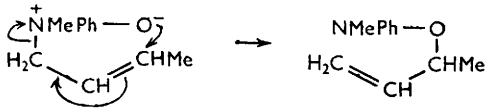
816. *The Rearrangement of Amine Oxides.*

By A. H. Wragg, T. S. Stevens, and D. M. Ostle.

Further evidence is provided that the Meisenheimer rearrangement of amine oxides to trisubstituted hydroxylamines is an intramolecular process independent of added alkali. Substituents in the amine oxides have in part their expected effect on the speed of rearrangement, showing a parallelism with the effect of the same substituents on the rearrangement of quaternary ammonium ions, but the " stationary groups " have an effect not easily understood.

The Meisenheimer rearrangement of amine oxides to *ONN*-trisubstituted hydroxylamines was examined in some detail by Cope and his collaborators,[1] who showed that but-2-enylmethylaniline oxide afforded *N*-methyl-*O*-1-methylallyl-*N*-phenylhydroxylamine, so that in this case at least the rearrangement appears to be intramolecular, proceeding by a cyclic mechanism:



They also effected the rearrangement, under slightly modified conditions, of amine oxides not containing an *N*-aryl group. It is a very important, though not quite a necessary, condition that the migrating radical be of allyl or benzyl type.

This rearrangement is comparable with that of phenacylammonium salts: $^{+}NRMe_2{\cdot}CH_2{\cdot}COPh \longrightarrow H^{+} + {}^{+}NRMe_2{\cdot}{}^{-}CH{\cdot}COPh \longrightarrow NMe_2{\cdot}CHR{\cdot}COPh$, in which an allyl, 1-phenylethyl, diphenylmethyl, or fluorenyl radical migrates much faster than benzyl, and the process is accelerated by electron-attracting *meta*- and *para*-substituents and by all *ortho*-substituents in a migrating benzyl radical. We have explored the recurrence of these relations in the amine oxide rearrangement by simple kinetic experiments, which also indicate that the process is of the first order in free amine oxide and independent of the presence of the alkali used in excess by Meisenheimer.

In the first series (Table 1) the oxides of benzylmethylaniline and analogous bases were isomerised in alcoholic solution, and the reaction followed at each stage by titrating the remaining oxide with titanous sulphate. Here, again, the allyl group migrates faster than

Table 1.

No.	Amine oxide	k_{20}	k_{30}	k_{60}
1	$Ph{\cdot}CH_2{\cdot}N^{+}(O^{-})MePh$	—	—	0·0062
2	$Ph{\cdot}CH_2{\cdot}{}^{+}N(O^{-})Me{\cdot}C_6H_4Br(p)$	—	—	0·014
3	$CH_2{=}CH{\cdot}CH_2{\cdot}{}^{+}N(O^{-})MePh$	—	0·0071	—
4	$CH_2{=}CH{\cdot}CH_2{\cdot}{}^{+}N(O^{-})Ph{\cdot}CH_2Ph$	0·013	0·055	—

benzyl (cases 1 and 3); in case 4, the allyl group migrates exclusively. Electron-attracting substituents in either of the " stationary " radicals should accelerate the reaction, which removes the positive formal charge of the nitrogen atom to which they are attached; this is the effect of the bromine substituent in case 2, and of the additional phenyl group in 4 as compared with 3.

While benzyl- and allyl-dialkylamine oxides rearrange with some reluctance and the production of by-products, dialkyldiphenylmethylamine oxides are transformed very smoothly, and variously substituted examples are relatively easy to prepare. In these cases the progress of rearrangement was followed by directly isolating the resulting trialkylhydroxylamines, and the results are set out in Table 2, which also contains for comparison the approximate basic dissociation constants (K_b) of the tertiary amines from which the

[1] Cope *et al.*, *J. Amer. Chem. Soc.*, 1944, **66**, 1929; 1949, **71**, 3423, 3929.

oxides are derived. In each of the series (*A*), (*B*), and (*C*), the velocity of rearrangement increases as the basic strength of the tertiary amine decreases; the effect of the electron-

TABLE 2. *Rearrangement of oxides* $^{-}O{\cdot}N^{+}RR'R''$.

No.	Migrating group, R		Stationary groups, R′, R″: Me_2 (*A*)	$-[CH_2]_5-$ (*B*)	$-[CH_2]_2{\cdot}O{\cdot}[CH_2]_2-$ (*C*)
5	Diphenylmethyl	10^3k	4·4	3·5	1·8
		$10^{10}K_b$	350	100	3·4
6	9-Fluorenyl	10^3k	5·3	5·1	3·5 —
		$10^{10}K_b$	210	21	3·0
7	Phenyl-*o*-tolylmethyl	10^3k	11·8	10·0	5·2
		$10^{10}K_b$	140	14	2·5
8	Di-*p*-nitrophenylmethyl	10^3k	200	—	—
		$10^{10}K_b$	1·4	—	—
9	Di-α-naphthylmethyl	10^3k	—	—	130
		$10^{10}K_b$	—	—	0·09

attracting nitro-groups is outstanding. *p*-Nitro- and *o*-methyl substituents have the same influence here as when introduced into a migrating benzyl group in the quaternary ammonium salt rearrangement. On the other hand, those changes in the stationary groups which increase the basic strength of the tertiary amines (horizontal series) *accelerate* the isomerisation, an effect not easily accounted for. The piperidine derivatives in this series are weaker bases than their dimethylamine analogues.

The intramolecular character of the transformation has been confirmed by effecting the rearrangement of a mixture of the oxides 7*A* and 9*C*. Here the separation of *NN*-dimethyl-*O*-phenyl-*o*-tolylmethylhydroxylamine and *N*-di-α-naphthylmethoxymorpholine was easy by steam-distillation; they were obtained in almost quantitative yield, and no other product could be recognised such as would arise from any process of fission and cross-recombination. Though the velocities of rearrangement of 7*A* and 9*C* are more disparate than would be desired in such an experiment, the excellent yields of pure materials show the reaction to be at least predominantly intramolecular.

The compounds listed in Table 1 were prepared by oxidising the tertiary bases with monoperphthalic acid, and the nature of the new products of rearrangement was confirmed by reductive fission: $NRR'{\cdot}OR'' \longrightarrow NHRR' + HOR''$. For the compounds in Table 2, perbenzoic acid was used in the oxidation, and most of the tertiary bases were prepared from the appropriate secondary amine and diarylmethyl bromide. In two cases the following route was used: $Ph{\cdot}CHO + NHMe_2 + HCN \longrightarrow H_2O + Ph{\cdot}CH(CN){\cdot}NMe_2$; $Ph{\cdot}CH(CN){\cdot}NMe_2 + ArMgBr \longrightarrow Ph{\cdot}CHAr{\cdot}NMe_2 + MgBrCN$.

Members of series 5, 6, and 7, having two ethyl groups as stationary groups, were prepared and their rearrangement effected, but they did not lend themselves to kinetic study.

EXPERIMENTAL

Compound 1.—Benzylmethylaniline (10 g.) in ether (50 ml.) was treated at 0° with ethereal monoperphthalic acid [2] (10% excess). After 16 hr., the supernatant ether was decanted, and dry hydrogen chloride passed into the syrup dissolved in dry chloroform. Phthalic acid was filtered off and the solvent was removed under reduced pressure below 50°. The residual syrupy benzylmethylaniline oxide hydrochloride, crystallised from ethanol–ether (yield 7·8 g.) and then from acetone, had m. p. 131° (lit.,[3] 135°). When heated in 10% sodium carbonate solution at 90° it gave *O*-benzyl-*N*-methyl-*N*-phenylhydroxylamine having the recorded [3] properties, together with appreciable quantities of benzaldehyde, recognised as 2 : 4-dinitrophenylhydrazone.

Compound 2.—*p*-Bromo-*N*-methylaniline [4] had b. p. 128—133°/9 mm.; the *picrate* crystallised from ethanol–acetone in needles, m. p. 172—173° (Found: C, 38·2; H, 2·6. $C_{13}H_{11}O_7N_4Br$

[2] Böhme, *Org. Synth.*, 1940, **20**, 70.
[3] Meisenheimer, Glawe, Greeske, Schorning, and Vieweg, *Annalen*, 1926, **449**, 188.
[4] Fries, *Annalen*, 1906, **346**, 173.

requires C, 37·6; H, 2·6%), and the *hydrochloride* from ethanol–ether in prisms, m. p. 135—136° (Found: C, 38·4; H, 4·0; Cl, 16·1. C_7H_9NClBr requires C, 37·8; H, 4·0; Cl, 16·0%). The base (4·65 g.) was heated at 95° for 1 hr. with allyl bromide (3·32 g.), and the basic material distilled. *N*-Allyl-*p*-bromo-*N*-methylaniline (4·76 g.) had b. p. 134—138°/6 mm., and gave a *picrate*, prisms, m. p. 136°, from ethanol–acetone (Found: C, 42·3; H, 3·3. $C_{16}H_{15}O_7N_4Br$ requires C, 42·2; H, 3·3%). Oxidation with perphthalic acid failed to give a crystalline amine oxide hydrochloride. Benzyl chloride (19·9 g.) and *p*-bromo-*N*-methylaniline (27·9 g.) were heated at 95° for 3 hr. Distillation of the basic material gave *N*-benzyl-*p*-bromo-*N*-methylaniline [5] (27 g.), b. p. 195—205°/9 mm.; the *picrate*, pale yellow prisms from ethanol–acetone, had m. p. 129—129·5° (Found: C, 47·1; H, 3·4. $C_{20}H_{17}O_7N_4Br$ requires C, 47·5; H, 3·4%).

Compound 3.—Allylmethylaniline [6] was oxidised as in case (1) and the oxide salt and hydroxylamine were obtained having the recorded [6] properties.

Compound 4.—Allylaniline, b. p. 100—110°/9 mm., was prepared in 60% yield by refluxing an alcoholic suspension of sodium formanilide with allyl bromide (10% excess) for 1 hr., giving crude allylformanilide, b. p. 145—150°/10 mm., which was hydrolysed by 16 hours' boiling with 20% alcoholic potassium hydroxide. It was converted by Wedekind's method [7] into *N*-allyl-*N*-benzylaniline, b. p. 173—180°/9 mm.; the *hydrochloride* crystallised from ethanol–ether in prisms, m. p. 138° (Found: C, 73·8; H, 6·6; Cl, 14·0. $C_{16}H_{18}NCl$ requires C, 74·0; H, 6·9; Cl, 13·7%); and the *picrate* crystallised from ethanol in prisms, m. p. 128° (Found: C, 58·5; H, 4·4; N, 12·3. $C_{22}H_{20}O_7N_4$ requires C, 58·4; H, 4·4; N, 12·4%). When less pure specimens of allylaniline were used, the product gave a crude hydrochloride, m. p. 207°; the derived picrate had m. p. 110°, undepressed on admixture with *benzylaniline picrate*, which separated from ether as a microcrystalline powder, m. p. 113° (Found: C, 55·0; H, 3·9; N, 13·3. $C_{19}H_{16}O_7N_4$ requires C, 55·3; H, 3·9; N, 13·6%). Wedekind [7] records for allylbenzylaniline hydrochloride: m. p. 220—221°; Cl, 14·97 [calc. 14·46% (*sic*)]. Jones [8] stated that the hydrochloride had the properties described by Wedekind and that analyses (unquoted) corresponded with the formula $C_{16}H_{17}N,HCl$.

Compound 4 * (*Table* 3): N-*Methyl*-N-1-*phenylethylaniline*.—Methylaniline (32 g.) and 1-phenylethyl chloride (43·8 g.) were heated together at 95° for 20 hr. Distillation of the basic material gave *N*-methyl-*N*-1-phenylethylaniline (50·8 g.), b. p. 158—165°/7 mm. [*picrate*, prisms, m. p. 131°, from ethanol (Found: C, 57·6; H, 4·6. $C_{21}H_{20}O_7N_4$ requires C, 57·3; H, 4·5%); *hydrochloride*, prisms, m. p. 162°, from ethanol–ether (Found: C, 72·5; H, 6·9; N, 5·8; Cl, 14·5. $C_{15}H_{18}NCl$ requires C, 72·7; H, 7·3; N, 5·7; Cl, 14·3%)].

Compound 5*A*.—Potassium cyanide (33 g.) in water (200 ml.) was slowly added, with cooling, to benzaldehyde (53 g.) and dimethylamine hydrochloride (50 g.) in water (300 ml.) and methanol (100 ml.). After 2 hours' shaking, α-dimethylamino-α-phenylacetonitrile was extracted with ligroin, dried, and distilled (yield 69 g.; b. p. 120—125°/12 mm.). The nitrile (40 g.), in ether (100 ml.), was slowly added to phenylmagnesium bromide [from bromobenzene (78·5 g.), magnesium (12 g.), and ether (300 ml.)]. After 12 hr., ice and ammonium chloride were added, and the ethereal layer was concentrated and shaken with 10N-hydrochloric acid; the precipitated hydrochloride yielded diphenylmethyldimethylamine [9] (35 g.).

Compound 5*B*.—Diphenylmethyl bromide [10] (20 g.) and piperidine (20 g.) were refluxed for 1 hr. in benzene (50 ml.). The filtrate from piperidine hydrobromide was freed from benzene and piperidine by evaporation under reduced pressure, and treated with ether and 2N-sodium hydroxide. The ether layer gave, with 8N-hydrochloric acid, *N*-diphenylmethylpiperidine hydrochloride, m. p. 252° (Found: Cl, 12·3. Calc. for $C_{18}H_{22}NCl$: Cl, 12·3%). The free base (17·5 g.) crystallised from methanol in needles,[11] m. p. 77° (Found: C, 86·1; H, 8·4. Calc. for $C_{18}H_{21}N$: C, 86·1; H, 8·3%).

Compound 5*C*.—N-*Diphenylmethylmorpholine*, prepared from diphenylmethyl bromide and morpholine as in case 5B, crystallised from methanol in prisms, m. p. 74° (Found: C, 80·2; H, 7·5. $C_{17}H_{19}ON$ requires C, 80·6; H, 7·5%). The *hydrochloride* formed prisms, m. p. 239°, from ethanol (Found: Cl, 12·1. $C_{17}H_{20}ONCl$ requires Cl, 12·3%).

[5] Cf. Everatt, *J.*, 1908, **93**, 1236.
[6] Meisenheimer, *Ber.*, 1919, **52**, 1667.
[7] Wedekind, *Ber.*, 1899, **32**, 521; 1903, **36**, 3791 footnote.
[8] Jones, *J.*, 1905, **87**, 1722.
[9] Stevens, Cowan, and MacKinnon, *J.*, 1931, 2568.
[10] Courtot, *Ann. Chim.* (*France*), 1916, **5**, 80.
[11] Christiaen, *Bull. Soc. chim. belges*, 1924, **33**, 483.

Compound 5 ** (Tables 3 and 4).—Analogously diphenylmethyldiethylamine was prepared from diphenylmethyl bromide (10 g.) and diethylamine (6·5 g.) in nitromethane (25 ml.). After 20 min. at 95°, the cooled mixture was treated with ether and 5N-sodium hydroxide (heat evolved). The free base crystallised from methanol in prisms,[12] m. p. 58—59°.

Compound 6*A*.—Bromine (9 g.) in carbon tetrachloride (30 ml.) was added gradually to fluorene (8·3 g.) and dibenzoyl peroxide (0·5 g.) in boiling carbon tetrachloride (100 ml.). The mixture was refluxed for 30 min. after evolution of hydrogen bromide had ceased; the solvent was removed under reduced pressure, and the residue, dissolved in ether, was washed with sodium hydrogen carbonate solution and dried.[13] Crystallisation from ligroin gave 9-fluorenyl bromide (8·5 g.), m. p 103°. It yielded 9-fluorenyldimethylamine [14] [*hydrochloride*, needles, m. p. 235° (decomp.), from ethanol (Found: Cl, 14·3. $C_{15}H_{16}NCl$ requires Cl, 14·5%)].

Compound 6*B*.—Piperidine (5 ml.) and 9-bromofluorene (5 g.) reacted in the same way as in case 5B. The benzene solution was diluted with ether, washed with alkali, and evaporated. Crystallisation from methanol gave 9-fluorenylpiperidine [15] (4·5 g.), m. p. 97° (Found: C, 86·4; H, 7·5; N, 5·3. Calc. for $C_{18}H_{19}N$: C, 86·7; H, 7·6; N, 5·6%) [*hydrochloride*, prisms, m. p. 249°, from ethanol (Found: Cl, 12·7. $C_{18}H_{20}NCl$ requires Cl, 12·4%)].

Compound 6*C*. *N*-9-Fluorenylmorpholine,[16] prepared in the same way, formed plates, m. p. 150°, from acetone–ethanol (Found: C, 81·3; H, 6·5; N, 5·6. Calc. for $C_{17}H_{17}ON$: C, 81·3; H, 6·8; N, 5·6%) [*hydrochloride*, needles, m. p. 158° (decomp.), from methanol (Found: Cl, 12·5. $C_{17}H_{18}ONCl$ requires Cl, 12·3%)].

Compound 6 ** (Tables 3 and 4).—*Diethyl-9-fluorenylamine*, prepared substantially as diphenylmethyldiethylamine, in 85% yield, was a slightly yellow oil, b. p. 188°/14 mm. (Found: N, 5·5. $C_{17}H_{19}N$ requires N, 5·9%). The *hydrochloride* crystallised from ethanol in plates, m. p. 197—199° (Found: Cl, 12·7. $C_{17}H_{20}NCl$ requires Cl, 13·0%).

Compound 7*A*. *Dimethyl(phenyl-o-tolylmethyl)amine* was prepared by adding α-dimethylamino-α-phenylacetonitrile (25 g.) in ether (40 ml) to the Grignard reagent from *o*-bromotoluene (38 g), magnesium (5·5 g.), and ether (150 ml.), and refluxing the whole for ½ hr. after 48 hr. at room temperature. The base (22 g.), isolated as in case 5*A*, crystallised from methanol in prisms, m. p. 46° (Found: C, 85·1; H, 8·4; N, 6·4. $C_{16}H_{19}N$ requires C, 85·3; H, 8·4; N, 6·2%) [*hydrochloride*, needles, m. p. 273° (decomp.), from methanol (Found: Cl, 13·2. $C_{16}H_{20}NCl$ requires Cl, 13·5%)].

Compound 7*B*.—Phenyl-*o*-tolylmethanol (5 g.) was refluxed with 48% hydrobromic acid (20 ml.) for 5 min., distilled up to 126°, and refluxed for 15 min. more.[10] The ether-soluble material, washed with aqueous sodium hydrogen carbonate, was dried and distilled, giving *phenyl-o-tolylmethyl bromide* (5·45 g.), b. p. 200°/14 mm. (Found: Br, 30·3. $C_{14}H_{13}Br$ requires Br, 30·6%). As in case 5*B* it yielded N-*phenyl-o-tolylmethylpiperidine*, b. p. 113°/0·2 mm. (Found: N, 5·1. $C_{19}H_{23}N$ requires N, 5·3%); the *hydrochloride* crystallised from ethanol in plates, m. p. 258° (Found: Cl, 12·0. $C_{19}H_{24}NCl$ requires Cl, 11·8%).

Compound 7*C*.—N-*Phenyl-o-tolylmethylmorpholine*, prepared as in case 5*B*, was a viscous oil, b. p. 144°/0·4 mm. (Found: N, 5·0. $C_{18}H_{21}ON$ requires N, 5·2%); the *hydrochloride* formed needles, m. p. 264° (decomp.), from ethanol (Found: Cl, 11·8. $C_{18}H_{22}ONCl$ requires Cl, 11·7%).

Compound 7 ** (Tables 3 and 4).—Phenyl-*o*-tolylmethyl bromide (5·45 g.) reacted with diethylamine (7 ml.) in nitromethane (20 ml.) as in the preparation of diphenylmethyldiethylamine. Distillation of the basic reaction product gave *diethyl(phenyl-o-tolylmethyl)amine* (4·55 g.), b. p. 177°/15 mm. (Found: N, 5·5 $C_{18}H_{23}N$ requires N, 5·5%). The *hydrochloride* crystallised from ethanol in prisms, m. p. 229° (Found: Cl, 12·1. $C_{18}H_{24}NCl$ requires Cl, 12·2%).

Compound 8*A*.—Molten diphenylmethane (40 g.) was added during ½ hr. to ice-cooled nitric acid (140 ml.; *d* 1·5) kept between 20° and 25°. After 15 min. at room temperature the mixture was cooled in ice until it crystallised, and poured into water (1 l.). The solid was washed successively with water, sodium hydrogen carbonate solution, alcohol, and ether, boiled with ether, filtered off, and crystallised from benzene with rejection of sparingly soluble material. The 4 : 4′-dinitrodiphenylmethane (20 g.; m. p. 183—184°) so obtained was refluxed in carbon

[12] Sommelet, *Compt. rend.*, 1922, **175**, 1150.
[13] Cf. Wittig and Vidal, *Chem. Ber.*, 1948, **81**, 368.
[14] Wittig and Nagel, *ibid.*, 1950, **83**, 106.
[15] Pinck and Hilbert, *J. Amer. Chem. Soc.*, 1946, **68**, 377.
[16] Cf. Bamford and Stevens, *J.*, 1952, 4675.

tetrachloride (300 ml.) with dibenzoyl peroxide (1·1 g.); then bromine (4 ml.) in carbon tetrachloride (20 ml.) was added. Within 30 min. evolution of hydrogen bromide ceased and the solid dissolved; after removal of the solvent, the residue was crystallised from acetone–ligroin and from carbon tetrachloride, giving 4 : 4′-*dinitrodiphenylmethyl bromide* (22·5 g.), prisms, m. p. 90·5° (Found: N, 8·3. $C_{13}H_9O_4N_2Br$ requires N, 8·3%). This bromide (33·2 g.) in pure, dry nitromethane, was treated at −15° with anhydrous dimethylamine (13 g.) in nitromethane (100 ml.), and the deep red solution kept at 0° for 6 days. The solid (4 : 4′-*dinitrodiphenylmethyl*)*dimethylamine* crystallised from benzene–ethanol in needles (18 g.), m. p. 158—159° (Found: C, 59·6; H, 5·1; N, 13·7. $C_{15}H_{15}O_4N_3$ requires C, 59·8; H, 5·0; N, 13·9%). The *hydrochloride*, prepared in acetone–ether, crystallised from methanol–ethanol in needles, m. p. 242° (decomp.) (Found: Cl, 10·2. $C_{15}H_{16}O_4N_3Cl$ requires Cl, 10·5%). When the preparation was carried out in ether–benzene, the main, non-basic product crystallised from benzene in needles, m. p. 299°, apparently solvated *tetra*-p-*nitrophenylethylene* (Found: C, 64·8; H, 3·8; N, 9·9. $C_{26}H_{16}O_8N_4,C_6H_6$ requires C, 65·1; H, 3·7; N, 9·5%).

Compound 9C.—Bromodi-α-naphthylmethane [17] (15 g.) was refluxed for 1 hr. with benzene (20 ml.) and morpholine (19 ml.). After addition of water and ether, the separated organic layer was shaken with 6N-hydrochloric acid. The precipitated hydrochloride yielded *N-di-α-naphthylmethylmorpholine* (18·5 g.), m. p. 174° after crystallisation from benzene–ligroin (Found: C, 84·9; H, 6·6; N, 4·1. $C_{25}H_{23}ON$ requires C, 85·0; H, 6·5; N, 4·0%).

Amine Oxide Salts.—Those containing an aryl group directly attached to nitrogen were prepared in the same way as in case 1 above. Allylmethylaniline oxide hydrochloride solution [6] was evaporated in a desiccator; the residue solidified after 9 weeks. Of the dialkyldiarylmethylamine oxide *salts* listed in Table 3, those containing two *N*-methyl groups were prepared

TABLE 3. *Amine oxide salts.*

					Found (%)				Required (%)		
No.	Salt	Form	Solvent	M. p.	C	H	N	Formula	C	H	N
2	Hydrochloride	Prisms	EtOH–Et_2O	122°	(HCl, 11·0)			$C_{14}H_{15}ONBrCl$	(HCl, 11·1)		
	Picrate	—	EtOH–$COMe_2$	125—126	46·4	3·4	10·4	$C_{20}H_{17}O_8N_4Br$	46·1	3·3	10·7
4	Hydrochloride	Prisms	EtOH–Et_2O	118	(HCl, 13·6)			$C_{16}H_{18}ONCl$	(HCl, 13·2)		
	Picrate	Prisms	EtOH	119—121	56·9	4·5	12·4	$C_{22}H_{20}O_8N_4$	56·4	4·3	12·0
4 *	Picrate	Prisms	EtOH–$COMe_2$	126—128	55·6	4·6	12·4	$C_{21}H_{20}O_8N_4$	55·3	4·4	12·3
5*A*	Benzoate	Needles	$COMe_2$–Et_2O	108	—	—	3·9	$C_{22}H_{23}O_3N$	—	—	4·0
	Picrate	Needles	EtOH	158	55·7	4·4	12·1	$C_{21}H_{20}O_8N_4$	55·3	4·4	12·3
5*B*	Picrate	Plates	MeOH–$COMe_2$	166	57·8	4·5	—	$C_{24}H_{24}O_8N_4$	58·1	4·8	—
5*C*	Picrate	Needles	$COMe_2$	168—169	55·7	4·1	—	$C_{23}H_{22}O_9N_4$	55·7	4·4	—
5**	Picrate	Needles	EtOH–$COMe_2$	141	57·4	5·0	11·2	$C_{23}H_{24}O_8N_4$	57·0	5·0	11·6
6*A*	Benzoate	Needles	$COMe_2$–Et_2O	103	—	—	4·2	$C_{22}H_{21}O_3N$	—	—	4·0
	Picrate	Prisms	$COMe_2$	167	—	—	12·3	$C_{21}H_{18}O_8N_4$	—	—	12·3
6*B*	Picrate	Rhombs	EtOH–$COMe_2$	183	58·6	4·5	11·3	$C_{24}H_{22}O_8N_4$	58·3	4·5	11·3
6*C*	Picrate	Plates	EtOH–$COMe_2$	187	55·7	4·2	11·0	$C_{23}H_{20}O_9N_4$	55·7	4·0	11·3
6**	Picrate	Prisms	MeOH–EtOH	152	57·5	4·7	11·2	$C_{23}H_{22}O_8N_4$	57·3	4·6	11·6
7*A*	Benzoate	Needles	$COMe_2$–Et_2O	103	—	—	3·7	$C_{23}H_{25}O_3N$	—	—	3·9
	Picrate	Prisms	EtOH	130	56·3	4·7	11·7	$C_{22}H_{22}O_8N_4$	56·2	4·7	11·9
7*B*	Picrate	Needles	EtOH–$COMe_2$	153	58·7	5·2	11·2	$C_{25}H_{26}O_8N_4$	58·9	5·1	11·0
7*C*	Picrate	Needles	$COMe_2$–dioxan	173	55·9	4·8	11·0	$C_{24}H_{24}O_9N_4$	56·2	4·7	10·9
7**	Picrate	Prisms	EtOH–$COMe_2$	130	57·7	5·2	11·3	$C_{24}H_{26}O_8N_4$	57·9	5·2	11·3
8*A*	Picrate	Prisms	$COMe_2$	154	—	—	15·3	$C_{21}H_{18}O_{12}N_6$	—	—	15·4
9*C*	Hydrochloride	—	$CHCl_3$–Et_2O	150	(Cl, 8·8)		3·2	$C_{25}H_{24}O_2NCl$	(Cl, 8·8)		3·2

* *N*-Methyl-*N*-1-phenylethylaniline oxide; did not rearrange smoothly.

thus: diphenylmethyldimethylamine (10 g.) in dry toluene (75 ml.) was slowly added to a solution of perbenzoic acid (6·7 g.) in toluene (120 ml.) kept at 2°. After 10 min., precipitation was completed by addition of ligroin, and the solid, washed with ligroin and a little ether, yielded 14·6 g. of pure diphenylmethyldimethylamine oxide benzoate, which with ethanolic picric acid gave the picrate. In the other cases, with two exceptions (below), ether was added after the reaction was complete and the solution extracted repeatedly with N-hydrochloric acid; aqueous picric acid then precipitated the amine oxide picrate.

[17] Tschitschibabin, *Ber.*, 1911, **44**, 443.

4 : 4′-Dinitrodiphenylmethyldimethylamine (5 g.) in toluene (130 ml.) was added dropwise to perbenzoic acid (3 g.) in toluene (50 ml.) kept below 0°. Precipitation of gummy solid was completed by adding chilled ligroin (250 ml.), and the gum, washed with ether, was dissolved in a minimum of cold acetone. Concentrated hydrochloric acid (10 ml.) was added at 0° and the mixture shaken with ether and sufficient water to dissolve the amine oxide hydrochloride. Picric acid then precipitated the oxide picrate from the aqueous layer.

Di-α-naphthylmethylmorpholine (4 g.) in toluene (60 ml.) was treated at −10° with perbenzoic acid (2·5 g.) in toluene (150 ml.). Precipitation was completed by addition of cold ligroin, and the gummy product was washed with ether and dissolved in ice-cold acetone. The amine oxide hydrochloride was precipitated by adding a solution of hydrogen chloride in acetone, followed by ether.

Trisubstituted Hydroxylamines.—The amine oxide salts (benzoates, picrates, or hydrochlorides) dissolved easily in 1% aqueous ammonia, and were rearranged by heating these solutions at 90—95° for the periods stated in Table 4, where the properties of the hydroxylamines are collected. In all cases in which the m. p. of the picrate of a hydroxylamine was near that of the parent amine oxide, a mixed m. p. showed a marked depression. To establish the constitution of the hydroxylamine from allylbenzylaniline oxide, this product (1·79 g.) in acetic acid (30 ml.) was reduced with zinc dust (7 g.) for 1·5 hr. at 95°. By ether-extraction after basification the mixture gave an oil (1·20 g.), b. p. 303—306°, which afforded benzylaniline picrate (mixed m. p.). In the same way the hydroxylamine from *N*-benzyl-*p*-bromo-*N*-methylaniline gave *p*-bromo-*N*-methylaniline, identified as picrate, in good yield.

TABLE 4. *Trisubstituted hydroxylamines.*

Case	Description	Found (%) C	H	N	Formula	Required (%) C	H	N	Heating (hr.)
2	Base (b. p. 102—107°/0·02 mm.)	58·4	4·8	4·8 [a]	$C_{14}H_{14}ONBr$	57·6	4·8	4·8 [c]	[a]
4	Base (b. p. 86—91°/0·04 mm.)	80·3	7·6	5·8	$C_{16}H_{17}ON$	80·3	7·2	5·8	[a]
5*A*	Base (b. p. 164°/16 mm.)	—	—	6·0	$C_{15}H_{17}ON$	—	—	6·2	3
	Picrate, plates (EtOH), m. p. 153°	—	—	12·3	$C_{21}H_{20}O_8N_4$	—	—	12·3	
5*B*	Base (b. p. 70°/0·2 mm.)	—	—	5·0	$C_{18}H_{21}ON$	—	—	5·2	16
	Picrolonate, needles (EtOH), m. p. 153°	63·0	5·2	—	$C_{28}H_{29}O_6N_5$	63·3	5·5	—	
5*C*	Base (b. p. 60°/0·2 mm.)	—	—	4·9	$C_{17}H_{19}O_2N$	—	—	5·2	18 [b]
	Picrolonate, needles (EtOH), m. p. 141°	60·5	5·2	—	$C_{27}H_{27}O_7N_5$	60·8	5·1	—	
5**	Base (b. p. 120°/0·4 mm.)	—	—	5·5	$C_{17}H_{21}ON$	—	—	5·5	3
	Picrate, needles, (EtOH), m. p. 129°	57·4	5·0	11·5	$C_{23}H_{24}O_8N_4$	57·0	5·0	11·6	
6*A*	Base (b. p. 160°/13 mm.)	—	—	6·2	$C_{15}H_{15}ON$	—	—	6·2	2
	Picrate, needles (EtOH), m. p. 163—164°	55·7	4·1	—	$C_{21}H_{18}O_8N_4$	55·5	4·0	—	
	Picrolonate, needles (EtOH), m. p. 140°	—	—	14·2	$C_{25}H_{23}O_6N_5$	—	—	14·3	
6*B*	Base (b. p. 100°/0·15 mm.)	—	—	5·1	$C_{18}H_{19}ON$	—	—	5·3	5 [b]
	Picrate, needles (EtOH), m. p. 132°	58·1	4·4	10·9	$C_{24}H_{22}O_8N_4$	58·3	4·5	11·3	
6*C*	Base, needles (EtOH), m. p. 162—163°	76·5	6·3	5·1	$C_{17}H_{17}O_2N$	76·4	6·4	5·2	4
6**	Base (b. p. 114°/0·2 mm.)	—	—	5·4	$C_{17}H_{19}ON$	—	—	5·5	4½ [b]
	Picrate, plates (EtOH–$COMe_2$), m. p. 143°	57·5	4·6	11·3	$C_{23}H_{22}O_8N_4$	57·3	4·6	11·6	
7*A*	Base (b. p. 110°/0·2 mm.	—	—	5·6	$C_{16}H_{19}ON$	—	—	5·8	3
	Picrate, needles (MeOH), m. p. 140° ...	55·6	4·7	11·8	$C_{22}H_{22}O_8N_4$	56·2	4·7	11·9	
7*B*	Base (b. p. 126°/0·4 mm.)	—	—	4·8	$C_{19}H_{23}ON$	—	—	5·0	5 [b]
	Picrate, needles (EtOH), m. p. 133°	59·1	5·1	11·1	$C_{25}H_{26}O_8N_4$	58·9	5·1	11·0	
7*C*	Base (b. p. 135°/0·4 mm.)	—	—	4·7	$C_{18}H_{21}O_2N$	—	—	4·9	5
	Picrate, prisms (EtOH), m. p. 128°	56·1	4·9	11·0	$C_{24}H_{24}O_9N_4$	56·2	4·7	10·9	
7**	Base (b. p. 113°/0·2 mm.)	—	—	4·9	$C_{18}H_{23}ON$	—	—	5·2	3½ [b]
	Picrate, plates (EtOH), m. p. 139°	58·1	5·2	11·3	$C_{24}H_{26}O_8N_4$	57·9	5·2	11·2	
8*A*	Base, needles (EtOH–$CHCl_3$), m. p. 154—155°	56·6	4·7	—	$C_{15}H_{15}O_5N_3$	56·8	4·7	—	½
9*C*	Base, needles (EtOH–$CHCl_3$), m. p. 183°	81·3	6·2	3·8	$C_{25}H_{23}O_2N$	81·3	6·2	3·8	½

[a] Steam-distilled from sodium carbonate solution. [b] Isomerised in 70% ethanol. [c] Found: Br, 27·1. Required Br, 27·3%.

Kinetic Experiments.—Cases 1—4. The amine oxide hydrochloride in 99·7% alcohol, and alcoholic sodium ethoxide, were separately brought to the required temperature and mixed. Successive portions of 10 ml. were added to 0·5N sulphuric acid and 5 ml. of ligroin (which dissolves the hydroxylamine but not the amine oxide(, and made up with acid to 50 ml. The

unchanged oxide was determined in duplicate by boiling 20 ml. portions of the aqueous layer for 4 min. with a known excess of 0·05M-titanous sulphate and back-titration with 0·05N-iron alum solution in presence of thiocyanate. The apparatus was that of Thornton and Wood.[18] Allowance was made for a loss of 1·4% in the strength of titanous sulphate solutions boiled for 4 min. in control experiments. The hydroxylamines produced by rearrangement reduced less than 0·02 of an equivalent of titanous sulphate under the same conditions.

In a typical experiment, benzylmethylaniline oxide hydrochloride (0·8 g.) in 100 ml. of solution containing sodium ethoxide (1 mol.) reacted at 60° with the following results:

Time (min.)	0	46	110	150	195	240	288
Unchanged oxide [ml. of $Ti_2(SO_4)_3$]	16·78	13·43	7·88	6·31	5·15	3·69	3·08
k_1 (min.)	—	0·0048	0·0069	0·0065	0·0061	0·0063	0·0059

A run in which the sodium ethoxide concentration was doubled gave the mean constant 0·0060, and one in which both concentrations were halved gave 0·0062. The rearrangement is thus of the first order in amine oxide, and unaffected by alkali in excess of that used to liberate the base from its hydrochloride. Runs with the other oxides of this series were conducted in the same way as the typical experiment.

Cases 5*A*—9*C*. A preliminary run with diphenylmethyldimethylamine oxide benzoate in 1% aqueous ammonia, followed up to 72% conversion, showed that the reaction velocity *increased* with time. This may be accounted for by the separation of the insoluble liquid *O*-diphenylmethyl-*NN*-dimethylhydroxylamine, in which solvent of low dielectric constant the isomerisation of remaining amine oxide would be faster than in water. The solvent used in subsequent experiments was ethanol–water (7 : 3 by weight). The weighed amine oxide salt with the required amount of solvent was brought to the thermostat temperature (45° ± 0·1°), and an equal volume of solvent containing 1% of ammonia, at the same temperature, added; any solid salt dissolving at once on mixing. The final amine oxide solution was 0·071M, usually 30—50 ml. Reaction was stopped by chilling in acetone–carbon dioxide, and the mixture was transferred, with *ca.* 60 ml. of water and 60 ml. of ligroin (b. p. 40—50°), to a separating funnel. The water layer was washed with ligroin (2 × 30 ml.) and the combined ligroin extracts were washed with 0·5% aqueous ammonia (2 × 30 ml.) and water (50 ml.). These extracts were dried (K_2CO_3) and brought to constant weight in a vacuum. This hydroxylamine afforded the pure picrate or picrolonate in almost quantitative yield. In cases 8*A* and 9*C*, the chilled reaction mixture was diluted with water and the crystalline hydroxylamine filtered off through a Gooch crucible, washed, and dried to constant weight. When the united aqueous layers from which the hydroxylamine had been removed were acidified, with addition of picric acid if the original salt was not the picrate, unchanged amine oxide was precipitated quantitatively as picrate, which was collected after several hours at 0° and examined for purity, its complete solubility in 1% aqueous ammonia showing absence of the picrate of the hydroxylamine. This analytical separation was tested on known mixtures in each case, with 97—99% recovery. A typical series, with diphenylmethyldimethylamine oxide benzoate, gave the results:

Time of heating (min.)	20	30	60	125	150
Benzoate taken (g.)	0·7286	0·6646	0·8094	0·7951	0·5941
Hydroxylamine formed (g.)	0·0430	0·0588	0·1204	0·2032	0·1785
k_1 (sec.$^{-1}$)	0·0048	0·0049	0·0044	0·0040	0·0041

A series in which the amine oxide picrate was used, at twice the normal dilution, gave the same average value of k_1 0·0044. In cases 6*A* and 7*A* both benzoate and picrate were used, with similarly concordant results; 9*C* was studied as the hydrochloride, and in the other cases the picrate only was used.

The approximate K_b values for the tertiary bases were determined in the usual manner from the pH–neutralisation curves of the hydrochlorides with sodium hydroxide in dioxan–water (1 : 1 by volume).

Mixing Experiments.—*N*-Di-α-naphthylmethylmorpholine oxide hydrochloride (0·408 g.) and phenyl-*o*-tolylmethyldimethylamine oxide benzoate (0·400 g.) in ethanol (18 ml.) and water (6 ml.) with aqueous ammonia (0·5 ml.; *d* 0·880) were heated at 45° for 1 hr. and refluxed for 30 min. After addition of water the mixture was distilled exhaustively in steam. The ether extract (2 × 60 ml.) of the distillate was dried (Na_2SO_4) and evaporated, and the residue brought

[18] Thornton and Wood, *Ind. Eng. Chem.*, 1927, **19**, 150.

to constant weight (0·2953 g., 97·7%) in a vacuum. This *NN*-dimethyl-*O*-phenyl-*o*-tolylmethylhydroxylamine gave 0·4970 g. (98·3%) of picrate, m. p. and mixed m. p. 139—140°, which depressed the m. p. of *N*-phenyl-*o*-tolylmethoxymorpholine picrate to 118—120°. The non-volatile material from the rearrangement was extracted with chloroform (2 × 50 ml.); the extract was evaporated and the residue dried to constant weight (0·3670 g., 98·9%). This product melted at 179°, and crystallisation from ethanol–chloroform gave *N*-di-α-naphthylmethoxymorpholine (0·3502 g.), m. p. and mixd m. p. 183°.

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