(103 g., 0.66 mole) in 200 ml. of pentane at 0°. The solution was stored in a freezer for 8 hr. The pentane was evaporated at 0° and the residue was crystallized by immersion in a Dry Ice-acetone bath. The solid was filtered and washed with cold pentane to leave pale yellow granules (90 g., 70%). The compound had m.p. 41-42° (sublimed) and $\bar{\nu}_{max}$ 1780 cm.$^{-1}$. The n.m.r. spectrum has a doublet at δ 1.18 (6H) due to the nonequivalent methyl groups, a morpholino pattern at 2.35 and 3.7, methylene protons at 2.5, and the proton under N at 3.1.

Anal. Calcd. for $C_{10}H_{17}NO_2$: C, 65.57; H, 9.29; N, 7.65. Found: C, 65.73; H, 9.38; N, 7.71.

Rearrangement of 5.—One gram of **5** was heated to 50° in a sealed tube for 10 min. The resulting oil (1 g.) had an infrared spectrum identical with that of 1-N-morpholino-4-methyl-1-penten-3-one.

Anal. Calcd. for $C_{10}H_{17}NO_2$: C, 65.54; H, 9.35; N, 7.64. Found: C, 65.78; H, 9.45; N, 7.64.

1-N-Morpholino-4-methyl-1-penten-3-one (6).—2-Methylpent-4-yn-3-one[15] (362 mg., 3.77 mmoles) was dissolved in 7 ml. of anhydrous ether, cooled to 0°, and treated with 324 mg. (3.77 mmoles) of morpholine in 4 ml. of ether. The solution was warmed to 25° over 8 hr. and concentrated to a pale yellow oil. This oil had λ_{max} 307 mμ (ϵ 7600) and $\bar{\nu}_{max}$ 1650, 1550, and 1120 cm.$^{-1}$.

Reaction of 4-(1-Butenyl)morpholine and Ketene.—The enamine (3.9 g., 0.03 mole) in 50 ml. of ether was treated with 0.1 mole of ketene at 20°. After standing for 2 hr., the solution was concentrated to a yellow oil which showed infrared absorption at 1780 and 1650 cm.$^{-1}$. Distillation through a semimicro column separated 4.0 g. (68%) of a straw yellow oil which had b.p. 144-145° (2 mm.) and $\bar{\nu}_{max}$ 1650, 1550, and 1120 cm.$^{-1}$. The n.m.r. spectrum has the vinyl proton doublet of **8** and the vinyl singlet of **9** at δ 7.4 and 7.05 in the ratio of 4:1.

Anal. Calcd. for $C_{10}H_{17}NO_2$: C, 65.52; H, 9.29; N, 7.65. Found: C, 65.17; H, 9.40; N, 7.66.

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[15] We wish to thank Professor N. J. Leonard of the University of Illinois for a generous sample of this compound.

Sterically Crowded Amines. IV. Secondary and Tertiary Bispropargylic Amines and Their Hydrogenation Products[1]

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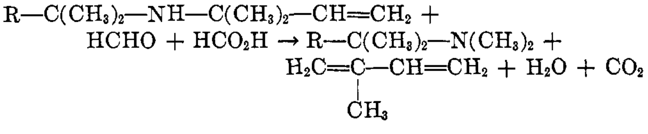
A series of sterically crowded amines of the type $R^1C(CH_3)_2N(R^2)C(CH_3)_2R^3$ in which R^1 and R^3 are C≡CH, CH=CH$_2$, and CH$_2$CH$_3$ *in all possible combinations* and R^2 = H or CH$_3$ has been prepared. The formation of pyrrolines and pyrrolidines *via* a new cyclization reaction of bispropargylic and propargylic-allylic amines with sodium in liquid ammonia is described. The basicities of some sterically crowded amines are reported.

The facile synthesis of some sterically crowded acetylenic amines $R^1R^2C(NR^3R^4)$—C≡CH described in earlier papers[3,4] and the finding[5] that many of these have notable hypotensive properties prompted a study of the preparation of other compounds of this type having enhanced steric crowding, varying degrees of unsaturation (both propargylic and allylic), and the relation of unsaturation to basicity in sterically crowded amines.

Primary and secondary amines of the type $(CH_3)_2C(NHR^1)R^2$ where R^1 = H or CH$_3$ and R^2 = C≡CH, CH=CH$_2$, and —CH$_2$CH$_3$ were alkylated with 3-chloro-3-methyl-1-butyne in a manner similar to that previously reported.[3] The products, obtained in good yield where R^1 = H, were subjected to selective catalytic hydrogenation which usually proceeded without extensive hydrogenolysis. Notable exceptions were the attempts to prepare di-*t*-amylamine hydrochloride from bis(1,1-dimethylpropargyl)amine and 3-*t*-amylamino-3-methyl-1-butyne hydrochlorides using platinum oxide catalyst. Di-*t*-amylamine (XII) was prepared, however, from the above amines in good yields using Raney nickel catalyst.

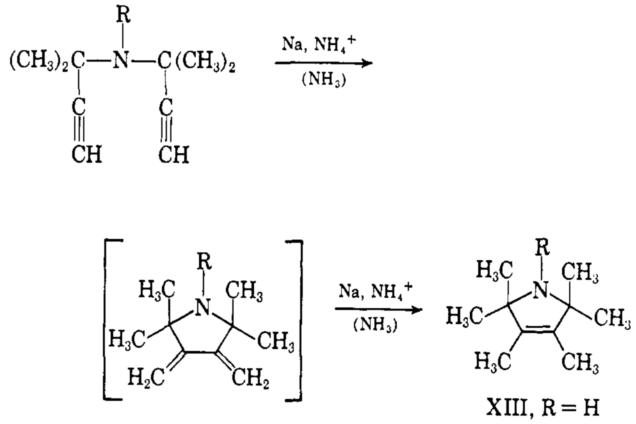
Some of the sterically crowded secondary amines were converted to tertiary amines *via* the previously described[4] Clarke-Eschweiler methylation. In cases of severe steric crowding this procedure either failed or led to extensive decomposition as shown.



$$\mathrm{R{-}C(CH_3)_2{-}NH{-}C(CH_3)_2{-}CH{=}CH_2 + HCHO + HCO_2H \rightarrow R{-}C(CH_3)_2{-}N(CH_3)_2 + H_2C{=}\underset{\displaystyle CH_3}{\underset{|}{C}}{-}CH{=}CH_2 + H_2O + CO_2}$$

R = C≡CH, CH=CH$_2$

Attempted semihydrogenation of the bispropargylic and propargylic-allylic amines with sodium in liquid ammonia led to the discovery of a new reaction, namely intramolecular C-C coupling across the two unsaturated centers. The presumed course of the reaction is as shown. Conjugated dienes are known[6] to undergo reduction with 1,4 addition of hydrogen under the reaction conditions.



XIII, R = H
XIIIa, R = CH$_3$

In the two cases where propargylic-allylic amines (VIII and VIIIa) were treated with sodium in liquid ammonia, the isomeric 3-methylenepyrrolidines (XIV

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[1] Paper No. 79 on substituted acetylenes. Previous paper: G. F. Hennion and P. E. Butler, *J. Org. Chem.*, **27**, 2088 (1962).

[2] Eli Lilly Co. Fellow, 1962-1964. Abstracted from a portion of the Ph.D. Dissertation of C. V. D.

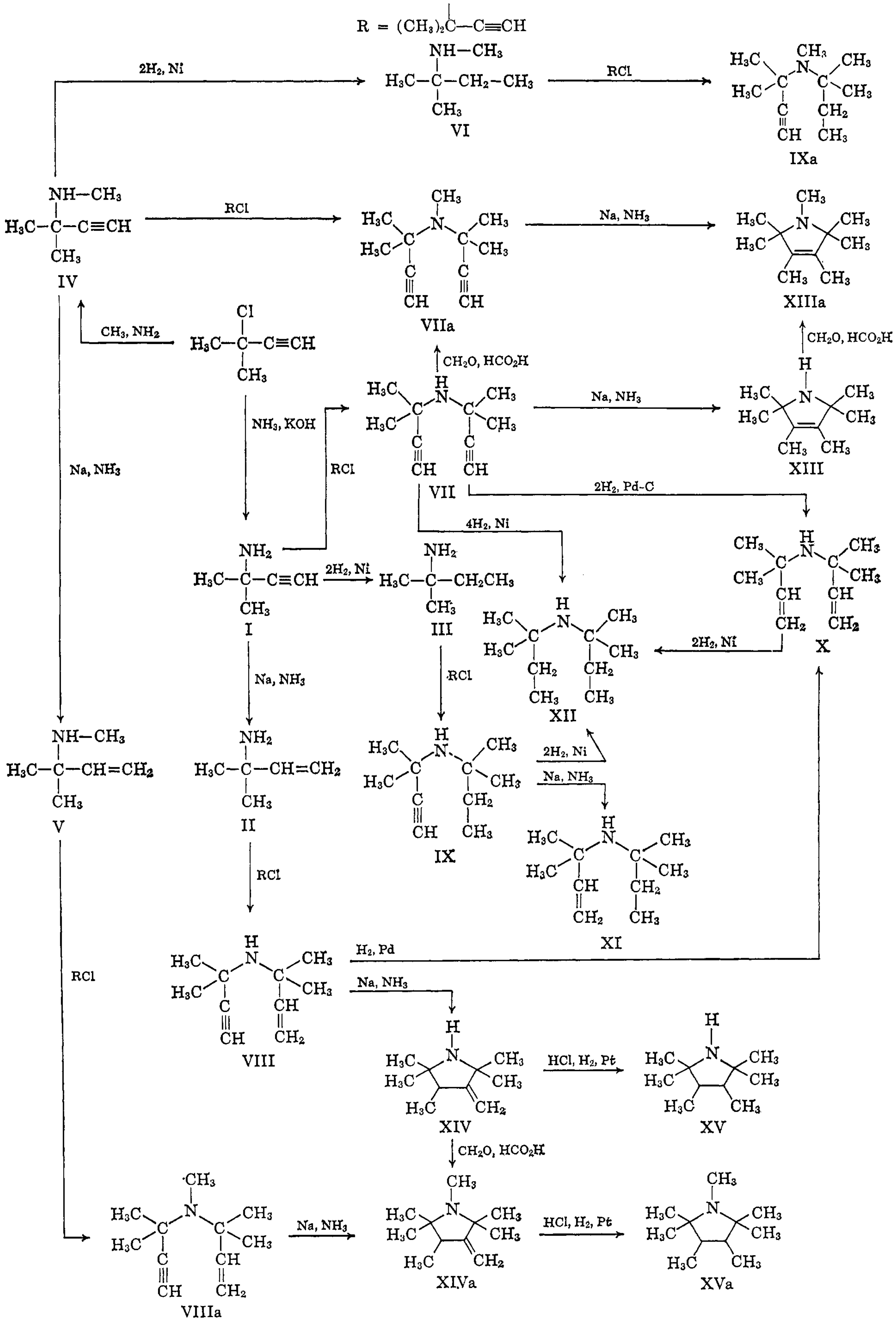
[3] G. F. Hennion and R. S. Hanzel, *J. Am. Chem. Soc.*, **82**, 4908 (1960).

[4] C. Ainsworth and N. R. Easton, *J. Org. Chem.*, **26**, 3776 (1961).

[5] N. R. Easton, Abstracts of papers presented at the 138th National Meeting of the American Chemical Society, New York, N. Y., Sept. 1960, p. 46 O.

[6] N. L. Bauld, *J. Am. Chem. Soc.*, **84**, 4347 (1962).

SCHEME I
PREPARATION OF STERICALLY CROWDED AMINES



$R = (CH_3)_2C{-}C{\equiv}CH$

Table I

Primary and Secondary Amines

$(CH_3)_2C(R^1)NHR^2$

Compd.	R^1	R^2	B.p., °C.	n^{22}_D	Yield, %	Hydrochlorides: Formula	M.p., °C.	% C Calcd.	% C Found	% H Calcd.	% H Found	% N Calcd.	% N Found
I[a]	C≡CH	H	75–80	1.4189	65	$C_5H_{10}ClN$	234	50.47	50.21	8.37	8.43	11.52	11.71
II	CH═CH₂	H	74–76	1.4110	59	$C_5H_{12}ClN$	220	49.45	49.38	9.73	9.95	11.35	11.52
III[b,c]	CH_2CH_3	H	71–79	1.3959	75	$C_5H_{14}ClN$	233	48.55	48.57	11.35	11.41	11.25	11.33
IV[d]	C≡CH	CH_3	96–98	1.4228	49	$C_6H_{12}ClN$	216–217	54.10	53.96	9.08	8.99	10.73	10.49
V	CH═CH₂	CH_3	92–98	1.4152	46	$C_6H_{14}ClN$	94–95	53.32	53.13	10.41	10.40	10.58	10.33
VI	CH_2CH_3	CH_3	95–98	1.4066	75	$C_6H_{16}ClN$	113–115	52.14	52.35	11.78	11.72	10.27	10.18

[a] See ref. 12. [b] See ref. 13. [c] See ref. 14. [d] See ref. 3.

and XIVa) were obtained. The structures of the products were confirmed by n.m.r. and infrared spectral evidence.

The n.m.r. spectrum of heptamethyl-3-pyrroline (XIIIa) showed three singlets at τ 9.09, 8.65, and 7.91, respectively, with peak height ratios of 4:2:1. The infrared spectrum showed a peak at 6.03 μ but no peaks in the 10–11-μ region indicating a tetrasubstituted double bond. The n.m.r. spectrum of 3-methylene-2,2,4,5,5-pentamethylpyrrolidine hydrochloride (XIV HCl) in chloroform-*d* showed two doublets at about τ 5 assigned to the olefin protons, a multiplet at τ 7.24 assigned to the C-4 proton, peaks τ 8.2 and 8.7 assigned to the C-5 methyl protons *cis* and *trans* to the C-4 methyl group, respectively, a singlet at τ 8.28 assigned to the C-2 methyl protons, and a small peak at τ 6.44 assigned to the nitrogen protons. The infrared spectrum of the amine shows peaks at 6.01 and 11.01 μ characteristic of $R_2C{=}CH_2$.

Hydrogenation of the 3-methylenepyrrolidine hydrochlorides with platinum oxide catalyst led to the saturated compounds (XV and XVa). Presumably, these have the methyl groups at positions 3 and 4 in the *cis* configuration owing to the fact that the face of the molecule containing the C-4 hydrogen is sterically less crowded than the face containing the C-4 methyl group. The melting point of the hydriodide of 2,2,-3,4,5,5-hexamethylpyrrolidine was observed at 322–326° (lit.[7] m.p. 281–285°), which would be expected since the *meso* compound is more symmetrical than the form presumably obtained earlier.

The n.m.r. spectrum of 2,2,3,4,5,5-hexamethylpyrrolidine-1-*d* deuteriochloride in chloroform-*d* showed a multiplet centered at τ 8.04 assigned to the protons on C-3 and C-4, singlets at τ 8.70 and 8.78 assigned to the methyl protons on C-2 and C-5 *cis* and *trans* to the C-3 and C-4 methyl groups, respectively, and a doublet at τ 9.30 assigned to the C-3 and C-4 methyl protons.

The preparations of the amines studied in this work are correlated and summarized in Scheme I and the compounds are described in Tables I and II. It will be noted that most of the compounds were prepared in two or three alternative ways in order to confirm structural assignments.

The pK_a values of the hydrochloride salts of some of the amines prepared in the course of this work are shown in Table II.

It was previously observed[3] that the electron-withdrawing ethynyl group sharply reduces basicity relative to the corresponding allylic and saturated groups. It will be noted that two such groups result in a very weak base as in VII and VIIa. It will be seen also that the tertiary amines have basicities similar to the corresponding secondary amines which is submitted as further evidence for the Trotman-Dickenson theory[8] as modified by Hall.[9] The pK_a values for XII and XV agree excellently with the value (11.25 in water) for 2,2,6,6-tetramethylpiperidine[10] which is taken as supporting evidence for the structures assigned.

Experimental

The 3-chloro-3-methyl-1-butyne used was prepared as previously described.[11]

3-Amino-3-methyl-1-butyne (I).—3-Chloro-3-methyl-1-butyne (306 g., 3 moles) was added dropwise with vigorous stirring to 2 l. of liquid ammonia containing 336 g. (6 moles) of powdered potassium hydroxide. Liquid ammonia (1 l.) was then added followed by 500 ml. of ether and the ammonia was allowed to evaporate overnight. Water (1 l.) was added with stirring and the layers were separated. The aqueous layer was extracted with four 100-ml. portions of ether which were combined with the organic layer. The ethereal solution was dried over anhydrous potassium carbonate. Distillation gave 163 g. of the product (65% yield); b.p. 75–80°, n^{25}_D 1.4189 (lit.[12] b.p. 79–80°, n^{25}_D 1.4183).

3-Amino-3-methyl-1-butene (II).—Sodium metal (23 g.) was added in small pieces with stirring to a solution of 166 g. (2 moles) of 3-amino-3-methyl-1-butyne in 2 l. of liquid ammonia. Ammonium chloride (1 mole, 54 g.) was then added slowly. Alternate additions of sodium and ammonium chloride were repeated until a total of 113 g. (5 g.-atoms) of sodium and 270 g. (5 moles) of ammonium chloride had been added. The total volume was maintained at 2 l. by periodic addition of liquid ammonia. Ether (500 ml.) was added and the liquid ammonia was allowed to evaporate overnight. The mixture was filtered and the solid was washed with 250-ml. portions of ether which were combined with the filtrate. The combined filtrates were dried over anhydrous potassium carbonate. Distillation afforded 100 g. (59% yield), b.p. 74–76°, n^{25}_D 1.4110.

***t*-Amylamine** (III).—A solution of 33.2 g. of 3-amino-3-methyl-1-butyne (I) in 50 ml. of absolute ethanol containing 0.6 g. of Raney nickel (wet with ethanol) was hydrogenated at room temperature and an initial pressure of 50 p.s.i.g. After the pressure dropped to 20 p.s.i.g. the system was repressurized to 50 p.s.i.g. The total pressure drop was 68 p.s.i.g. during 24 hr. The catalyst was removed by filtration and the alcoholic solution was acidified by the dropwise addition of 34 ml. of concentrated hydrochloric acid. The solvent was removed *in vacuo* and the salt was crystallized from ethanol plus ethyl acetate. The salt was covered with 100 ml. of ether and 12 ml. of water was added. Sodium hydroxide pellets (12 g.) were added with gentle swirling. The liquid was decanted and the solid was washed with 50 ml. of ether. The combined etheral solution was dried over potassium

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(7) W. R. Wragg, W. Green, and L. Bretherick, U. S. Patent 3,020,288 (1962).

(8) A. F. Trotman-Dickenson, *J. Chem. Soc.*, 1293 (1949).

(9) H. K. Hall, Jr., *J. Am. Chem. Soc.*, **79**, 5441 (1957).

(10) H. K. Hall, Jr., *ibid.*, **79**, 5445 (1957).

(11) G. F. Hennion, J. J. Sheehan, and D. E. Maloney, *ibid.*, **72**, 3542 (1950).

(12) G. F. Hennion and E. G. Teach, *ibid.*, **75**, 1653 (1953).

TABLE II

STERICALLY CROWDED SECONDARY AND TERTIARY AMINES

$R^1C(CH_3)_2N(R^3)C(CH_3)_2R^2$

							Hydrochlorides									
									% C		% H		% N		pK_a[a]	
Compd.	R¹	R²	R³	B.p., °C. (20 mm.)	$n^{22}D$	Yield, %	Formula	M.p., °C.	Calcd.	Found	Calcd.	Found	Calcd.	Found	In H_2O[b]	In 66% DMF
VII	C≡CH	C≡CH	H	65–69	[c]	47	$C_{10}H_{16}ClN$	222–223	64.65	64.48	8.43	8.69	7.54	7.54	6.45	5.65
VIIa	C≡CH	C≡CH	CH_3	84–88	1.4645	12	$C_{11}H_{18}ClN$	181–182	65.94	66.15	8.88	9.08	6.74	7.01	6.65	5.50
VIII	C≡CH	CH=CH₂	H	62–68	1.4456	47	$C_{10}H_{18}ClN$	174	64.13	63.98	9.95	9.66	7.30	7.46	8.20	7.35
VIIIa	C≡CH	CH=CH₂	CH_3	80–85	1.4673	12	$C_{11}H_{20}ClN$	[d]	65.52	65.49	9.95	9.99	6.76	6.94		
IX	C≡CH	CH_2CH_3	H	65–68	1.4359	53	$C_{10}H_{20}ClN$	174–175	63.49	63.30	10.70	10.63	7.49	7.38	9.0	8.0
IXa	C≡CH	CH_2CH_3	CH_3	80–84	1.4592	2	$C_{11}H_{22}ClN$	[d]	64.70	64.84	10.98	10.89	6.58	6.86		
X	CH=CH₂	CH=CH₂	H	65–69	1.4435	65	$C_{10}H_{20}ClN$	158–161	63.18	63.30	10.73	10.62	7.38	7.38	10.1	9.10
XI	CH=CH₂	CH_2CH_3	H	67–69	1.4353	82	$C_{10}H_{22}ClN$	162–164	62.82	62.63	11.64	11.57	7.30	7.30	10.8[e]	9.65
XII[f]	CH_2CH_3	CH_2CH_3	H	91–95[g]	1.4279	52	$C_{10}H_{24}ClN$	199–200	62.23	61.98	12.72	12.48	7.27	7.23	11.6[e]	10.55
XIII	-C(CH₃)=C(CH₃)-		H	64–70	1.4470	75	$C_{10}H_{20}ClN$	326–330	63.60	63.30	10.81	10.62	7.13	7.38	10.5	9.75
XIIIa	-C(CH₃)=C(CH₃)-		CH_3	82–85	1.4537	72	$C_{11}H_{22}ClN$	222–229	64.72	64.84	11.05	10.89	6.77	6.87	10.8[e]	9.40
XIV	-CH(CH₃)C(=CH₂)-		H	62–68	1.4466	84	$C_{10}H_{20}ClN$	279–284	63.25	63.30	10.74	10.62	6.97	7.38		
XIVa	-CH(CH₃)C(=CH₂)-		CH_3	77–80	1.4569	61	$C_{11}H_{22}ClN$	171–176	64.96	64.84	10.99	10.89	6.57	6.87		
XV	-CH(CH₃)CH(CH₃)-		H	70–74	1.4385	84[h]	$C_{10}H_{22}ClN$	240–245	62.94	62.64	11.84	11.57	7.19	7.30	11.4[e]	10.25
XVa	-CH(CH₃)CH(CH₃)-		CH_3	[i]	[i]	62[h]	$C_{11}H_{24}ClN$	234–236	64.06	64.21	11.74	11.76	6.80	6.81		

[a] Titration at 25°; measurements by L. Spangler, The Lilly Research Laboratories, Indianapolis, Ind. [b] Values ±0.1. [c] M.p. 32–34.5°. [d] Decomposes over a wide temperature range. [e] Values ±0.2; amine slightly soluble in water; solution becomes turbid during titration. [f] See ref. 15. [g] B.p. at 60 mm. [h] Yield of hydrochloride salt. [i] Isolated as hydrochloride salt only.

hydroxide pellets. Distillation gave 26.5 g. of the product (75% yield), b.p. 71–79°, $n^{25}D$ 1.3959 (lit.[13] b.p. 77–78°).

The hydrochloride salt had m.p. 233° (lit. m.p. *ca.* 225°[14a]; 195°[14b]).

3-Methylamino-3-methyl-1-butyne (IV).—Copper powder (0.5 g.) in 40% methylamine solution (700 g.) was stirred with cooling at 32–35° during dropwise addition of freshly distilled 3-chloro-3-methyl-1-butyne (307.5 g., 3 moles). Stirring was continued for 5 hr. and the mixture was allowed to stand overnight. The layers were separated and the aqueous portion was extracted with three 50-ml. portions of ether which were combined with the organic portion. The crude product was treated with 230 ml. of concentrated hydrochloric acid with cooling and stirring. After extracting with three 50-ml. portions of ether (discarded), the aqueous portion was treated with 200 g. of 60% sodium hydroxide solution. The resulting layers were separated and the aqueous layer was extracted with three 50-ml. portions of ether which were combined with the organic portion. The ethereal solution was dried over anhydrous potassium carbonate. Distillation gave 143 g. of the product (49% yield), b.p. 96–98°, $n^{25}D$ 1.4228 (lit.[3] b.p. 96–98°, $n^{25}D$ 1.4234). The hydrochloride salt had m.p. 216–217° (lit.[3] m.p. 216–217°).

3-Methylamino-3-methyl-1-butene (V) was prepared in a manner analogous to that described for 3-amino-3-methyl-1-butene (II) except that 59 g. of 3-methylamino-3-methyl-1-butyne was used with 27.6 g. (1.2 g.-atoms) of sodium and 199 g. (1.5 moles) of ammonium sulfate. Distillation gave 27.5 g. (46% yield), b.p. 92–98°, $n^{25}D$ 1.4152.

N-Methyl-*t*-amylamine (VI).—A solution of 38.8 g. (0.4 mole) of 3-methylamino-3-methyl-1-butyne in 50 ml. of Cellosolve containing 1.5 g. of Raney nickel (wet with ethanol) was hydrogenated at room temperature at an initial pressure of 40 p.s.i.g. After a pressure drop to 20 p.s.i.g. the system was repressurized to 50 p.s.i.g. and the total pressure drop was 68 p.s.i.g. overnight. The catalyst was removed by filtration and the solution was dried over anhydrous potassium carbonate. The product was recovered from the solvent by distillation and collected over potassium hydroxide. The layers of the distillate were separated and the amine was dried over metallic sodium. Redistillation from sodium gave 30.3 g. (75% yield), b.p. 95–98°, $n^{25}D$ 1.4066.

Bis(1,1-dimethylpropargyl)amine (VII).—3-Amino-3-methyl-1-butyne (I) (83 g., 1 mole), 30 ml. of 40% potassium hydroxide solution, 153.7 g. (1.5 moles) of 3-chloro-3-methyl-1-butyne, and *ca.* 0.1 g. of copper bronze powder were mixed and maintained at 25–30°. After 24 hr. an additional 30-ml. portion of potassium hydroxide was added with an additional 0.1 g. of copper powder. Five additional 30-ml. portions of potassium hydroxide were added, one after each 24-hr. period. On the eighth day after the reaction was started the entire mixture was steam distilled and the layers of the distillate were separated. The aqueous portion was extracted with three 50-ml. portions of ether which were added to the organic layer. The ethereal solution was treated with 80 ml. of concentrated hydrochloric acid which was added dropwise with stirring and cooling. The resulting mixture was filtered (suction) and the solid was washed with 100 ml. of ether. The layers of the filtrate were separated and the aqueous layer was extracted with 50 ml. of ether (discarded). The aqueous layer and the solid were combined and 150 ml. of water was added. The mixture was treated with 81 g. of 60% sodium hydroxide solution which was added dropwise with stirring and cooling. A portion of the amine released solidified and was filtered. The filtrate was extracted with three 50-ml. portions of ether which were combined with the solid. The ethereal solution was dried over anhydrous potassium carbonate. Distillation gave 73 g. (49% yield), b.p. 60–70° (20 mm.). Redistillation afforded 70 g. (47% yield), b.p. 65–60° (20 mm.), m.p. 32–35°.

N,N-Bis(1,1-dimethylpropargyl)methylamine (VIIa) was prepared in a similar manner from 85 g. (0.88 mole) of 3-methylamino-3-methyl-1-butyne (IV), 154 g. (1.5 moles) of 3-chloro-3-methyl-1-butyne, 0.1 g. of copper bronze powder, and 132 g. (2 moles) of potassium hydroxide dissolved in 200 ml. of water. The KOH solution was added in nine equal portions, one every 24 hr., and the reaction mixture was steam distilled on the tenth

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(13) R. Brown and W. E. Jones, *J. Chem. Soc.*, 782 (1946).

(14) (a) F. C. Whitmore and A. H. Homeyer, *J. Am. Chem. Soc.*, **54**, 3437 (1932); (b) G. Vexlerschi, *Compt. rend.*, **228**, 1655 (1949).

day. Distillation gave 19.6 g. of starting amine and 17.7 g. (12% yield) of the product, b.p. 84–88° (20 mm.), $n^{25}\mathrm{D}$ 1.4645.

The Clarke–Eschweiler methylation of bis(1,1-dimethylpropargyl)amine (VII) as previously described[4] for the preparation of N-methyl-3-*t*-butylamino-3-methyl-1-butyne gave a much better yield of the same compound. VII (74.5 g., 0.5 mole) yielded 55 g. (67% yield), b.p. 85–89° (20 mm.), $n^{25}\mathrm{D}$ 1.4648; the hydrochloride had the same melting point and mixture melting point.

N-(1,1-Dimethylallyl)-1,1-dimethylpropargylamine (VIII).—To 62.3 g. (0.75 mole) of 3-amino-3-methyl-1-butene (II) and 0.1 g. of copper powder were added 28 ml. of 40% potassium hydroxide solution and 12.8 g. of 3-chloro-3-methyl-1-butyne. The reaction temperature was maintained between 25 and 30°. After 12 hr. another 28 ml. of potassium hydroxide solution and 12.8 g. of 3-chloro-3-methyl-1-butyne were added and the temperature was maintained as above. Six additional portions of potassium hydroxide solution (a total of 89.6 g., 1.6 moles, of KOH) and six of 3-chloro-3-methyl-1-butyne (a total of 102.5 g., 1.0 mole) were added over a period of 4 days. Twenty-four hours after the final addition the mixture was steam distilled and the layers of the distillate were separated. The aqueous portion was extracted with three 50-ml. portions of ether which were combined with the organic layer. The ethereal solution was dried over anhydrous potassium carbonate. Distillation gave 53.7 g. (47% yield), b.p. 62–68° (20 mm.). Redistillation gave 48 g. (42% yield), b.p. 65–67° (20 mm.), $n^{25}\mathrm{D}$ 1.4456.

N-(1,1-Dimethylallyl)-N-(1,1-dimethylpropargyl)methylamine (VIIIa) was prepared as described above from 89 g. (0.9 mole) of 3-methylamino-3-methyl-1-butene (V), 0.1 g. of copper powder, 182 g. of 40% potassium hydroxide solution (1.3 moles of KOH), and 110 g. (1.1 moles) of 3-chloro-3-methyl-1-butyne in 12% yield. The potassium hydroxide solution and 3-chloro-3-methyl-1-butyne were added, each in 10 equal portions, at 12-hr. intervals. The product had b.p. 80–85° (20 mm.), $n^{25}\mathrm{D}$ 1.4673.

3-*t*-Amylamino-3-methyl-1-butyne (IX) was prepared as described above from 48.5 g. of *t*-amylamine, 0.1 g. of copper powder, 166 g. of 40% potassium hydroxide solution (1 mole of KOH), and 77 g. (0.75 mole) of 3-chloro-3-methyl-1-butyne in 53% yield. The potassium hydroxide solution and 3-chloro-3-methyl-1-butyne were added, each in 10 equal portions, at 4-hr. intervals. The product had b.p. 65–68° (20 mm.), $n^{25}\mathrm{D}$ 1.4359.

The hydrochloride had m.p. 174–175° (lit.[15] m.p. 167–169°).

3-(N-Methyl-*t*-amylamino)-3-methyl-1-butyne (IXa) was prepared as described above from 80.8 g. (0.8 mole) of N-methyl-*t*-amylamine, 0.1 g. of copper powder, 175.3 g. of 40% potassium hydroxide solution, and 102.5 g. (1.0 mole) of 3-chloro-3-methyl-1-butyne in 2.5% yield. The potassium hydroxide solution and 3-chloro-3-methyl-1-butyne were added, each in 10 equal portions, at 24-hr. intervals. The product had b.p. 80–84° (20 mm.), $n^{25}\mathrm{D}$ 1.4592.

The hydrochloride had m.p. 135–136° with resolidification and remelting at 220–223°.

Bis(1,1-dimethylallyl)amine (X).—A solution of N-(1,1-dimethylallyl)-1,1-dimethylpropargylamine (VIII, 15.3 g., 0.1 mole) in 50 ml. of Skellysolve "B" (petroleum ether) containing 0.03 g. of 10% palladium on activated charcoal was hydrogenated at room temperature at an initial pressure of 30 p.s.i.g. The pressure dropped by 8.5 p.s.i.g. during 2 hr. The catalyst was removed by filtration. Distillation gave 10 g. (65% yield), b.p. 65–69° (20 mm.), $n^{25}\mathrm{D}$ 1.4435.

3-*t*-Amylamino-3-methyl-1-butene (XI) was prepared by reduction of 38.3 g. (0.25 mole) of 3-*t*-amylamino-3-methyl-1-butyne (IX) with sodium (11.5 g., 0.5 g.-atom) in liquid ammonia (900 ml.) using ammonium chloride (27 g., 0.5 mole). The ammonium chloride and sodium were added alternately in five equivalent portions each. After all the ammonia had evaporated, 150 ml. of water was added with stirring and the resulting layers were separated. The aqueous layer was extracted with 100 ml. of ether which was added to the organic portion and the ethereal solution was dried over anhydrous potassium carbonate. Distillation gave 31.8 g. (82% yield), b.p. 67–69° (20 mm.), $n^{25}\mathrm{D}$ 1.4353.

Di-*t*-amylamine (XII).—A solution of 15.3 g. (0.1 mole) of 3-*t*-amylamino-3-methyl-1-butyne (IX) in 50 ml. of ethanol containing 1.0 g. of Raney nickel (wet with ethanol) was hydrogenated at room temperature and an initial pressure of 40 p.s.i.g. The pressure dropped by 17 p.s.i.g. over a period of 9 hr. The catalyst was removed by filtration. Distillation gave 8.2 g. (52% yield), b.p. 91–95° (60 mm.), $n^{25}\mathrm{D}$ 1.4279.

The hydrochloride had m.p. 199–200° (lit.[15] m.p. 183–185°).

2,2,3,4,5,5-Hexamethyl-3-pyrroline (XIII).—A mixture of 25.8 g. (0.17 mole) of bis(1,1-dimethylpropargyl)amine in 1 l. of liquid ammonia was treated with sodium metal and ammonium chloride as follows. Sodium was added in small pieces at 3–5-min. intervals, with stirring, until the characteristic blue color of dissolved sodium persisted (*ca.* 5–6 g.). A corresponding amount of ammonium chloride (*ca.* 11.5–14 g.) was added slowly (*caution*, frothing). Alternate additions of sodium and ammonium chloride (12 of each) were repeated until a total of 23 g. (1 g.-atom) of sodium and 54 g. (1 mole) of ammonium chloride had been added. Ether (250 ml.) was added and the mixture was allowed to reach room temperature without stirring. Another 250 ml. of ether and 200 ml. of water were then added with stirring. The resulting layers were separated and the aqueous layer was extracted with 50 ml. of ether which was added to the organic layer. The ethereal solution was dried over anhydrous potassium carbonate. Distillation gave 19.4 g. (75% yield) of impure product, b.p. 64–70° (20 mm.), $n^{25}\mathrm{D}$ 1.4470.

Purification was achieved *via* the hydrochloride salt which, precipitated from ether and crystallized from ethanol plus ethyl acetate, had m.p. 326–329°; 11 g. (50% yield) was recovered.

Heptamethyl-3-pyrroline (XIIIa) was prepared as described above in 72% yield from 40.7 g. (0.25 mole) of N,N-bis(1,1-dimethylpropargyl)methylamine (VIIa). The product had b.p. 82–85° (20 mm.), $n^{25}\mathrm{D}$ 1.4582.

The methiodide had m.p. 258–260° after crystallization from ethyl acetate.

Anal. Calcd. for $C_{12}H_{24}IN$: C, 46.61; H, 7.82; N, 4.53. Found: C, 46.34; H, 7.78; N, 4.34.

The picrate had m.p. 229–234° (lit.[16] m.p. 226–230°).

3,-Methylene-2,2,4,5,5-pentamethylpyrrolidine (XIV) was prepared in 84% yield as described above from 30 g. (0.2 mole) of N-(1,1-dimethylallyl)-1,1-dimethylpropargylamine (VIII), 11.5 g. (0.5 g.-atom) of sodium, and 27 g. (0.5 mole) of ammonium chloride. The product had b.p. 62–68° (20 mm.), $n^{25}\mathrm{D}$ 1.4466.

3-Methylene-1,2,2,4,5,5-hexamethylpyrrolidine (XIVa) was prepared in 61.5% yield from 12.4 g. (0.075 mole) of N-(1,1-dimethylpropargyl)methylamine (VIIIa), 4.6 g. (0.2 g.-atom) of sodium, and 10.8 g. (0.2 mole) of ammonium chloride. Water was not added but the mixture was filtered and the solid was washed with ether. The product had b.p. 77–80° (20 mm.), $n^{25}\mathrm{D}$ 1.4569.

Clarke–Eschweiler methylation[4] of XIV gave the same product in 65% yield, b.p. 85–88° (25 mm.), $n^{25}\mathrm{D}$ 1.4577; the hydrochloride had the same melting point and mixture melting point.

2,2,3,4,5,5-Hexamethylpyrrolidine Hydrochloride (XV HCl).—A solution of 4.1 g. (0.027 mole) of 3-methylene-2,2,4,5,5-pentamethylpyrrolidine hydrochloride (XIV HCl) in 50 ml. of ethanol containing 0.075 g. of platinum oxide was hydrogenated at room temperature at an initial pressure of 50 p.s.i.g. The catalyst was removed by filtration. The solvent was removed *in vacuo*. The crude product (3.5 g., 84% yield) had m.p. 230–236°. The analytical sample had m.p. 240–245°.

A sample of the free amine liberated from the hydrochloride had b.p. 70–74° (20 mm.), $n^{25}\mathrm{D}$ 1.4385.

The hydriodide had m.p. 322–326° crystallized from ethanol plus ethyl acetate (lit.[7] m.p. 281–285°).

Anal. Calcd. for $C_{10}H_{20}IN$: C, 42.41; H, 7.83; N, 4.94. Found: C, 42.48; H, 7.90; N, 4.84.

1,2,2,3,4,5,5-Heptamethylpyrrolidine Hydrochloride (XVa HCl).—A solution of 5.1 g. (0.025 mole) of 3-methylene-1,2,2,4,5,5-hexamethylpyrrolidine (XIVa HCl) in 25 ml. of ethanol containing 0.05 g. of platinum oxide was hydrogenated at room temperature at an initial pressure of 50 p.s.i.g. During 5 hr. the pressure dropped 2.5 p.s.i.g. The catalyst was removed by filtration. The solvent was removed *in vacuo*. The crude product (4.0 g., 78.4% yield) had m.p. 200–210°. Crystallization from ethanol plus ethyl acetate gave 3.18 g. (62% yield), m.p. 230–234°. The analytical sample had m.p. 234–236°.

The hydriodide had m.p. 215–255° crystallized from ethanol plus ethyl acetate.

Anal. Calcd. for $C_{11}H_{22}IN$: C, 44.75; H, 7.51; I, 42.99; N, 4.74. Found: C, 44.91; H, 7.66; I, 42.99; N, 4.62.

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Hydrochlorides described in Tables I and II were precipitated from ethereal solutions of the amines with ethereal hydrogen chloride (ice bath) and were crystallized (with the exception of VIIIa HCl, Table II) from mixtures of ethyl acetate and absolute ethanol. Compound VIIIa HCl decomposed even on gentle heating in attempts to crystallize and hence was analyzed in the crude form.

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Sterically Crowded Amines. V. Hydrogen Chloride Elimination with Rearrangement in Some β-Chloroamines[1]

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Hydrogen chloride elimination from β-chloroamines, $R^1CH_2C(CH_2R^2)(NR^3R^4)CH(Cl)CH_3$, yielding rearranged allylic amines, $R^1CH{=}C(CH_2R^2)CH(NR^3R^4)CH_3$, was studied. A mechanism, involving an aziridinium ion, is proposed. Solvent effects, product studies, and hydrogenation of the allylic amines gave evidence supporting the mechanism and helped define the scope and limitations of the reaction. A competing side reaction with probable intermediacy of an alkylideneaminium ion (or enamine) was discovered.

Discussion

An earlier paper[3] in this series reported that 3-methyl-3-isopropylamino-2-chlorobutane hydrochloride was converted to 2-methyl-3-isopropylamino-1-butene hydrochloride by thermal elimination of hydrogen chloride with rearrangement. The same product was also obtained from either 2-methyl-3-isopropylamino-2-chlorobutane hydrochloride or 1-isopropyl-2,2,3-trimethylaziridinium chloride. This rearrangement reaction has now been examined in greater detail to determine its mechanism, scope, and limitations.

The chloroamine hydrochlorides used in this work were prepared by the action of thionyl chloride on the hydrochlorides of the corresponding β-amino alcohols as previously reported.[3] In most cases the crude product of the thionyl chloride reaction was not purified, but was simply heated *in vacuo* to effect the rearrangement.

$$R^1CH_2C(CH_2R^2)(NR^3R^4)CH(OH)CH_3 \xrightarrow[2.\ SOCl_2]{1.\ HCl(g)}$$

$$R^1CH_2C(CH_2R^2)(NR^3R^4)CH(Cl)CH_3\cdot HCl \xrightarrow[2.\ NaOH(aq)]{1.\ \Delta}$$

$$R^1CH{=}C(CH_2R^2)CH(NR^3R^4)CH_3$$

The resulting mixture was then made alkaline and steam distilled. The distillate was extracted with ether and the ethereal solution was dried and distilled to give the allylic amine. Some reactions (discussed below) were performed using purified chloroamine hydrochlorides[3] as starting materials.

The physical properties and yields of the allylic amines, with supporting analytical data for the corresponding hydrochloride salts, are found in Table I. The structures of the final products were established by their infrared spectra, in some cases also by their n.m.r. spectra, and by comparison of the melting points of the hydrochloride salts with those of the hydrochlorides of the isomeric "unrearranged" allylic amines previously prepared[4] by semihydrogenation of propargylic amines.

$$R^1CH_2C(CH_2R^2)(NR^3R^4)C\equiv CH \xrightarrow{H_2-Pd}$$

$$R^1CH_2C(CH_2R^2)(NR^3R^4)CH{=}CH_2$$

Low-pressure catalytic hydrogenation of the products also gave evidence supporting the proposed structures. The hydrogenation products and the analytical data for the hydrochloride salts are found in Table II. The "unrearranged" isomers of these saturated compounds had been prepared and described previously.[4a] Melting points of the rearranged product hydrochlorides, both saturated and allylic, were different from the unrearranged isomers so that it was easily possible to demonstrate that rearrangement, rather than 1,2 elimination of hydrogen chloride from the β-chloroamines, had occurred. Repeated attempts to hydrogenate compounds VI–VIII with nickel, platinum oxide, and palladium catalysts consistently met with failure, however, presumably for steric reasons.

The previously mentioned facts served not only to show that the allylic amines were indeed products of rearrangement, but also that no 1,2 elimination products had formed. This was also borne out by g.l.c. examination of compounds III and IX which showed only one peak and by the sharp melting points of the hydrochloride salts of the butene and cyclohexene products. The melting points of the pentene hydrochlorides (compounds VI and VII) covered a wide range, as was expected, since these rearranged allylic amines could exist as mixtures of *cis* and *trans* isomers.

The rearrangement was not limited to monoalkylamino groups since both pyrrolidino and dimethylamino also migrated (compounds V and VIII). Alkyl groups attached to the tertiary carbon atom had little effect on the outcome of the reaction as shown by the

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(1) Paper No. 80 on substituted acetylenes. Previous paper: G. F. Hennion and C. V. DiGiovanna, *J. Org. Chem.*, **30**, 2645 (1965).

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