above-described procedure.

Silver salts 1a—3a. A solution of $AgNO_3$ (1.7 g, 10 mol) in water (5 mL) was added with stirring to a solution of salt **1d**, **2d**, or **3d** (10 mmol) in water (5 mL) at room temperature. The resulting precipitate was filtered off, washed with water (2 mL), methanol (5 mL), and dry ether (10 mL), and dried on a filter in the dark for 30 min. The yield was ~80%. Salts **1a**, **2a**, and **3a** are white amorphous powders, which are poorly soluble in water and turn dark in the light. IR of salt **1a**, ν/cm^{-1}: 3280, 2990, 1410, 1322, 1280, 1183, 1143, 1090, 1070, 980, 940, 910, 842, 763.

Tetramethylammonium salt 1f. A solution of $Me_4N^+Cl^-$ (1.34 g, 12 mmol) in ethanol (5 mL) was added to a solution of salt **1d** (1.58 g, 10 mmol) in ethanol (10 mL) at room temperature. The resulting precipitate was filtered off and washed with cold ethanol (2 mL). The filtrate was concentrated to dryness *in vacuo*. The residue was suspended in anhydrous acetonitrile (20 mL). The insoluble precipitate was filtered off and washed with hot anhydrous acetonitrile (20 mL). The filtrate was concentrated *in vacuo*. The oily residue of salt **1f** was crystallized out when triturated with cold anhydrous acetonitrile. The yield was 1.74 g (~90%). Salt **1f** is hygroscopic, m.p. 130—135 °C (decomp., MeCN). Found (%): C, 42.40; H, 9.57; N, 21.04. $C_7H_{19}N_3O_3$. Calculated (%): C, 43.51; H, 9.91; N, 21.74. IR, ν/cm^{-1}: 3150, 3025, 2975, 1490, 1390, 1270, 1220, 1190, 1145, 1100, 1073, 960, 950, 940, 920, 865, 758.

General procedure for alkylation of salts 1—3

Alkylation of silver salts 1a—3a with alkyl halides. The corresponding alkyl halide (4 mmol) was added to a suspension of **1a—3a** (2 mmol) in methanol (10 mL). The reaction mixture was stirred at room temperature for one day. Then the residue was filtered off and washed with methanol (5 mL). The filtrate was concentrated *in vacuo*. The oily residue was subjected to preparative TLC. The yields and the selected physicochemical characteristics of the resulting ADOs and NHAs are given in Tables 1—3.

Alkylation of alkali-metal salts 1b—d, 2d, and 3d with alkyl halides. A mixture of **1b—d**, **2d**, or **3d** (2.5 mmol) and the corresponding alkyl halide (4 mmol) in the corresponding solvent (10 mL) was stirred under dry nitrogen. Then the resulting solution was concentrated *in vacuo*. The oily residue was subjected to preparative TLC. The reaction conditions and the yields of ADOs and NHAs are given in Table 1. The physicochemical characteristics of the compounds prepared according to this procedure are identical to those of the products obtained by alkylation of salts **1a—3a**.

Alkylation of tetramethylammonium salt 1f with alkyl halides. A mixture of salt **1f** (0.39 g, 2 mmol) and the corresponding alkyl halide (4 mmol) in anhydrous acetonitrile (20 mL) was stirred under dry nitrogen. The resulting precipitate was filtered off and washed on a filter with acetonitrile (5 mL). The filtrate was concentrated *in vacuo*. The oily residue was emulsified in acetone (20 mL) and kept for 30 min. The precipitate that formed was filtered off and washed with acetone (5 mL). The filtrate was concentrated *in vacuo*. The residue was subjected to preparative TLC. The reaction conditions and the yields are given in Table 1. The compounds ADOs and NHAs prepared according to this procedure are identical to those synthesized with the use of other salts.

Alkylation of salts 1c—e, 2d, and 3d with dimethyl sulfate. Freshly distilled dimethyl sulfate (0.43 g, 3.4 mmol) was added to a solution of salt **1c—e**, **2d**, or **3d** (2.8 mmol) in a 3 : 1 mixture of acetone with water (or with DMF) (20 mL). The reaction mixture was stirred (the temperature is given in Table 1). After storage, the mixture was concentrated *in vacuo* to 1/3 of the initial volume. The residue was extracted with chloroform (5×5 mL). The combined extracts were dried with $MgSO_4$. The solvent was evaporated *in vacuo*. When salts **1c—e** were used, the residue was subjected to preparative TLC. In the case of salts **2d** and **3d**, the residue was crystallized from the corresponding solvent. The reaction conditions and the yields of ADOs are given in Table 1. The compounds ADOs prepared according to this procedure are identical to those synthesized according to the above-described procedures.

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References

1. S. G. Zlotin and O. A. Luk'yanov, *Usp. Khim.*, 1993, **62**, 157 [*Russ. Chem. Rev.*, 1993, **62** (Engl. Transl.)].

2. W. E. H. White, M. Y. Todd, M. Ribl, T. Y. Reyan, and A. F. Sieber, *Tetrahedron Lett.*, 1970, 4476; V. D. Cherepinskii-Malov, A. S. Mukhametzyanov, V. G. Andriyanov, and G. A. Marchenko, *Zh. Strukt. Khim.*, 1983, **24**, 164 [*J. Struct. Chem. USSR*, 1983, **24** (Engl. Transl.)].
3. US. Pat. 2.589.635; *Chem. Abstrs.*, 1952, **46**, 4937h.
4. W. Kliegel and H. Becker, *Ber.*, 1977, **110**(6), 2067.
5. I. N. Zyuzin, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1985, 2626 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1985, **34**, 2433 (Engl. Transl.)].
6. V. N. Yandovskii, V. S. Kuznetsov, I. V. Tselinskii, and G. M. Frolova, *Zh. Org. Khim.*, 1982, **18**, 508 [*J. Org. Chem. USSR*, 1982, **18** (Engl. Transl.)].
7. R. A. Moss, M. J. Landon, K. M. Luchter, and A. Mamantov, *J. Am. Chem. Soc.*, 1972, **94**, 4392.
8. I. N. Zyuzin and D. 3. Lempert, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1985, 831 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1985, **34**, 753 (Engl. Transl.)].
9. L. J. Bellamy, *Advances in Infrared Group Frequencies*, Methuen, Suffolk, 1968.
10. Pol. PL 149.681; *Chem. Abstrs.*, 1991, **114**, 23416b.
11. C. D. Hurd and M. E. Nilson, *J. Org. Chem.*, 1955, **20**, 927.
12. E. Schmidt, A. Ascherl, and L. Mayer, *Ber.*, 1925, **58**[B], 2430.
13. V. Kral and L. Lešeticky, *Coll. Czechoslov. Chem. Commun.*, 1975, **40**(9), 2816.

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