SYNTHESIS AND PROPERTIES OF N-ALKYL-N'-METHOXYDIAZENE N-OXIDES

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N-Alkyl-N'-alkoxydiazene N-oxides (AADO) have been known since the end of the last century [1], but only a few compounds of this type had been described up to the early 1970's [2-5]. Interest in AADO has increased considerably in recent years [6-8], and a new method for their preparation by oxidizing O-alkylhydroxylamines in the presence of nitroso compounds has been developed [8]. This method is, however, restricted to tert-alkyl nitroso compounds, and the starting materials are not readily accessible. The general method for the synthesis of AADO is by alkylating nitrosohydroxylamines (NHA) or their salts. In earlier communications, one or two NHA were employed, and the alkylating agents were varied, the dependence of the properties of AADO on the substituents at the oxygen atom being investigated. On the other hand, in the present investigation a variety of NHA have been alkylated with dimethyl sulfate, and the dependence of the properties of the AADO on substitution at nitrogen has been examined.

$$\underset{(Ib-e)}{RN(NO)O^-M^+} + (MeO)_2SO_2 \rightarrow \underset{(IIb-e)}{RN^+(O^-)=NOMe}$$

$$M = MgBr\ (Ib),\ MgCl\ (Ic),\ K\ (Id,e);\ R = Et\ (b),\ i\text{-}Pr\ (c),\ t\text{-}Bu\ (d),\ t\text{-}BuCH_2\ (e).$$

The NHA salts were obtained by reacting Grignard reagents with NO at −25 to −5°C:

$$RMgHal + 2NO \rightarrow RN((NO)OMgHal$$

The reaction proceeds too slowly at lower temperatures, and at higher temperatures side reactions of the Grignard reagent with the NHA salt occur, which under some conditions may result in the reaction becoming uncontrollable.

Products (Ib) and (Ic) were alkylated with dimethyl sulfate without prior purification to give (IIb) and (IIc) in ∿20% yields. When this method was used to synthesize (IId) and (IIe), however, difficulties arose in isolation and purification, since these compounds tend to distill with the solvents, and according to GLC the reaction mixtures contained substantial amounts of impurities with similar retention times, in addition to the required product. For this reason, tert-butyl- and neopentylnitrosohydroxylamines were isolated and purified by recrystallization as the copper complexes (IIId) and (IIIe), followed by conversion into the potassium salts of (Id) and (Ie), which were then alkylated without isolation from their aqueous solutions:

$$RN(NO)OMgCl \xrightarrow{CuSO_4} \underset{(IIId,\ e)}{[RN((NO)O]_2Cu} \xrightarrow{KOH} \underset{(Id,\ e)}{RN(NO)OK}$$

$$R = t\text{-}Bu\ (d),\ t\text{-}BuCH_2\ (e).$$

Compounds (IId) and (IIe) were obtained in yields in excess of 70%, but the yield of (IId) calculated on the original tert-butyl chloride was only 23%. Hence, the low overall yields of (IIb-d) were due to low yields of (Ib-d). This is probably due to the fact that, as has been reported [10], only half of the Grignard reagent reacts readily with NO, the second half forming a complex with the NHA salt which separates from solution and reacts much more slowly. Thus, the yield of (IIIe) and the overall yield of (IIe) were doubled as compared with (IIId) and (IId) by passing a tenfold excess of NO through an ethereal suspension of this complex at elevated temperatures (Table 1).

The purities of (IIa-e) were checked by GLC. After repeated vacuum distillation, the amounts of detectable impurities did not exceed 0.2% in any of the products. Compounds (IIa-c, e) were colorless liquids, and (IId) crystallized at ∿20°C, but could be kept for extended periods in the supercooled state.

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TABLE 1. N-Alkyl-N'-methoxydiazene N-Oxides $RN^+(O^-){=}NOMe$ (IIa-e)

Compound	R	Yield, %	bp, °C (p, mm Hg)	n_D^{20}	d_4^{20}	MR_D		UV spectrum, λmax, nm (log ε)	IR spectrum, ν, cm^{-1}, $N^+(O^-){=}N{-}O$	PMR spectrum, δ, ppm	GLC retention time, min	Found calc. N, %
						found	calc.					
(IIa)	Me	29[a]	71 (14)	1,4528	1,1286	21,56	21,50	234 (3,92)	1320, 1390, 1425, 1510	3,87 s (MeN), 3,95 s (MeO)	11,85	30,70 31,13
(IIb)	Et	18[b]	57–58 (5)	1,4473	1,0652	26,13	26,14	234 (3,94)	1310, 1390, 1450, 1470, 1510	3,95 s (MeO), 4,11 q (CH_2N), 1,40 t (MeC), J=7,3 Hz (Et)	11,9	26,80 26,91
(IIc)	*i*-Pr	19[b]	58 (8)	1,4450	1,0187	30,86	30,79	234 (3,93)	1320, 1390, 1470, 1510	3,93 s (MeO), 4,52 m (CHN) 1,35 d (Me_2C), J=6,5 Hz (Me_2–CH)	10,7	23,82 23,71
(IId)	*t*-Bu	23[b] 71[c]	mp 27–28°	1,4471[d]	1,0007[d]	35,29	35,44	237 (3,86)	1315, 1375[d], 1405, 1480, 1510	3,89 s (MeO), 1,45 s (MeC)	10,0	24,48 21,20
(IIe)	*t*-$BuCH_2$	43[b] 74[c]	72 (4)	1,4476	0,9732	40,18	40,09	236 (3,80)	1320, 1380, 1410, 1490, 1515	3,93 s (MeO), 3,83 s (CH_2) 1,00 s (MeC)	13,9	19,32 19,16

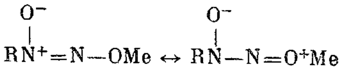
[a] Calculated on N-methyl-N'-toluenesulfoxydiazene N-oxide.
[b] Calculated on alkyl halide used to prepare the Grignard reagent.
[c] Calculated on the copper salt of the nitrosohydroxylamine (IIId, e).
[d] In the supercooled state.

The polarities of the AADO decrease regularly with increasing size of the alkyl radical. Thus at ∿20°C (IIa-c) are miscible with water in all proportions, whereas (IId) and (IIe) are only soluble to a limited extent in water. The GLC retention times on a polar liquid phase decrease in the sequence (IIa-d) despite the fact that the molecular weight increases (Table 1), which also indicates a decrease in polarity when H is replaced by methyl as the substituent on nitrogen in (IIa). The following relationship of the vapor pressure of (IIa) to temperature has been obtained for the temperature range 60-150°C:

$$\ln p\ (\mathrm{mm}) = (19.08 \pm 0.08) - (5620 \pm 18)/T.$$

This relationship was used to calculate the boiling point (178.3 ± 2.8°C at 760 mm), heat of evaporation (46.8 ± 0.2 kJ/mole), and entropy of evaporation at the boiling point (103.5 ± 1.0 J/mole·K). The last value shows that (IIa) deviates considerably in the positive direction from Trouton's rule (84-92 J/mole·K), behavior which is typical of strongly polar compounds which tend to form associates in the liquid phase. It was not possible to measure the dependence of vapor pressure on temperature for compounds (IIb-d), since these undergo considerable decomposition above temperatures as low as 120°C.

Compounds (IIb, c, e) and (IIId, e) are new. Their structures were proved by their IR, UV, and PMR spectra, elemental analyses, and the good agreement between the calculated and experimental values for the molecular refractions (Table 1). The IR spectra of the AADO show strong absorption at 1510-1515 and 1310-1320 $\mathrm{cm^{-1}}$, typical of aliphatic azoxy compounds [11]. The UV spectra of aqueous solutions of AADO show a shift in the π—π^* transition absorption to longer wavelengths as compared with aliphatic azoxy compounds (234-237 as against 217.5-222.5 nm [11]), indicating the occurrence of p—π conjugation:



$$\mathrm{R}\overset{\mathrm{O^-}}{\overset{|}{\mathrm{N}}}{}^{+}\mathrm{=N-OMe} \leftrightarrow \mathrm{R}\overset{\mathrm{O^-}}{\overset{|}{\mathrm{N}}}\mathrm{-N=O^{+}Me}$$

A similar shift in the π—π^* transition band when the alkyl radical is replaced by alkoxy, caused by p—π conjugation, is seen in diazenium salts, the cations of which resemble azoxy compounds in structure [12].

EXPERIMENTAL

The IR spectra were obtained on a UR-20 instrument, the PMR spectra on an NMR spectrometer with a cryogenic magnet, developed in the Institute of Chemical Physics, Academy of Sciences of the USSR (^{1}H, 294 MHz, no solvent, internal standard TMS; for (IId), 10% in $\mathrm{CCl_4}$, internal standard HMDS), and the UV spectra on a Specord UV-VIS (solvent water, cell thickness 10 mm). GLC analyses were carried out on an LKhM-8MD model 5 chromatograph, flame-ionization detector, carrier gas nitrogen. Steel columns, 2 m × 3 mm, 15% Carbowax-20M on Chromosorb W-HMDS, 80-100 mesh. Carrier gas flow rate 30 ml/min, column temperature 160°C.

Neopentyl chloride was obtained as described in [13], and the alkylmagnesium halides as described in [14]. Nitric oxide was purified by passing it successively through 40% KOH solution, granular KOH, and $\mathrm{P_2O_5}$. N-Methyl-N'-methoxydiazene N-oxide was obtained as described in [2], by reacting N-methyl-N'-tosyloxydiazene N-oxide with NaOMe in MeOH. In addition to (IIa), 20% of methyl tosylate was obtained. The dependence of the vapor pressure of (IIa) on temperature was measured in a glass vessel with a sickle-shaped membrane.

Methanol Solutions Containing RN(NO)OMgHal (IIb) and (IIc). Nitric oxide was passed through an ethereal solution of the Grignard reagent (EtMgBr, i-PrMgCl, t-BuMgCl, or t-$\mathrm{BuCH_2MgCl}$, 1.0-1.5 moles) with stirring and cooling, at such a rate that the temperature of the mixture remained within the range −20 to −10°C. A solid separated, which was resinous in the case of EtMgBr and i-PrMgCl, and a white suspension in the case of t-BuMgCl and t-$\mathrm{BuCH_2MgCl}$. When the rate of absorption of nitric oxide decreased, the temperature of the mixture was raised to ∿20°C in a stream of nitric oxide. The mixture was flushed out with argon, and unreacted Grignard reagent decomposed with methanol. The ether was distilled off, and the methanol solution filtered.

N-Ethyl- and N-Isopropyl-N'-methoxydiazene N-Oxides (IIb) and (IIc). To a solution of $\mathrm{RN_2O_2MgHal}$, obtained from 1.0 mole of RMgHal, in 0.5 liter of methanol was added with stirring 2 moles of $\mathrm{Me_2SO_4}$. There was a slight liberation of heat, with evolution of gaseous $\mathrm{Me_2O}$. The mixture was then kept for 1 day at ∿20°C, and boiled for 3 h under reflux. Unreacted $\mathrm{Me_2SO_4}$ was decomposed with 40% KOH solution, neutralized with 2 M $\mathrm{H_2SO_4}$, and the mixture diluted with water to 1.5 liters, and extracted with methylene chloride for 8 h in an automatic extractor. The extract was dried over $MgSO_4$, the solvent distilled off, and the residue twice distilled in vacuo.

Copper Salts of tert-Butyl- and Neopentylnitrosohydroxylamines (IIId) and (IIIe). A methanol solution of RN(NO)OMgCl, obtained from 1.0 mole of RMgCl, was evaporated in vacuo. The residue was dissolved with cooling (−5 to +5°C) in 0.25 liter of 2 M H_2SO_4. The resulting solution was treated with saturated aqueous $CuSO_4$ (0.53 mole in the case of R = t-Bu and 0.35 mole when R = t-$BuCH_2$). A dark-blue solid separated. The reaction mixtue was extracted repeatedly with CH_2Cl_2, and the extract dried over $MgSO_4$. After removal of the solvent, the product was recrystallized from ethanol. Yield of (IIId) 39%, mp 158-158.5°C. IR spectrum (ν, cm^{-1}, paste in CCl_4): 950, 1150, 1180, 1240, 1260, 1370, 1390, 1450, 1475. Found: Cu 21.16%. $C_8H_{18}N_4O_4Cu$. Calculated: Cu 21.34%. Yield of (IIIe) 59% (84% on $CuSO_4$), mp 120.5-121°C. IR spectrum (ν, cm^{-1}, paste in CCl_4): 970, 1130, 1210, 1270, 1295, 1370, 1470. Found: Cu 19.29%. $C_{10}H_{22}N_4O_4Cu$. Calculated: Cu 19.50%.

N-tert-Butyl- and N-Neopentyl-N'-methoxydiazene N-Oxides (IId) and (IIe). To a hot solution of 0.1 mole of (III) in 150 ml of ethanol was added 0.2 mole of 40% aqueous KOH, and the mixture was heated with stirring for 3 h. The solvent was distilled off in vacuo, the residue suspended in water (150 ml), the precipitated copper oxide removed by centrifugation, and the resulting solution of RN(NO)OK (Id-e) was treated with 0.4 mole of $KHCO_3$ and 0.4 mole of Me_2SO_4. The mixture was stirred for 5 h at ∿20°C and 2 h at 90°C. Compounds (IId) and (IIe) were isolated and purified as for (IIb) and (IIc).

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CONCLUSIONS

1. A method has been developed for the preparation of N-alkyl-N-nitrosohydroxylamine salts by treating alkylmagnesium halides with nitric oxide, yields of 40-60% being obtained. The reaction of chloromagnesium or potassium salts of N-alkyl-N-nitrosohydroxylamines with dimethyl sulfate has afforded 20-30% of N-alkyl-N'-methoxydiazene N-oxides, calculated on the alkylmagnesium halide taken.

2. According to their IR spectra, p—π conjugation is present in N-alkyl-N'-methoxydiazene N-oxides.

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