

140. *Amine Oxidation. Part VIII.* The Reaction of Tri-n-butylamine with Ozone.*

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Oxidation of tributylamine by ozone in chloroform or methanol gives the *N*-oxide (50—60%), and small amounts of dibutylamine, dibutylformamide, and dibutylbutyramide. When a hydrocarbon is used as solvent, the major products are either dibutylamine (from reaction at -78°) or dibutylformamide (from reaction at 15°). Intermediate production of a carbinolamine is postulated to account for these results.

REACTIONS of simple trialkylamines with ozone proceed explosively unless conducted in (a preferably cooled) solution.^{1,2} Trimethylamine in chloroform at -78° is converted by ozone into trimethylamine *N*-oxide,³ and good yields of *N*-oxides have been obtained from other trialkylamines under similar conditions.⁴ A more detailed study of the products from the action of ozone upon tributylamine has now been made with the aid of gas-liquid chromatography (g.l.c.).

Reaction of this amine with ozone ("ozonised oxygen") at -45° in chloroform or methanol gave tributylamine *N*-oxide (isolated as its picrate) in 61 and 52% yields, respectively. Gas-liquid chromatography of the remainder of the product revealed the presence of dibutylamine (10—15%) and small amounts of dibutylformamide and dibutylbutyramide.

The ratio of these products changed drastically when a hydrocarbon was used as solvent: dibutylamine was obtained as the main product from reaction of the amine with ozone

* Part VII, Curragh, Henbest, and Thomas, *J.*, 1960, 3559.

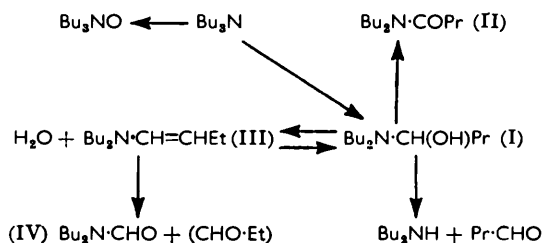
¹ Manchot, *Ber.*, 1913, **46**, 1089.

² Strecker and Thienemann, *Ber.*, 1920, **53**, 2102.

³ Strecker and Baltes, *Ber.*, 1921, **54**, 2693.

⁴ Horner, Schaefer, and Ludwig, *Ber.*, 1958, **91**, 75.

at -45 or -78° , but dibutylformamide became the chief product from similar oxidation at 15° . These and other observations are clarified by the following reaction scheme.



Tributylamine *N*-oxide is formed in methanol or chloroform; the hydrogen-bonding capacity of these solvents may assist the reaction because 1-chlorobutane behaved as did pentane in giving mainly amide. 1-Chlorobutane has a higher dipole moment (1.97 D) than chloroform (1.10 D) or methanol (1.66 D), but its capacity for hydrogen bonding must be very small. In pentane, cyclohexane, or 1-chlorobutane it is suggested that the reaction of ozone with tributylamine first gives the carbinolamine (I). This compound is fairly stable at -45° or below, but is hydrolysed to dibutylamine when the mixture is treated with water or aqueous acid during the isolation procedure. However, small amounts of the carbinolamine are also oxidised to the amide (II) or converted by loss of water into the enamine (III), followed by ozonolysis of this unsaturated amine to the formamide (IV). At higher temperatures dehydration to the enamine occurs more rapidly and the formamide becomes the main product (44%). (Loss of water from an intermediate carbinolamine occurs in the preparation of an enamine from a secondary amine and an aldehyde at 20° .⁵)

The following confirmatory experiments were carried out. The enamine (III) was formed (34% by g.l.c.) when tributylamine in pentane was treated with ozone at -78° and the solution was then warmed to 15° . Under these conditions (-78°) the enamine itself was oxidised by ozone to the formamide (IV), suggesting that in the tributylamine reaction an intermediate (the carbinolamine) is produced which is relatively stable to ozone.

The yield of the amide (II) was approximately the same (5–10%) from reactions at -78 , -45 , or 15° . The carbinolamine is regarded as its precursor; an example of the oxidation of a secondary alcohol to a ketone by ozone is known.⁶

Evidence was obtained for the presence of aldehydes (propanal from the enamine and/or butanal by decomposition of the carbinolamine) in the final reaction solutions, but their separate identification proved difficult. Butanal was, however, readily isolated when a suspension of tributylamine in water at 15° was ozonised. The yield of aldehyde was 47% and that of dibutylamine 50%, corresponding to their formation by hydrolysis of the carbinolamine. The low yield of *N*-oxide (0.5%) under these conditions is noteworthy in view of the results in methanol and chloroform, but tributylamine is sparingly soluble in water and much of the oxidation may be occurring in the amine and not the aqueous phase.

The yields mentioned in this discussion are based on the amounts of tertiary amine not recovered from each experiment. The yields of the components of many of the mixtures were determined fairly accurately and are given in the Experimental section.

EXPERIMENTAL

Ozonised oxygen was produced at a constant rate by passing dry oxygen through a Towers ozone apparatus. A typical figure for ozone production was 0.0142 mole/hr.

⁵ *inter al.*; Buckley, Henbest, and Slade, *J.*, 1957, 4891.

⁶ Oliveto, Smith, Gerold, Rausser, and Hershberg, *J. Amer. Chem. Soc.*, 1956, **78**, 1414.

Silicone oil (8% on Celite) was used as the stationary phase for g.l.c. Typical retention times (in min.) were dibutylamine (6 at 100°), tributylamine (24 at 100°; 11 at 140°), *N*-but-1-enyldibutylamine (13 at 140°), dibutylformamide (15 at 140°), dibutylpropionamide (26 at 140°; used as internal standard for the amides), and dibutylbutyramide (38 at 140°).

Experiment No.:	1	2	3	4	5	6	7
Bu ₃ N (g.)	5.96	5.99	5.97	6.10	20.76	23.30	5.39
(mole)	0.0322	0.0324	0.0323	0.033	0.112	0.126	0.029
Solvent (150 ml.)	CHCl ₃	MeOH	C ₆ H ₁₁ Cl	C ₆ H ₁₂	C ₆ H ₁₂	C ₆ H ₁₂	H ₂ O
Temp.	-45°	-45°	-45°	-45°	-78°	15°	15°
Time (hr.)	2	2	2	2	7	7	1.5
Ozone (mole)	0.0283	0.0283	0.0283	0.0283*	0.0992*	0.0992	0.0212
Unchanged Bu ₃ N (g.)	2.49	1.37	2.42	2.73	8.70	3.82	2.83
(mole)	0.0136	0.0074	0.0131	0.0148	0.0470	0.0206	0.0153
(%)	57	77	59	55	58	84	47
Bu ₂ NO (g.)	2.30	2.58	0.09	0.02	0.08	3.82	0.02
(mole)	0.0114	0.0129	0.0004	0.00007	0.0004	0.0190	0.00007
(%)	61	52	2	0.5	0.5	18	0.5
Bu ₂ NCOPr (g.)	0.14	0.23	0.41	0.40	1.10	1.59	0.37
(mole)	0.0007	0.0012	0.0021	0.0020	0.0055	0.0080	0.0018
(%)	4	5	11	11	8.5	8	13
Bu ₂ NCHO (g.)	0.03	0.07	0.14	0.12	0.30	7.26	0.14
(mole)	0.0002	0.0004	0.0009	0.0007	0.0019	0.0462	0.0009
(%)	1	2	5	4	3	44	6
Bu ₂ NH (g.)	0.11	0.33	1.22	1.24	5.30	0.29	0.94
(mole)	0.0009	0.0025	0.0095	0.0097	0.0410	0.0023	0.0073
(%)	5	10	49	53	63	2	53

* In these two experiments the ozone was incompletely absorbed.

The results are summarised in the Table. One experiment will be given in detail: Ozone (0.099 mole) was absorbed when tributylamine (23.3 g., 0.126 mole) in cyclohexane (150 ml.) at 15° was treated with ozonised oxygen for 7 hr. A water-soluble oil separated as a lower layer during the oxidation. The *N*-oxide was extracted* from the total mixture by water (50 ml.); a saturated solution of picric acid in water was added to give tributylamine *N*-oxide picrate, m. p. and mixed m. p. 110°. Ether (150 ml.) was added to the cyclohexane solution, and the amines were extracted with a solution of concentrated hydrochloric acid (11.5 ml.) in water (100 ml.). Sodium hydroxide (12 g.) was added to this extract and the amines recovered by continuous extraction with ether. The ether solution was dried (MgSO₄) and concentrated to ca. 15 ml. for analysis. The residual ether-cyclohexane solution was washed with aqueous solutions of potassium carbonate and then sodium metabisulphite, and finally dried and concentrated to ca. 15 ml. Distillation at 0.01 mm. (bath temp. 73–135°) gave several fractions whose infrared spectra, refractive indices, and retention times on gas chromatography were compared with those of authentic samples of the amides (II) and (IV). The first fraction consisted only of dibutylformamide, n_D^{20} 1.4419 (Found: C, 68.15; H, 12.0; N, 8.7. Calc. for C₈H₁₆ON: C, 68.75; H, 12.2; N, 8.9). The last fraction consisted of the formamide and dibutylbutyramide in the ratio 6.7 : 1 (by g.l.c.), n_D^{20} 1.4470 (Found: C, 71.5; H, 12.9; N, 6.9. Calc. for a 6.7 : 1 mixture: C, 71.7; H, 12.6; N, 7.3%).

Identification of dibutylamine. The basic material from Experiment No. 5 containing dibutylamine (5.3 g.) and tributylamine (8.7 g.) was treated with phenyl isothiocyanate (2 g.) and heated under reflux for 15 min. Chromatography on deactivated alumina (100 g.) gave *NN*-dibutyl-*N'*-phenylthiourea [2.2 g.; eluted with benzene–light petroleum (1 : 1)], m. p. and mixed m. p. 83° (from aqueous ethanol).

N-But-1-enyldibutylamine (III). Dibutylamine (12.9 g., 0.1 mole) was added slowly to butanal (7.2 g., 0.1 mole) in cyclohexane (100 ml.) at 15°. The solution was dried (MgSO₄) and evaporated. Distillation (twice) gave *N-but-1-enyldibutylamine* (7.1 g., 38%; 56% yield by g.l.c.), b. p. 62°/0.5 mm., n_D^{18} 1.4364 (Found: C, 78.2; H, 13.55; N, 8.5. C₁₃H₂₅N requires C, 78.6; H, 13.75; N, 7.65%). The compound gave strong peaks in the infrared spectrum at 930 and 1640 cm.⁻¹, and was hydrogenated (over platinum) to tributylamine quantitatively.

Tributylamine (3.54 g., 0.0192 mole) was ozonised in pentane (120 ml.) at -78° for 2 hr. Ozone (0.0283 mole) was passed but incompletely absorbed. The solution was warmed to 20°

* A small quantity of dibutylamine was lost by extraction into the aqueous phase; this did not form a picrate under the conditions used to estimate the *N*-oxide.

and examined by g.l.c.: the enamine (0.70 g., 0.0038 mole, 34%), dibutylamine (0.51 g., 0.004 mole, 35%), and tributylamine (1.5 g., 0.0081 mole) were detected. The characteristic peaks of the enamine were also present in the infrared spectrum of the solution. When a sample of the reaction solution was hydrogenated the g.l.c. peak height ratio of tributylamine : dibutylamine changed from 1.04 : 1 to 2.66 : 1, and the peak due to the enamine disappeared.

Dibutylformamide was rapidly produced when the enamine in pentane at -78° was ozonised. The formamide was not formed from dibutylbutyramide under similar conditions.

Oxidation of tributylamine suspended in water. The amine (9.94 g., 0.0537 mole) in water (150 mole) was ozonised for 3 hr. at 15° . Ozone (0.0425 mole) was passed but incompletely absorbed. Hydrochloric acid (15 ml.) in water (50 ml.) was added and the mixture was steam-distilled. The distillate afforded butanal 2,4-dinitrophenylhydrazone (0.54 g., 47%), m. p. 123° . Basification of the acid solution and ether extraction gave a fraction containing dibutylamine (1.16 g., 50%) and tributylamine (7.03 g.).

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