

- (11) C. J. Pedersen, *J. Am. Chem. Soc.*, **89**, 7017 (1967).  
 (12) For a description of the types of toxicity associated with crown ethers see: C. J. Pedersen, *Org. Synth.*, **52**, 66 (1972), and B. K. J. Leong, T. O. T. Ts'o, and M. B. Chenoweth, *Toxicol. Appl. Pharmacol.*, **27**, 342 (1974).  
 (13) Except for the adenine alkylations where the product was not volatile. In

- those examples mesitylene was used as an internal standard and the rate of alkylation was determined only by monitoring the disappearance of alkylating agent.  
 (14) Analyses were performed on a Hewlett-Packard Gas Chromatograph Model 5830A using a 6-ft column packed with 3% SE-30.

## Ozonation of Nucleophiles. 8. Secondary Amines<sup>1</sup>

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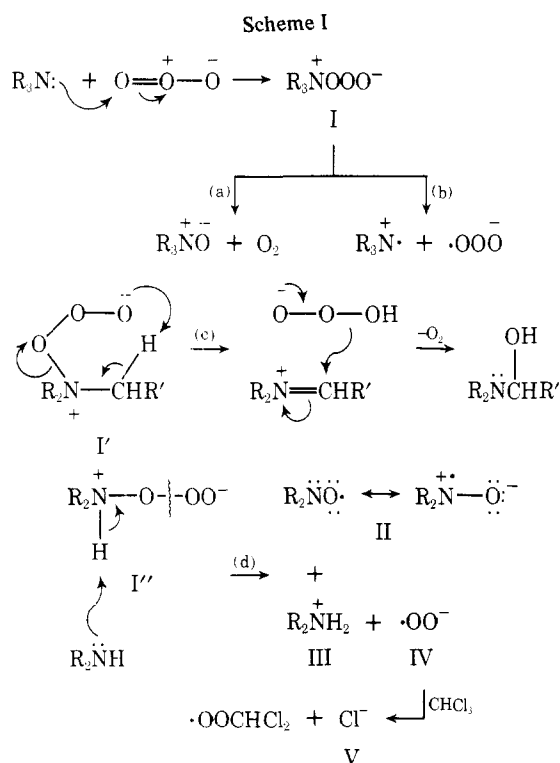
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Secondary amines react with ozone via two major routes, one involving nitroxide and ammonium salt formation and the other involving side-chain oxidation. The first appears to be the only reaction type with di-*tert*-butylamine and the major route with diisopropylamine. Side-chain oxidation is the major route with di-*n*-butylamine. Detailed mechanisms are proposed based on present findings and theories developed in earlier studies with primary, secondary, and tertiary amines bearing primary, secondary, and/or tertiary alkyl groups.

Previous papers in this series have been concerned with ozonations of various primary, secondary, and tertiary amines,<sup>2-7</sup> as well as with a similar study regarding certain dialkyl sulfides.<sup>1</sup> Studies with primary amines having primary, secondary, and tertiary alkyl substituents have been published,<sup>2,4,7</sup> but the only secondary and tertiary amines so far included are di-*tert*-butylamine,<sup>5</sup> tri-*n*-butylamine,<sup>2,3</sup> and 1-di-*n*-butylamino-2-butanone.<sup>3</sup> These investigations have led to the proposal of four competing fates (Scheme I) for the initially formed ozone-amine adduct (I). The equations representing these fates (a-d, Scheme I) depict only the initial steps; additional reactions generally follow.

The present paper describes ozonations of diisopropylamine and di-*n*-butylamine and completes and summarizes our studies concerning secondary amines possessing primary, secondary, and tertiary alkyl substituents, as did our earlier paper<sup>7</sup> with primary amines.

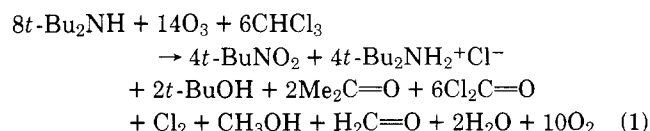
The ozonations of diisopropylamine were performed with



1 mol of amine in chloroform (at  $-65^\circ\text{C}$ ), methylene chloride ( $-78^\circ\text{C}$ ) and carbon tetrachloride ( $-20^\circ\text{C}$ ). Ozone reacted quantitatively and the molar ratio of ozone to amine reacting was approximately 2 in the chloroform and methylene chloride reactions and 1 in the carbon tetrachloride reaction. The molecular oxygen yield was 0.7–0.9 mol/mol of ozone reacting. These and other results are shown in Table I, along with results from ozonation of diisopropylhydroxylamine.

The results in chloroform solvent (experiment 1, Table I) were similar to those obtained with di-*tert*-butylamine in the same solvent,<sup>5</sup> with the exception that the nitroalkane yield was only about half as high as with di-*tert*-butylamine and that obvious side-chain oxidation products were obtained. A major product was diisopropylammonium chloride, analogous to findings with di-*tert*-butylamine<sup>5</sup> (as well as with primary amines<sup>7</sup>). However, the ratio of salt to nitro compound was greater than 1 with diisopropylamine but less than 1 with di-*tert*-butylamine.<sup>5</sup> The origin of the salt was shown to be fate d (Scheme I,  $R = i\text{-Pr}$ ), as found also for di-*tert*-butylamine,<sup>5</sup> rather than the cation radical-ozonate anion radical route (fate b, Scheme I) characteristic of primary amines.<sup>7</sup> EPR studies, in pentane at  $-100^\circ\text{C}$ , Freon 11 at  $-120^\circ\text{C}$ , or the neat amine at  $-70^\circ\text{C}$ , gave no indication of the ozonate anion radical but showed a strong nine-line signal characteristic of diisopropyl nitroxide (II, Scheme I,  $R = i\text{-Pr}$ )<sup>8</sup> (cf. ref 5). Other workers also have shown that dialkyl or diaryl nitroxides are produced in the first stage of ozonation of secondary amines.<sup>9</sup>

The ozonations of di-*tert*-butylamine in chloroform, to give di-*tert*-butyl nitroxide (II,  $R = t\text{-Bu}$ ) and di-*tert*-butylammonium chloride (III + V, Scheme I,  $R = t\text{-Bu}$ ), and of di-*tert*-butyl nitroxide to give 2-methyl-2-nitropropane and other products, were described in previous papers.<sup>5,6</sup> Equation 1 describes the overall results.<sup>5</sup>



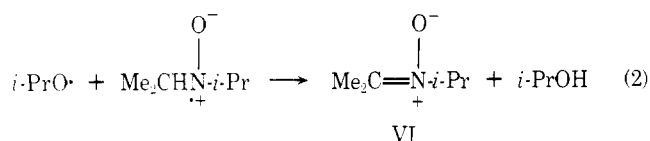
Reactions analogous to most of those leading to eq 1 (eq 7–10, ref 5 and 6–8, ref 6) would also be expected to occur during ozonations of diisopropylamine and diisopropyl nitroxide, with, however, different weightings and certain additions, the principal one of which has to do with the difference in stabilities of the dialkyl nitroxides involved. Dialkyl nitroxides

Table I. Ozonation of Diisopropylamine

Expt	Solvent <sup>a</sup>	Temp, °C	O <sub>3</sub> /amine reacting <sup>b</sup>	O <sub>2</sub> /O <sub>3</sub> evolved <sup>c</sup>	<i>i</i> -Pr <sub>2</sub> -NH <sub>2</sub> <sup>+</sup> Cl <sup>-d</sup>	Me <sub>2</sub> -C=N- <i>i</i> -Pr <sup>d</sup>	CH <sub>3</sub> C-(=O)-N(-H)- <i>i</i> -Pr <sup>d</sup>	Me <sub>2</sub> -C=O <sup>d</sup>	<i>i</i> -Pr-NO <sub>2</sub> <sup>d</sup>	<i>i</i> -PrN(O)N(O)- <i>i</i> -Pr <sup>d,e</sup>	Me <sub>2</sub> -C=N-OH <sup>d</sup>	<i>i</i> -Pr-NH <sub>2</sub> <sup>d</sup>	Other <sup>d</sup>	% accounting <sup>d</sup> for fragments	
														N <sup>f</sup>	<i>i</i> -Pr <sup>g</sup>
1	CHCl <sub>3</sub> <sup>h</sup>	-65	2.1	0.7	36	3	2	50	27	5	9	6	3 <sup>i</sup>	93	94
2	CH <sub>2</sub> Cl <sub>2</sub> <sup>h</sup>	-78	2.1	0.9	17	4	3	59	23	7	18	17	<i>j</i>	96	90
3	CCl <sub>4</sub>	-20	1.1	0.8	24	10	4	33	12	0	0	0	3 <sup>i</sup>	54	67
4	CHCl <sub>3</sub> <sup>m</sup>	-65	1.0 <sup>m</sup>	0.5	31 <sup>m</sup>	0	0	38	14	<i>n</i>	0	0	4 <sup>k,l</sup>	45	57

<sup>a</sup> In the first two experiments 20 mmol of amine in 20 mL of solvent was employed. In the other experiments, 3–10 mmol of amine in 5–15 mL of solvent was used. <sup>b</sup> In each case 1 mmol of ozone (in a nitrogen stream) per mmol of starting amine was used and reacted completely. Unreacted amine was determined and the ratio is that of O<sub>3</sub> to amine reacting. <sup>c</sup> Moles of molecular oxygen evolved per mole of ozone reacting. These values were obtained in separate, smaller experiments. <sup>d</sup> Percentage yields based on amine used up, rounded off to the nearest whole number. <sup>e</sup> 2-Nitrosopropane dimer. <sup>f</sup> The N fragment accounting includes amine salt, imine, amide, 2-nitrosopropane, 2-nitrosopropane dimer, acetone oxime, and isopropylamine. <sup>g</sup> The isopropyl group accounting is based on two isopropyl groups in the starting amine and includes all products shown. <sup>h</sup> The values in these experiments are averages of two experiments. <sup>i</sup> 2-Propanol. <sup>j</sup> Not determined. <sup>k</sup> Active oxygen containing material, possibly 2-isopropyl-3,3-dimethyloxazirane. <sup>l</sup> A small amount of triisopropylurea was isolated. <sup>m</sup> In this experiment the starting amine was diisopropylhydroxylamine and the corresponding hydrochloride was a product. Here, yields are based on starting amine because no method was found for determining unreacted hydroxylamine. This is one reason why the accounting is low. <sup>n</sup> Present. <sup>o</sup> 2-Propanol was identified by GLC.

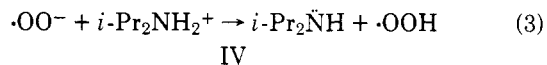
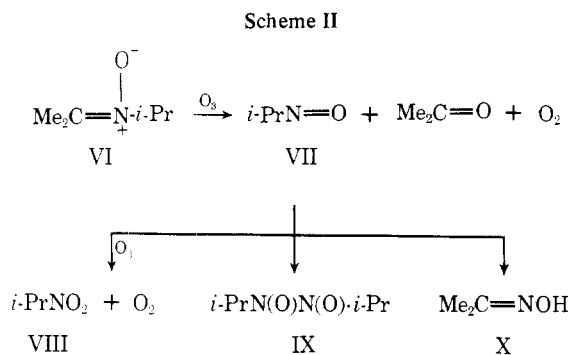
possessing primary or secondary alkyl groups are much less stable than those with tertiary alkyl groups and are susceptible to attack by radicals to give the corresponding nitrones (VI).<sup>10,11</sup> Thus, the isopropoxide radical would be expected to react as shown in eq 2, rather than to attack the solvent or



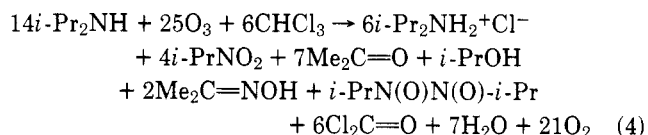
to decompose, as suggested for the *tert*-butoxy radical during the ozonation of di-*tert*-butyl nitroxide.<sup>6</sup> Similar reactions would also be expected for radicals such as  $\cdot\text{OOH}$  (to give VI +  $\text{HOOH}$ ) and  $\cdot\text{OOCHCl}_2$  (to give VI +  $\text{HOCHCl}_2$ , followed by  $\text{HOCHCl}_2 \rightarrow \text{HOH} + \text{O}=\text{CCl}_2$ ).

Ozonation of nitron VI should lead to acetone and 2-nitrosopropane (VII), as illustrated in Scheme II.<sup>12</sup> A pale blue color, characteristic of the nitroso compound, was observed throughout the ozonation of diisopropylamine. Various fates of the nitrosopropane (VII) include oxidation by ozone to 2-nitrosopropane (VIII), dimerization to IX, and isomerization to acetone oxime (X).

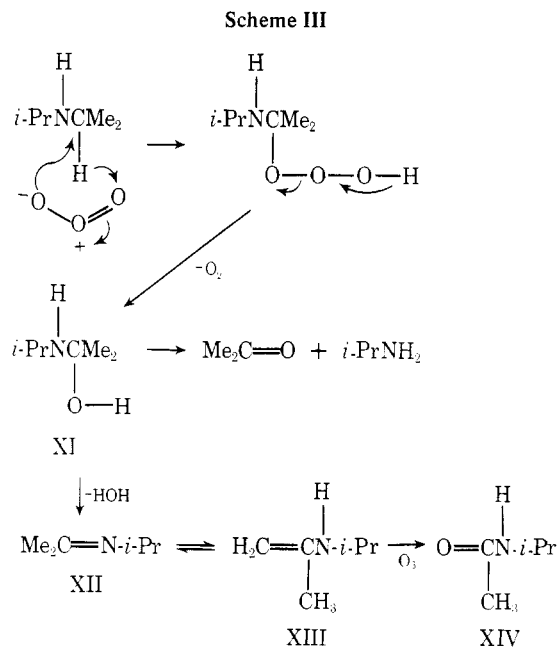
In addition to these reactions, reactions such as expressed by eq 3, not previously considered,<sup>5</sup> would be expected to occur during ozonations of both diisopropylamine and di-*tert*-butylamine, since the superoxide anion radical (IV) should behave not only as a nucleophile,<sup>13–16</sup> as previously considered in its attack on the solvent<sup>5</sup> (Scheme I), but also as a base.



Judicious weightings of these various indicated reactions, along with the likelihood of some oxidation by ozone of isopropyl alcohol to acetone, leads to summation eq 4, which furnishes a reasonably accurate accounting for the products obtained by the nitroxide pathway (fate d, Scheme I, R = *i*-Pr) during ozonation of diisopropylamine.



Along with the products shown in eq 4 were obtained side-chain oxidation products (Table I, experiment 1). These are rationalized in Scheme III. 1,3-Dipolar insertion<sup>17</sup> is chosen over fate c (Scheme I) for the initiating reaction because of recent results with diisopropylethylamine<sup>18</sup> which showed







ever, are consistent with the tri-*n*-butylamine ozonation results and the mechanism of fate c (Scheme I) for side-chain attack.<sup>3</sup> In pentane, it appears that only side-chain attack occurred and, in carbon tetrachloride, it was, by far, the major reaction. Since no nitron was isolated in the carbon tetrachloride experiment, the source of the ammonium salt is uncertain. Either reactions analogous to eq 3 failed to occur or else fate b (Scheme I) was the source of the ammonium salt (see ref 4).

Table III shows the approximate contributions of the various ozonation routes occurring during the ozonations of di-*tert*-butylamine, diisopropylamine, and di-*n*-butylamine under various conditions. In summary, it is evident that, judging from the examples studied, the nitroxide pathway (fate d, Scheme I) is by far the major ozonation route utilized by secondary amines having tertiary and secondary alkyl groups. With those bearing primary alkyl groups, however, side-chain oxidation is predominant in most solvents.

It is surprising that, with di-*n*-butylamine, side-chain oxidation was the major reaction even with chloroform solvent. With tri-*n*-butylamine,<sup>3</sup> amine oxide formation was by far the major reaction in chloroform at  $-60^{\circ}\text{C}$ , while side-chain oxidation was predominant in hydrocarbon solvents. This was also true, though to a lesser degree, with *n*-butylamine.<sup>7</sup> The fact, however, that with di-*n*-butylamine side-chain oxidation increased to 100% in pentane (compared to 56% in chloroform) indicates that side-chain oxidation occurred by the mechanism of fate c (Scheme I) with both di-*n*-butylamine and tri-*n*-butylamine (see discussions in ref 3 and 7). The result with di-*n*-butylamine in methylene chloride (Table III), however, is anomalous. As stated earlier, we suggest that the side-chain oxidation with diisopropylamine occurs by 1,3-dipolar insertion (Scheme III, see ref 18).

Finally, it is noteworthy that the major side-chain oxidation product from ozonation of di-*n*-butylamine was the imine (XVII), whereas acetone and isopropylamine were the principal side-chain oxidation products from diisopropylamine. This reflects the difference in stabilities of the initial oxidation products, amino alcohols XI and XVI. The former, being structurally a product of addition between a primary amine and a ketone, would most easily revert back to these substances, whereas with the latter, derived from an aldehyde and a primary amine, the equilibrium tends to favor the imine.

### Experimental Section

**Materials.** The di-*n*-butylamine and diisopropylamine were J. T. Baker reagent grade; they were dried over potassium hydroxide pellets and distilled. Diisopropylhydroxylamine was synthesized by the procedure of Dustan and Goulding:<sup>19</sup> bp 47–49 (8 mm);<sup>20</sup> mol wt 117 (mass spectroscopy); NMR  $\delta$  1.08 (12 H, doublet), 3.08 (2 H, heptet), 6.81 (1 H singlet, diffuse). *N*-Isopropylacetamide was prepared by the method of Lock and Sagar,<sup>21</sup> and isopropylideneisopropylamine was prepared by the method of Norton et al.<sup>22</sup> 2-Nitrosopropane dimer (mp 50–51  $^{\circ}\text{C}$ )<sup>23</sup> and 1-nitrosobutane dimer (UV<sub>max</sub> 287)<sup>23</sup> were prepared by the procedure of Emmons.<sup>24</sup> *N*-*n*-Butylformamide was prepared by formylation of *n*-butylamine using chloral,<sup>25</sup>  $n^{25}\text{D}$  1.4387.<sup>26</sup> *N*-*n*-Butylidene-*n*-butylamine was prepared by the method of Campbell et al.<sup>27</sup> Di-*n*-butylhydroxylamine was obtained by the amine oxide pyrolysis procedure of Cope and Ciganek,<sup>28</sup> mp 51–52  $^{\circ}\text{C}$ .<sup>28b</sup> *C*-*n*-Propyl-*N*-*n*-butylnitron was prepared by hydrogen peroxide oxidation of di-*n*-butylhydroxylamine as described by Utzinger:<sup>29</sup> UV<sub>max</sub> 232 nm; NMR,  $\delta$  6.73 (t,  $J = 6$  Hz,  $\text{CH}=\text{N}$ ), 3.79 (t,  $J = 7$  Hz,  $\text{CH}_2\text{N}$ ), 2.57 (m,  $\text{CH}_2\text{CH}=\text{N}$ ), 1.63 (m,  $\text{CH}_2\text{CH}_2\text{CH}=\text{NCH}_2\text{CH}_2\text{CH}_2$ ), 0.99 (t, 3), 0.96 (t, 3). The other materials used were either obtained commercially or were prepared by standard procedures.

**General Procedures.** The ozonation setup and procedures, including the use of ozone–nitrogen and the determination of molecular oxygen yields,<sup>30</sup> EPR,<sup>5,7</sup> NMR,<sup>7</sup> and GLC<sup>7</sup> procedures, were as described in earlier papers. The GLC columns employed were: (1) 20% Carbowax 20M on Chromosorb P,  $\frac{1}{4}$  in. by 15 ft; (2) 10% Carbowax 20M–10% NaOH on Chromosorb P,  $\frac{1}{4}$  in. by 20 ft; (3) 5% Celanese ester No. 9 on Haloport F,  $\frac{1}{4}$  in. by 10 ft; (4) 30% silicone gum rubber

**Table III. Competitions in Ozonations of Secondary Amines Having Tertiary, Secondary, and Primary Alkyl Groups**

Amine	Solvent	Temp, $^{\circ}\text{C}$	Nitroxide pathway, %	Side-chain oxidation, %
<i>t</i> -Bu <sub>2</sub> NH	CHCl <sub>3</sub>	-65	100	
<i>i</i> -Pr <sub>2</sub> NH	CHCl <sub>3</sub>	-65	87.5	12.5
<i>i</i> -Pr <sub>2</sub> NH	CH <sub>2</sub> Cl <sub>2</sub>	-78	75	25
<i>n</i> -Bu <sub>2</sub> NH	CHCl <sub>3</sub>	-60	44	56
<i>n</i> -Bu <sub>2</sub> NH	CHCl <sub>3</sub>	0	25	75
<i>n</i> -Bu <sub>2</sub> NH	CH <sub>2</sub> Cl <sub>2</sub>	-60	50	50
<i>n</i> -Bu <sub>2</sub> NH	Pentane	-60	0	100

SE-30 on Chromosorb P,  $\frac{1}{4}$  in. by 10 ft; (5) 20% Dowfax 9N9, 2.5% NaOH on Chromosorb W,  $\frac{1}{4}$  in. by 10 ft; (6) 15% Carbowax 20M on Chromosorb W (AW),  $\frac{1}{4}$  in. by 10 ft; (7) 5% DEGS, 2% H<sub>3</sub>PO<sub>4</sub> on Chromosorb P,  $\frac{1}{4}$  in. by 10 ft; (8) 5% Versamid 900 on Chromosorb G (AW),  $\frac{1}{4}$  in. by 5 ft.

**Ozonation of Diisopropylamine and Diisopropylhydroxylamine.** In these experiments 3–20 mmol of amine in 5–20 mL of solvent was ozonized with 1 molar equiv of ozone at the indicated temperature (Table I). The solution was then divided into three equal portions for analysis. With one portion gas chromatographic analyses were performed for 2-nitropropane (column 1, 125  $^{\circ}\text{C}$ ); acetone, isopropyl alcohol, isopropylamine, and isopropylideneisopropylamine (column 2, 75  $^{\circ}\text{C}$ ); and *N*-isopropylacetamide (column 3, 125  $^{\circ}\text{C}$ ). Yields were determined by comparison with standard solutions. Another portion was used for quantitative NMR analyses for diisopropylamine, 2-nitrosopropane dimer, and acetone oxime, using relative peak height ratios and 2-nitropropane as an internal standard. The peaks measured were the high field spikes of the 2-nitropropane and 2-nitrosopropane methyl doublets, the center line of the diisopropylamine methyne heptet, and the acetone oxime methyl singlet. The third reaction mixture portion was used for a Volhard chloride titration in determining the yield of diisopropylammonium chloride.

From the carbon tetrachloride ozonations, there was found, in addition to the above, small amounts of triisopropylurea (water insoluble precipitate; mp 77–78  $^{\circ}\text{C}$ , identified by IR and mass spectra comparison with an authentic sample) and, presumably, 2-isopropyl-3,3-dimethylloxazirane (tentatively identified by NMR methyl peaks  $\delta$  1.47 and 1.57, in comparison with a pure sample, and by the fact it gave positive active oxygen, but negative hydroperoxide, tests).

**Ozonation of Di-*n*-butylamine.** In these experiments 5–20 mmol of amine in 2–3 mL of solvent/mmol of amine was ozonized with 1 molar equiv of ozone at the indicated temperature (Table II). Usually a precipitate formed which, however, melted or decomposed as the temperature of the reaction mixture rose to room temperature. Aliquots were taken for analysis. Unreacted di-*n*-butylamine and *N*-*n*-butylidene-*n*-butylamine were determined on column 5 (75  $^{\circ}\text{C}$ , 4 min, then increased to 175  $^{\circ}\text{C}$  at 6  $^{\circ}\text{C}/\text{min}$ ), using propylbenzene as an internal standard. These determinations were also checked by quantitative NMR, using 1,1-diphenylethylene as an internal standard. The bands employed were: Ph<sub>2</sub>C=CH<sub>2</sub> ( $\delta$  5.45 s), PrCH=NCH<sub>2</sub>Pr ( $\delta$  3.35, t), and (PrCH<sub>2</sub>)<sub>2</sub>NH ( $\delta$  2.62, t). The nitron was also determined by quantitative NMR, employing the following band: PrCH=N(O)Bu ( $\delta$  6.63, t). 1-Nitrobutane was determined on column 4 (90  $^{\circ}\text{C}$ ) using toluene as an internal standard; butyraldehyde was determined on column 6 (90  $^{\circ}\text{C}$ ), ethylbenzene internal standard; *N*-*n*-butyl-*n*-butyramide and *N*-*n*-butylformamide were determined on column 8 (170  $^{\circ}\text{C}$ ), phenyl propyl ketone internal standard; and butyric acid was determined on column 7 (120  $^{\circ}\text{C}$ ), phenyl propyl ketone internal standard (after extraction of the reaction mixture with potassium hydroxide, acidification, and ether extraction). The di-*n*-butylammonium chloride was determined as described for the corresponding salt from diisopropylamine.

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**Registry No.**—Diisopropylamine, 108-18-9; dibutylamine, 111-92-2; di-*tert*-butylamine, 21981-37-3; diisopropylhydroxylamine, 5765-61-7.

## References and Notes

- (1) Paper 7: P. S. Bailey and A. Y. Khashab, *J. Org. Chem.*, **43**, 675 (1978).
- (2) P. S. Bailey, J. E. Keller, D. A. Mitchard, and H. M. White, *Adv. Chem. Ser.*, No. 77, 58 (1968).
- (3) P. S. Bailey, D. A. Mitchard, and A. Y. Khashab, *J. Org. Chem.*, **33**, 2675 (1968).
- (4) P. S. Bailey and J. E. Keller, *J. Org. Chem.*, **33**, 2680 (1968).
- (5) P. S. Bailey, J. E. Keller, and T. P. Carter, Jr., *J. Org. Chem.*, **35**, 2777 (1970).
- (6) P. S. Bailey and J. E. Keller, *J. Org. Chem.*, **35**, 2782 (1970).
- (7) P. S. Bailey, T. P. Carter, Jr., and L. M. Southwick, *J. Org. Chem.*, **37**, 2997 (1972).
- (8) H. J. B. Benon and J. M. Gebicki, "Atlas of Electron Spin Resonance Spectra", Academic Press, New York, N.Y., 1967, p 390.
- (9) S. D. Razumovskii, A. L. Buchachenko, A. B. Shapiro, E. G. Rozantsev, and G. E. Zaikov, *Dokl. Chem. (Engl. Transl.)*, **183**, 1086 (1968).
- (10) E. G. Rozantsev, *Russ. Chem. Rev. (Engl. Transl.)*, **35**, 658 (1966).
- (11) K. Adamic, D. F. Bowman, and K. U. Ingold, *J. Am. Chem. Soc.*, **92**, 1093 (1970).
- (12) (a) A. H. Riebel, R. E. Erickson, C. J. Abshire, and P. S. Bailey, *J. Am. Chem. Soc.*, **82**, 1801 (1960); (b) R. E. Erickson and T. M. Myskiewicz, *J. Org. Chem.*, **30**, 4326 (1965); (c) R. E. Erickson, P. J. Andrulis, J. C. Collins, M. L. Lungie, and G. D. Mercer, *ibid.*, **34**, 2961 (1969).
- (13) I. Vol'nov, "Peroxides, Superoxides and Ozonides of Alkali and Alkaline Earth Metals", translated by J. Woroncow, A. W. Petrocelli, Ed., Plenum Press, New York, N.Y., 1966.
- (14) M. V. Merritt and D. T. Sawyer, *J. Org. Chem.*, **35**, 2157 (1970).
- (15) M. Schmidt and H. Bipp, *Z. Anorg. Allg. Chem.*, **303**, 190, 201 (1960).
- (16) (a) A. Le Berre and Y. Berguer, *Bull. Soc. Chim. Fr.*, 2363, 2368 (1966); (b) A. LeBerre and Y. Berguer, *C. R. Hebd. Seances Acad. Sci.*, **260**, 1995 (1965).
- (17) J. E. Batterbee and P. S. Bailey, *J. Org. Chem.*, **32**, 3899 (1967).
- (18) P. S. Bailey, D. A. Lerdal, and T. P. Carter, Jr., *J. Org. Chem.*, following paper in this issue.
- (19) W. R. Dunstan and E. Goulding, *J. Chem. Soc.*, **75**, 792 (1899).
- (20) G. Zinner and W. Kliegel, (*Weinheim, Ger.*), *Arch. Pharm.*, **299**, 166 (1966).
- (21) M. V. Lock and B. F. Sagar, *J. Chem. Soc. B*, 690 (1966).
- (22) D. G. Norton, V. E. Haury, F. C. Davin, L. J. Mitchell, and S. A. Ballard, *J. Org. Chem.*, **19**, 1054 (1954).
- (23) B. G. Gowenlock and J. Trotman, *J. Chem. Soc.*, 1670 (1956).
- (24) W. D. Emmons, *J. Am. Chem. Soc.*, **79**, 6522 (1957).
- (25) F. F. Blicke and C. J. Lu, *J. Am. Chem. Soc.*, **74**, 3933 (1952).
- (26) P. L. de Benneville, J. S. Strong, and V. T. Elkind, *J. Org. Chem.*, **21**, 772 (1956).
- (27) K. N. Campbell, A. H. Sommers, and B. K. Campbell, *J. Am. Chem. Soc.*, **66**, 82 (1944).
- (28) (a) A. C. Cope and E. Ciganek, "Organic Syntheses", Collect. Vol. IV, Wiley, New York, N.Y., 1963, p 612; (b) A. C. Cope and H. H. Lee, *J. Am. Chem. Soc.*, **79**, 964 (1957).
- (29) G. E. Utzinger, *Justus Liebigs Ann. Chem.*, **556**, 50 (1944).
- (30) A. M. Reader, P. S. Bailey, and H. M. White, *J. Org. Chem.*, **30**, 784 (1965).

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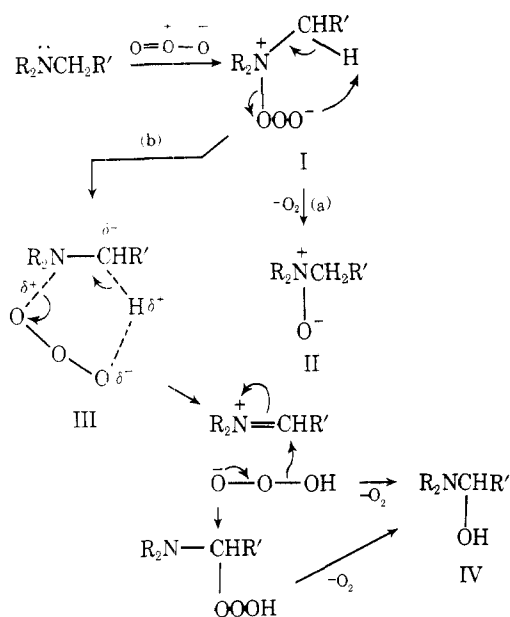
The study of the reactions of amines with ozone has been extended to triisopropylamine and ethyldiisopropylamine. Tertiary amines having primary or secondary alkyl groups react with ozone to give largely side-chain (alkyl group) oxidation products plus an amine oxide. The latter is a minor reaction except for ozonations, in a protic solvent, of tertiary amines bearing primary alkyl groups. With primary alkyl groups the major side-chain oxidation route appears to involve an internal oxidation of the amine-ozone adduct, whereas with secondary alkyl groups side-chain oxidation is best explained by 1,3-dipolar insertion.

Two previous papers<sup>1,2</sup> in this series have summarized our studies concerning the ozonation of primary<sup>2-4</sup> and secondary<sup>1,5</sup> amines bearing primary, secondary, and tertiary alkyl groups. The only tertiary amines previously included in our studies were tri-*n*-butylamine<sup>3,6</sup> and 1-di-*n*-butyl-

amino-2-butanone.<sup>6</sup> The results of these investigations can be rationalized by an electrophilic ozone attack on the amine followed by four competing fates of the amine-ozone adduct (I). The reactions pertinent to the ozonation of tertiary amines are outlined in Scheme I. These include (a) amine oxide (II) formation and (b) intramolecular side-chain oxidation, via III, to amino alcohol IV, followed by further reactions thereof.

Reaction (b), as a route to side-chain oxidation products, involves a transition state (III) with carbanion character.<sup>3,6</sup> The evidence is strong that this is the mechanistic type utilized in primary alkyl side-chain oxidations.<sup>2,3,6</sup> However, the situation is not so clear for secondary alkyl substituents<sup>2</sup> and it is quite possible that 1,3-dipolar insertion<sup>7</sup> (Scheme II) is

Scheme I



Scheme II

