chromatographed on Florisil (100–200 mesh) using purified pentane: yield 2.6 g (0.011 mol); ir *no* peak at 3250–3300 cm^{-1} (N–H); nmr (CCl_4) multiplet (aromatic), τ 2.6–3.0 (5 H), broad absorption (α-cyclohexyl), 6.5 (0.97 H), broad multiplet (β,γ,δ-cyclohexyl), 8.0–9.0, and singlet (methyl), 8.5 (combined, 16.0 H); uv λ_{max} 365 mμ (ε 30–35).

Anal. Calcd for $C_{15}H_{22}N_2$: C, 78.21; H, 9.63; N, 12.16. Found: C, 78.53; H, 9.83; N, 12.06. Greater than 94% theoretical nitrogen evolution on thermal decomposition (see text).

α-Cumylcyclohexane (2-Cyclohexyl-2-phenylpropane).—A sample of α-cumylazocyclohexane was dissolved in cumene and heated for 4 days under nitrogen at 110–115°. The compound corresponding to the single unidentified peak on an analytical glpc trace of the reaction mixture was collected by pseudo-preparative glpc methods and shown to be pure by glpc analysis on the analytical column (see next section). Nmr, mass spectral, and infrared data were obtained: nmr (neat) multiplet (aromatic), τ 2.8–3.2 (5 H), multiplet (cyclohexyl), 8.2–9.1, and singlet (methyl), 8.8, (combined, 17.7 H); mass spectrum parent peak 202 ($C_{15}H_{22}$, 202), base peak 119 (cumyl ion radical). Glpc retention time was consistent with a molecular weight of 202. These data and the infrared spectrum were consistent with the structural assignment of α-cumylcyclohexane.

Product Analyses.—Degassed ampoules containing a 0.1 *M* solution of α-cumylazocyclohexane in cumene were heated at 110° for 6 days and degassed ampoules containing a 0.1 *M* solution of carbo-*t*-butylperoxycyclohexane in cumene were heated at 110° for 6 days or at 79.6° for 4 days. The low boiling products (cyclohexane, cyclohexene, and α-methylstyrene) were resolved at 75° on a 10-ft $AgNO_3$–Carbowax column at a flow rate of about 30 ml/min. The high boiling products (*t*-butyl cyclohexyl ether, α-cumylcyclohexane and bicumyl) were resolved on a 6-ft 10% UC-W98 column using temperature programming from 65° up to 230° at a 10/min rate. Benzene was used as an internal standard, and standard solutions containing known amounts of the products were used to obtain relative and absolute yields.

Registry No.—A, 25683-93-6; P, 20396-49-0; cyclohexanone α-cumylhydrazone, 25683-95-8; cyclohexane-α-cumylhydrazine, 25683-96-9; α-cumylcyclohexane, 25683-97-0.

A Method for the Extension of Carbon Chains by γ-Alkylation of Metalated α,β-Ynamines

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α,β-Ynamines of type 1 can be metalated by alkyllithium–tetramethylethylenediamine complexes to form lithium derivatives which undergo alkylation upon treatment with a variety of halides. The resulting ynamines can be converted to amides and carboxylic acids, thus affording the overall transformation of a halide RX to a carboxylic acid derivative RCH_2CH_2COX.

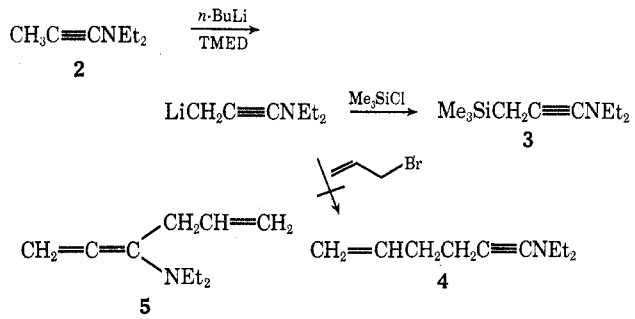
The introduction of a three-carbon chain terminating in a carboxyl function is often accomplished by the attachment of electrophilic reagents of type >C=CCOX to nucleophilic carbon by the Michael reaction[1] or by the addition of organoboranes to α,β-unsaturated aldehydes.[2] These methods are not applicable, however, when neither the metalloalkyl nor the organoborane derived from the unit to be elaborated, for example, the geranyl group, can be utilized satisfactorily.

A nucleophilic reagent, capable of performing the desired chain extension, would thus be a useful tool for the synthetic chemist. The lithium acetylide of propargyl tetrahydropyranyl ether[3] and the Grignard derived from the ethylene acetal of 3-bromopropionaldehyde[4] are two such reagents which have already been used in organic synthesis.

In principle the metalation of an ynamine of type **1** followed by reaction with a suitable electrophile,

$$\underset{\mathbf{1}}{CH_3C{\equiv}CNR_2} \xrightarrow{RLi} LiCH_2C{\equiv}CNR_2 \xrightarrow{R'X} R'CH_2C{\equiv}CNR_2 \xrightarrow[H^+]{H_2O} R'CH_2CH_2\overset{O}{\overset{\|}{C}}NR_2$$

coupled with the ready conversion of ynamines to amides or esters,[5] could provide a convenient and versatile method for the desired chain extension. We have studied such a procedure and report our results below.



Results

The first ynamine we chose to study was 1-diethylaminopropyne (**2**). This substance underwent metalation with *n*-butyllithium–tetramethylethylenediamine complex as evidenced by subsequent reaction with trimethylchlorosilane, which gave the acetylenic silane **3** in 85% yield (vpc analysis). Using identical conditions, however, reaction of this metalation product of **2** with either methyl iodide or allyl bromide gave neither of the expected acetylenic products nor any other material detectable by vpc analysis. The infrared spectra of the crude reaction mixtures contained allenic absorption at 5.2 μ, suggesting that the propargylic carbanion

(1) (a) E. D. Bergmann, D. Ginsburg, and R. Pappo, *Org. React.*, **10**, 179 (1959); (b) H. A. Bruson, *ibid.*, **5**, 79 (1949); (c) H. O. House in "Modern Synthetic Reactions," W. A. Benjamin, New York, N. Y., 1965, pp 204–215.

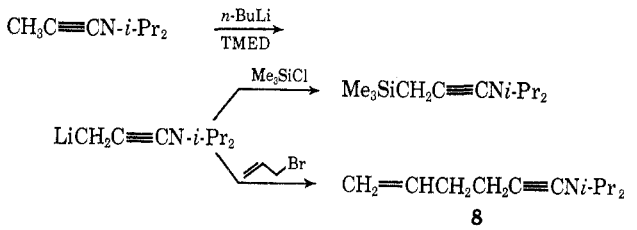
(2) (a) A. Suzuki, A. Arase, H. Matsumoto, M. Itoh, H. C. Brown, M. M. Rogić, and M. W. Rathke, *J. Amer. Chem. Soc.*, **89**, 5708 (1967); (b) H. C. Brown, M. M. Rogić, M. W. Rathke, and G. W. Kabalka, *ibid.*, **89**, 5709 (1967); (c) H. C. Brown and G. W. Kabalka, *ibid.*, **92**, 712, 714 (1970).

(3) (a) E. J. Corey, K. Achiwa, and J. A. Katzenellenbogen, *ibid.*, **91**, 4318 (1969); (b) E. J. Corey and K. Achiwa, *Tetrahedron Lett.*, 1839 (1969).

(4) G. Buchi and H. Wuest, *J. Org. Chem.*, **34**, 1122 (1969).

(5) For a review of ynamines and their reactions, see H. G. Viehe, *Angew. Chem., Int. Ed. Engl.*, **6**, 767 (1967), and references cited therein.

had been attacked exclusively at the carbon adjacent to the nitrogen, forming thereby an allenyl amine, **5**,[6] which is evidently thermally unstable. Attention was turned at this point to an ynamine containing bulkier groups on nitrogen. 1-Diisopropylaminopropyne (**6**), synthesized from the isomeric propargylamine[7] by the



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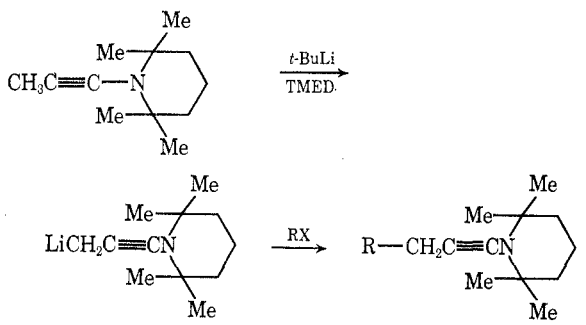
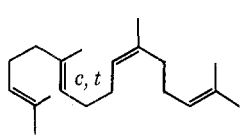
method of Viehe,[6a] could be metalated and then alkylated with trimethylchlorosilane in 80% (vpc) yield. Alkylation of the reagent from **6** with allyl bromide did afford the desired acetylenic product (**8**) but only in 40% yield even under optimum experimental conditions. The optimization experiments are summarized briefly in the Experimental Section.

A more effective reagent was found to be that derived from 1-propynyl-2,2,6,6-tetramethylpiperidine (**9**). *t*-Butyllithium–tetramethylethylenediamine rapidly and quantitatively metalated **9**, and reaction of the resultant carbanion with allyl iodide gave **10b** in 62% (vpc) yield.



10a, R = $(CH_3)_3Si$
b, R = CH_2=$CHCH_2$
c, R = CH_3
d, R = $CH_3(CH_2)_3$
e, R = geranyl



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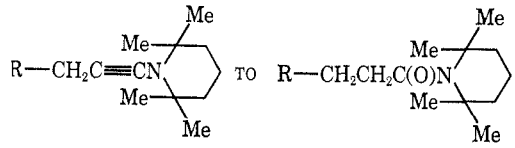
The reactions of the carbanion from **9** with a series of alkyl halides were examined; the results are recorded in Table I. As can be seen, fair yields of alkylated ynamines could be obtained. For the series allyl iodide, bromide, and chloride, the yield of **10b** decreased in that order. No unusual difficulties were encountered in reactions with simple *n*-alkyl iodides. However,

(6) (a) Allenyl amines are intermediates in the base-catalyzed rearrangement of propargyl amines to ynamines and may sometimes be isolated. See A. J. Hubert and H. G. Viehe, *J. Chem. Soc. C*, 228 (1968); A. J. Hubert and H. Reimlinger, *ibid.*, 606 (1968). (b) A stable allenyl amine is reported by J. L. Dumont, *C. R. Acad. Sci.*, **261**, 1710 (1965).

(7) Hindered propargyl amines were prepared by a two-step procedure: (1) reaction of 2,3-dibromopropene with the amine and (2) dehydrobromination with sodium amide. See R. F. Parcell and C. B. Pollard, *J. Amer. Chem. Soc.*, **72**, 2385, 3312 (1950). Reaction of the hindered amine directly with propargyl bromide gave only low (5–10%) yields of the desired product accompanied by large quantities of nondistillable resins.

TABLE I

CONVERSION OF R—X *via*

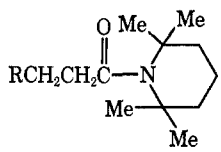


Alkyl halide	Yield of ynamine, % Vpc	Yield of ynamine, % Isolated	Yield of amide, %[a]
Allyl iodide	62	45	28
Allyl bromide	50		
Allyl chloride	0		
Trimethylchlorosilane	85	60	50
Methyl iodide	50	35	22
n-Butyl iodide		50	22
Geranyl bromide		40[b]	20

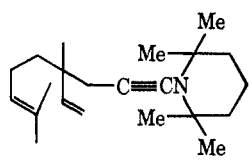
[a] Based on alkyl halide; two-step reaction. [b] Plus 20% **11**.

lithium–halogen exchange was a serious side reaction in alkylations with geranyl bromide. The ynamine **10e** was always accompanied by the hydrocarbon **11**. The chromatographic separation of **10e** and **11** resulted in concomitant hydrolysis of **10e** to the amide **12e** (see below). The nmr spectrum of the distilled ynamine–dimer mixture was consistent with the proposed structure **10e**, as was the mass spectrum which contained a parent ion of *m/e* 315.2926 (calcd for $C_{22}H_{37}N$: 315.2926). None of the product which would result from allylic transposition (**13**) was detected by nmr analysis.

Hydrolysis.—Whereas ynamines **2** and **6** and their derivatives could be smoothly and quantitatively converted to the corresponding amides under very mildly acidic conditions (magnesium sulfate and water), **9** proved resistant to the same hydrolytic procedures. Attempted hydrolysis with 0.1, 1.0, or 3.0 *N* hydrochloric acid or with magnesium sulfate produced varying quantities of amide severely contaminated by several by-products. An 83% yield of the amide **12f** could be obtained, however, upon passage of an ether solution of **9** through a column of activity II acidic alumina (Merck).



12a, R = $(CH_3)_3Si$
b, R = CH_2=$CHCH_2$
c, R = CH_3
d, R = $CH_3(CH_2)_3$
e, R = geranyl
f, R = H



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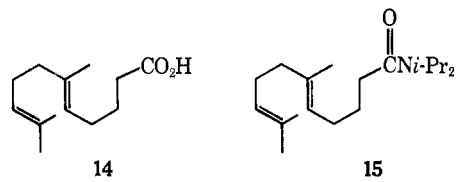
In practice, the ynamines could be isolated and then hydrolyzed in a subsequent step or, more conveniently, hydrolyzed directly by passage of the crude alkylation mixture through a column of alumina. Amides were then purified further by chromatography on silica gel.

Hydrolysis of the hindered amides with potassium hydroxide in refluxing ethylene glycol[8] gave the corre-

(8) J. Schmidt-Thomé, *Chem. Ber.*, **88**, 895 (1955).

sponding carboxylic acids. The hydrolysis of **12e** yielded 90% acid **14**, identical (nmr, ir, and tlc) with an authentic sample prepared by an alternate route.[3b]



14 15

From the above results it is clear that reactive nucleophiles can be generated by metalation of α,β-ynamines and also that these nucleophiles are susceptible to electrophilic attack at both α and γ carbons[9] with the balance depending to a high degree on steric factors.[10]

Experimental Section

Infrared spectra were taken using a Perkin-Elmer Model 137 infracord, and nmr data were obtained using a Varian Associates Model A-60 spectrometer. Nmr shifts are expressed in parts per million downfield from internal tetramethylsilane. Mass spectra were recorded on an AEI-MS-9 double focusing spectrometer. Vpc analyses were performed on an F & M Model 810 unit using a 9 ft × 0.125 in. column with 5% Carbowax plus 2% KOH on Chromosorb W acid washed, DMCS treated. Microanalyses were performed by the Scandinavian Microanalytical Laboratory, Herlev, Denmark.

Reagents.—The following reagents were used: *n*-butyllithium (Foote Mineral Co.), 1.3 *M* pentane solution; *t*-butyllithium (Foote), 1.8 *M* pentane solution, titrated; diethyl ether (Mallinckrodt A.R.), used from freshly opened can or dried over sodium wire; tetrahydrofuran, distilled from lithium aluminum hydride and stored under argon. All metalations with alkyllithiums were carried out under an argon atmosphere.

2-Bromo-3-(N,N-diisopropylamino)propene.—2,3-Dibromopropene (100 g, 0.5 mol) was added dropwise to a stirred solution of 280 ml (202 g, 2.0 mol) of diisopropylamine and 150 ml of dry benzene. The mixture was refluxed for 12 hr and then allowed to stand overnight. Nmr analysis of small aliquots withdrawn at various intervals served to monitor the course of the reaction. When the reaction was complete, ether was added, the reaction mixture was filtered, and the solvent was evaporated. Distillation of the residue provided 81.5 g of 2-bromo-3-(N,N-diisopropylamino)propene, bp 70–78° (10 mm).

Reaction of 2,2,6,6-Tetramethylpiperidine with 2,3-Dibromopropene.—A mixture of 91.7 g (0.65 mol) of 2,2,6,6-tetramethylpiperidine, 60 g (0.30 mol) of 2,3-dibromopropene, and 90 ml of dry toluene was refluxed for 22 hr and then diluted with 700 ml of ether and filtered. Concentration of the filtrate under reduced pressure and distillation of the residue gave 50.64 g (65%) of 2-bromo-3-(2,2,6,6-tetramethylpiperidyl)propene: bp 45–71° (0.25 mm); nmr (CCl_4) δ 1.01 (s, CH_3, 12 H), 1.50 (s, CH_2, 6 H), 3.24 (t, J = 2 Hz, allyl, 2 H), 5.48 (m, vinyl, 1 H), 6.23 (m, vinyl, 1 H); ir λ_{max}^{neat} 6.08 μ (C=C); mass spectrum m/e 261, 259, 246, 244, 190, 188. An exact mass determination gave m/e 261.0915 (calcd for $C_{12}H_{22}NBr$: 261.0916).

N,N-Diisopropylpropargylamine.—To a 1-l., three-neck flask, equipped with a Dry Ice–acetone condenser and Hershberg stirrer and containing 400 ml of ammonia was added 1 g of sodium. Addition of 0.5 g of ferric chloride discharged the deep blue color and caused evolution of hydrogen. Additional sodium was added in portions to a total of 20.3 g (0.88 g-atom), and the volume of ammonia was increased to 650 ml. After 1.5 hr of stirring, 81 g (0.37 mol) of 2-bromo-3-(N,N-diisopropylamino)propene was added dropwise and stirring was continued for 5 hr. The ammonia was then allowed to evaporate down to ~200 ml, and 200 ml of ether was added followed by cautious addition of 60 g (1 mol) of solid ammonium chloride. The resulting mixture was stirred overnight; then 200 ml of water was added along with 200 ml of ether. After filtration of the entire reaction mixture through Super-cel, the ether layer was separated, and the aqueous layer was extracted with 100 ml of ether. The combined ether portions were shaken with saturated sodium chloride solution, dried over sodium sulfate, the solvent was evaporated, and the residue was distilled to yield 41.7 g (81%) of N,N-diisopropylpropargylamine: bp 68–72.5° (42–50 mm) [lit.[7] bp 152.5–153° (760 mm)].

1-Propargyl-2,2,6,6-tetramethylpiperidine.—A 1-g piece of sodium was added to a 1-l., three-neck flask equipped with a Dry Ice–acetone condenser and a Hershberg stirrer and containing 500 ml of ammonia. Addition of 0.5 g of ferric chloride discharged the deep blue color and caused evolution of hydrogen. Additional sodium was added in portions to a total of 13.8 g (0.6 g atom). After 1.5 hr, 50 g (0.192 mol) of 2-bromo-3-(2,2,6,6-tetramethylpiperidyl)propene was added dropwise, and stirring was continued for 6 hr. Ether (200 ml) was added prior to cautious addition of 40 g (0.8 mol) of solid ammonium chloride. After 15 min, 250 ml of water was added, and the mixture was stirred an additional hour to evaporate the ammonia. Ether (100 ml) was then added followed by filtration of the entire reaction mixture through Super-cel. The ether layer was separated, and the aqueous phase was extracted with two 200-ml portions of ether. The combined ether solutions were shaken with saturated sodium chloride solution and dried over sodium sulfate, the solvent was evaporated, and the residue was distilled to yield 30.84 g (89%) of 1-propargyl-2,2,6,6-tetramethylpiperidine: bp 80–80.5° (8 mm); nmr (CCl_4) δ 1.10 (s, CH_3, 12 H), 1.47 (s, CH_2, 6 H), 1.90 (t, J = 2.5 Hz, C≡CH, 1 H), 3.27 (d, J = 2.5 Hz, CH_2C≡C, 2 H); ir λ_{max}^{neat} 3.1 μ (C≡C—H); mass spectrum m/e 179, 164, 108, 69, 42, 41, 39. An exact mass determination gave m/e 179.1677 (calcd for $C_{12}H_{21}N$: 179.1674).

N,N-Diisopropylamino-1-propyne[6a] **(6).**—A catalyst was prepared by dissolving 2.0 g of potassium in 100 ml of ammonia, then adding a crystal (~5 mg) of ferric chloride. The mixture was stirred for 1 hr after which 20 ml of dry basic alumina (Woelm) was added, and the ammonia was allowed to evaporate with stirring. The powder which remained was heated overnight at 65° under argon. The catalyst was poured, under argon, into a burette wrapped in heating tape and equipped with a thermometer. The column was heated to 63–65° and maintained at this temperature for the course of the reaction. A solution of 41 g (0.30 mol) of N,N-diisopropylpropargylamine in 65 ml of hexane was passed through the column at a flow rate of between 15 and 30 ml/hr (av 20 ml/hr). The eluent was collected in 5- to 10-ml portions and the contents analyzed by ir spectroscopy. All fractions showed a strong band at 4.4 μ (C≡C—N) and some absorption at 6.1 μ (C=C, dimers and polymers), and no bands at either 2.9 μ (C≡C—H) or 5.2 μ (C=C=C—N). The hexane was evaporated from the combined fractions, and the residual liquid was distilled from calcium hydride to give 30.75 g (75%) of **6**: bp 42.5–43.5° (12 mm); nmr (CCl_4) δ 1.10 (d, J = 6.5 Hz, $CHCH_3$, 12 H), 1.86 (s, ≡CCH_3, 3 H), 3.0 (sept, J = 6.5 Hz, CH, 2 H); ir $\lambda_{max}^{CCl_4}$ 4.48 μ (C≡C).

1-Propynyl-2,2,6,6-tetramethylpiperidine[6a] **(9).**—The isomerization catalyst, prepared as above, was poured, under argon, into a 60-ml addition funnel wrapped in heating tape and equipped with a thermometer. The column was heated to 63–65° and maintained at this temperature for the duration of the reaction. A solution of 30 g (0.16 mol) of 1-propargyl-2,2,6,6-tetramethylpiperidine in 50 ml of hexane was passed through the column at a flow rate of ~1 drop every 20 to 40 sec. The eluent was collected in 5- to 10-ml portions, and the contents were analyzed by ir spectroscopy. Any fractions containing a band at 3.1 μ (C≡C—H) were recirculated. The hexane was evaporated from the combined fractions, and the residual liquid was distilled from calcium hydride to give 22.6 g (75%) of the ynamine (**9**): bp 86–86.5° (12 mm); nmr (CCl_4) δ 1.18 (s, CH_3, 12 H), 1.45 (s, CH_2, 6 H), 1.88 (s, C≡CCH_3, 3 H); ir $\lambda_{max}^{CCl_4}$ 4.51 μ (C≡C); mass spectrum m/e 179, 164, 126, 109, 96, 70, 69, 58, 56, 55. An exact mass determination gave m/e 179.1674 (calcd for $C_{12}H_{21}N$: 179.1674).

Hydrolysis of N,N-Diisopropylamino-1-propyne (6).—A solution of 0.25 ml (0.20 g, 1.44 mmol) of N,N-diisopropylamino-1-propyne (**6**), in 1 ml of tetrahydrofuran was added dropwise to 10 ml of a 1:1 mixture of tetrahydrofuran and 1% aqueous magnesium sulfate at 0°. After 20 min of stirring at room temperature, the tetrahydrofuran was evaporated, and the residual solution was extracted with two 30-ml portions of ether. The ether extracts

(9) (a) For a theoretical treatment of one aspect of this problem, see G. Klopman, *J. Amer. Chem. Soc.*, **90**, 223 (1968); (b) R. Gompper, *Angew. Chem., Int. Ed. Engl.*, **3**, 558 (1964); (c) N. Kornblum, R. A. Smiley, R. K. Blackwood, and D. C. Iffland, *J. Amer. Chem. Soc.*, **77**, 6269 (1955).

(10) Compare (a) E. J. Corey and D. E. Cane, *J. Org. Chem.*, **34**, 3053 (1969), and (b) E. J. Corey and H. A. Kirst, *Tetrahedron Lett.*, 5041 (1968).

were then shaken with saturated aqueous sodium chloride and dried over magnesium sulfate. Evaporation of the solvent gave 0.250 g of the expected N,N-diisopropylpropionamide, identical with a sample prepared by reaction of diisopropylamine with propionyl chloride: nmr (CCl_4) δ 1.02 (t, J = 7.5 Hz, CH_3, 3 H), 1.25 (d, J = 7 Hz, $CHCH_3$, 12 H), 2.22 (q, J = 7.5 Hz, CH_2, 2 H), 3.0–4.3 (m, CH, 2 H); ir λ_{max}^{neat} 6.08 μ (C(O)N).

Hydrolysis of 1-Propynyl-2,2,6,6-tetramethylpiperidine (9).—1-Propynyl-2,2,6,6-tetramethylpiperidine (9) (0.186 g, 1.04 mmol) in 2 ml of ether was placed on a column packed with 5.1 g of acid-washed alumina (Merck, activity II). Ether (25 ml) was passed through the column, and evaporation of the solvent gave 0.176 g (83%) of 1-propionyl-2,2,6,6-tetramethylpiperidine (12f): nmr (CCl_4) δ 1.07 (t, J = 7 Hz, CH_2CH_3, 3 H), 1.42 (s, CH_3, 12 H), 1.73 (s, CH_2, 6 H), 2.28 (q, J = 7 Hz, CH_2CH_3, 2 H).

Metalation of N,N-Diethylamino-1-propyne (2).[11] Reaction with Trimethylchlorosilane.—*n*-Butyllithium (1.3 *M*, 21.0 ml, 27.3 mmol) was added to a dry flask, and the pentane was evaporated under vacuum. Ether (28 ml) was then added at 0° followed by 3.17 g (27.3 mmol) of tetramethylethylenediamine and 3.04 g (27.3 mmol) of **2**. The solution was stirred for 5.5 hr at 0°, after which 2.96 g (27.3 mmol) of trimethylchlorosilane was added, and stirring was continued for 14 hr. At this point a 1-ml aliquot was withdrawn, diluted with pentane, and filtered. Analysis by vpc (160°) showed three components: tetramethylethylenediamine (0.8 min, area 1); **2** (1.2 min, area 0.15); and **3** (2.4 min, area 0.85). The remainder of the reaction mixture was poured into 30 ml of 1% potassium carbonate solution at 0° and quickly extracted with two 30-ml portions of ether at 0°. The combined ether extracts were shaken with 5 ml of saturated sodium chloride solution containing 1% potassium carbonate, also at 0°, then dried over sodium sulfate containing a small amount of potassium carbonate. Evaporation of the solvent left 4.84 g of oil of which 3.37 g were distilled from calcium hydride in a Holtzmann apparatus to yield 1.92 g (57%) of **3**: bp 30° (0.02 mm); nmr (CCl_4) δ 0.08 (s, $SiCH_3$, 9 H), 1.14 (t, J = 7 Hz, CH_3, 6 H), 1.45 (s, $SiCH_2$, 2 H), 2.78 (q, J = 7 Hz, NCH_2, 4 H); ir $\lambda_{max}^{CCl_4}$ 4.50 μ (C≡C).

Metalation of N,N-Diethylamino-1-propyne (2). Reaction with Allyl Bromide.—N,N-Diethylamino-1-propyne (**2**) (3.90 mmol) was metalated in the manner described above. After 5.5 hr at 0° the solution was cooled to −40°, and 0.472 g (3.90 mmol) of allyl bromide was added. At the end of 0.5 hr, two 0.2-ml aliquots were withdrawn, diluted with pentane, and filtered. The first of these was analyzed by vpc (145°). Besides tetramethylethylenediamine (area 1) and **2** (area 0.15) there were no significant amounts of material with retention times longer than **2**. The ir spectrum of the second aliquot showed an allene absorption at 5.2 μ.

Metalation of N,N-Diisopropylamino-1-propyne (6). Reaction with Trimethylchlorosilane.—*n*-Butyllithium (1.3 *M*, 3.00 ml, 3.90 mmol) was added to a dry flask, and the pentane was evaporated under vacuum. Ether (2.0 ml) was added at 0° followed by 0.452 g (3.90 mmol) of tetramethylethylenediamine and 0.552 g (3.90 mmol) of **6**. The solution was stirred for 8.5 hr at 0°, after which 0.423 g (3.90 mmol) of trimethylchlorosilane was added. Vpc analysis (140°) of an aliquot showed three components: tetramethylethylenediamine (0.8 min, area 1), **6** (1.4 min, area 0.2), and **7** (3.2 min, area 0.8). Potassium carbonate (10 ml of 1% solution) was added to the remainder of the reaction mixture at 0°, and the resulting mixture was extracted with two 10-ml portions of ether at 0°. After shaking the combined ether extracts at 0° with 2 ml of saturated sodium chloride containing 1% potassium carbonate and drying over sodium sulfate–potassium carbonate, evaporation of the solvent gave 0.690 g of an oil shown by nmr analysis to consist of a mixture of **6** and **7** in a ratio of ~1:4: nmr (**7**) (CCl_4) δ 0.08 (s, $SiCH_3$, 9 H), 1.11 (d, J = 6.5 Hz, $CHCH_3$, 12 H), 1.53 (s, $SiCH_2$, 2 H), 3.00 (sept, J = 6.5 Hz, CH, 2 H).

Metalation of N,N-Diisopropylamino-1-propyne (6). Reaction with Allyl Bromide.—*n*-Butyllithium (1.3 *M*, 1.00 ml, 1.30 mmol) was added to a dry flask, and the pentane was evaporated under vacuum. Tetrahydrofuran (0.68 ml) was added at −20° followed by 0.15 g (1.27 mmol) of **6**. The solution was stirred for 17 hr at −20° after which 0.158 g (1.30 mmol) of allyl bromide was added, and the solution was stirred for 1.25 hr at 0°. At this point 0.112 g (0.65 mmol) of dodecane was added as an internal vpc standard followed by 5 ml of 1% potassium carbonate at 0°. After the extraction procedure described above, vpc analysis (145°) showed two major components: **6** (1.4 min, area 0.14), and **8** (3.8 min, area 0.40). In a separate experiment, distillation of 0.69 g of the crude reaction product gave, after a small forerun, 0.1 g of **8**: bp 60–62° (5 mm); greater than 90% pure by nmr (CCl_4), δ 1.10 (d, J = 6.5 Hz, CH_3, 12 H), 2.1–2.35 (m, CH_2, 4 H), 3.00 (sept, J = 6.5 Hz, CH, 2 H), 4.8–5.2 (m), and 5.5–6.2 (m) (vinyl, 3 H). See Table II.

TABLE II

METALATION AND ALLYLATION OF **6**

	Metalation		Allylation			
Solvent	Temp, °C	Time, hr	Temp, °C	Time, hr	% yield of **8**	% yield of **6**
Ether	0	16	0	1	25	20
THF	−20	16.5	0	1.25	40	14
THF	−20	19	0[a]	1	23	11
n-Pentane	25	19	25[b]	1	5[b]	10
THF	−20	16	0[c]	0.5	26	26

[a] Hexamethylphosphoramide (15% vol) added prior to reaction with allyl bromide. [b] Reaction with trimethylchlorosilane; yield of **7**. [c] Sodium methoxide (1 equiv) added prior to reaction with allyl bromide.

Metalation of N,N-Diisopropylamino-1-propyne (6). Reaction with Geranyl Bromide.—*n*-Butyllithium (1.3 *M*, 3.00 ml, 3.90 mmol) was added to a dry flask, and the pentane was evaporated under vacuum. Tetrahydrofuran (2.00 ml) was added at −20° followed by 0.45 g (3.90 mmol) of tetramethylethylenediamine and 0.544 g (3.90 mmol) of **6**. The solution was stirred for 17 hr at −20°. Geranyl bromide (0.846 g, 3.90 mmol), in 1 ml of tetrahydrofuran, was added dropwise at −10°, and the solution was stirred for 1.5 hr at 0°. The reaction mixture was then added dropwise to 30 ml of a 1:1 mixture of tetrahydrofuran and 1% aqueous magnesium sulfate at 0°. The tetrahydrofuran was evaporated, and the residual solution was extracted with three 40-ml portions of ether. Shaking of the ether extracts with saturated aqueous sodium chloride followed by drying over magnesium sulfate and evaporation of the solvent gave 0.886 g of crude oil. Preparative layer chromatography (silica gel, 6:2:1 hexane–methylene chloride–tetrahydrofuran) on 0.297 g of this oil gave two main bands (hot-wire visualization). The slower moving of the two (R_f 0.2–0.3) gave 0.064 g of the desired amide, **15**: nmr (**15**) (CCl_4) δ 1.23 (d, J = 7 Hz, $CHCH_3$, 12 H), 1.5–1.8 (m, $=CCH_3$, CH_2, 11 H), 1.8–2.5 (m, allyl, CH_2CO, 8 H), 2.5–4.2 (m, NCH, 2 H), 5.1 (m, vinyl, 2 H); ir λ_{max}^{neat} 6.08 μ (C(O)N).

Elution of the second band (R_f 0.33) gave 0.060 g of material shown by nmr and tlc analysis to consist of a mixture of **15** and an unidentified substance.

The Metalation–Alkylation of 1-Propynyl-2,2,6,6-tetramethylpiperidine (9). General Procedure.—*t*-Butyllithium (1.8 *M*, 0.72 ml, 1.3 mmol) was added dropwise to a solution of 0.15 g (1.30 mmol) of tetramethylethylenediamine and 0.232 g (1.30 mmol) of **9** in 0.5 ml of ether at −78°. The solution was then briefly warmed to 0° and stirred until homogeneous, then cooled to −50°. After several minutes a solid formed which dissolved upon rewarming to 0° for 0.5 hr. Alkyl halide (1.3 mmol) was added dropwise, and the resultant mixture was stirred overnight at 0°.

A. Isolation of Alkylated Ynamines.—Cold aqueous 1% potassium carbonate (4 ml) was added, and the reaction mixture was extracted at 0° with three 4-ml portions of ether. The ether extracts were shaken with saturated aqueous sodium chloride containing 1% potassium carbonate and then dried over sodium sulfate–potassium carbonate. The extractions were performed at 0° as rapidly as possible to avoid any unwanted hydrolysis. Filtration and evaporation of the solvent gave an oil which was purified by high-vacuum (0.0008 mm) bulb-to-bulb distillation.

B. Direct Hydrolysis to the Amide.—In this case the reaction mixture was diluted with additional ether, then passed through a column of 25 g of activity II acidic alumina (Merck) with 100 ml of ether. Evaporation of the solvent and preparative layer chromatography (plc) on silica gel yielded the pure amide.

1-(3-Trimethylsilylpropynyl)-2,2,6,6-tetramethylpiperidine (10a).—Trimethylchlorosilane (0.138 g, 1.30 mmol) was added at 0° to 1.3 mmol of the lithio anion of **9**, generated in the usual manner, and the reaction mixture was stirred overnight. Addi-

(11) Fluka, A. G., Buchs, Switzerland.

tion of 4 ml of 1% aqueous potassium carbonate followed by the usual isolation procedure gave 0.276 g of crude oil which was purified by bulb-to-bulb distillation at 25° (0.0008 mm) to give 0.203 g (62%) of **10a**: nmr (CCl_4) δ 0.08 [s, $(CH_3)_3Si$, 9 H], 1.13 (s, CH_3, 12 H), 1.4 (m, CH_2, 8 H); ir $\lambda_{max}^{CCl_4}$ 4.48 μ (C≡C); mass spectrum *m/e* 251, 236, 168, 126, 84, 83. An exact mass determination gave *m/e* 251.2070 (calcd for $C_{15}H_{29}NSi$: 251.2069).

1-(5-Hexen-1-ynyl)-2,2,6,6-tetramethylpiperidine (10b).—Allyl iodide (0.222 g, 1.30 mmol) was added to 1.3 mmol of the lithio anion of **9**, and the reaction mixture was stirred overnight. The usual isolation procedure gave 0.254 g of crude oil which was purified by bulb-to-bulb distillation at 25° (0.0008 mm) to give 0.126 g (42%) of **10b** as a clear oil: nmr (CCl_4) δ 1.15 (s, CH_3, 12 H), 1.46 (s, CH_2, 6 H), 2.20 (m, allyl, 4 H), 4.75–5.15 (m, vinyl, 2 H), 5.4–6.2 (m, vinyl, 1 H); ir $\lambda_{max}^{CCl_4}$ 4.49 (C≡C), 6.07 (C=C), 10.1 and 10.9 μ ($CH=CH_2$); mass spectrum *m/e* 219, 204, 178, 126, 122, 109, 94, 70, 69. An exact mass determination gave *m/e* 219.1985 (calcd for $C_{15}H_{25}N$: 219.1987).

1-Butynyl-2,2,6,6-tetramethylpiperidine (10c).—Methyl iodide (0.185 g, 1.30 mmol) was added to 1.3 mmol of the lithio anion of **9**, and the reaction mixture was stirred overnight. The usual isolation procedure gave 0.251 g of crude product which was purified by bulb-to-bulb distillation at 25° (0.0008 mm) to give 0.096 g (38%) of **10c**: nmr (CCl_4) δ 1.12 (t, J = 7 Hz, CH_3) and 1.18 (s, CH_3) (total 15 H), 1.47 (s, CH_2, 6 H), and 2.25 (q, J = 7 Hz, CH_2, 2 H); ir $\lambda_{max}^{CCl_4}$ 4.51 μ (C≡C); mass spectrum *m/e* 193, 178, 168, 126, 109. An exact mass determination gave *m/e* 193.1824 (calcd for $C_{13}H_{23}N$: 193.1830).

1-Heptynyl-2,2,6,6-tetramethylpiperidine (10d).—*n*-Butyl iodide (0.239 g, 1.30 mmol) was added to 1.3 mmol of the anion of **9**, and the reaction mixture was stirred overnight. The usual isolation procedure gave 0.293 g of crude product which was purified by bulb-to-bulb distillation at 30° (0.001 mm) to yield 0.149 g (49%) of **10d**: nmr (CCl_4) δ 1.1 (m, CH_3) and 1.18 (s, CH_3) (total area 15 H), 1.4 (m, CH_2, 12 H), 2.3 (m, $CH_2C{\equiv}C$, 2 H); ir $\lambda_{max}^{CCl_4}$ 4.50 μ (C≡C); mass spectrum *m/e* 235, 220, 180, 178, 168, 164, 126. An exact mass determination gave *m/e* 235.2291 (calcd for $C_{16}H_{29}N$: 235.2300).

Reaction of the Lithio Anion of 1-Propynyl-2,2,6,6-tetramethylpiperidine (9) with Geranyl Bromide.—Geranyl bromide (0.282 g, 1.30 mmol) was added to 1.3 mmol of the lithio anion of **9**, and the reaction mixture was stirred overnight. The usual isolation procedure gave 0.423 g of crude product which was bulb-to-bulb distilled at 50–80° (0.0008 mm) to give 0.270 g of oil: nmr analysis showed this material to consist of a mixture of 0.55 mmol of **10e** and 0.25 mmol of **11**: nmr (**10e**, interpolated) (CCl_4) δ 1.18 (s, CH_3, 12 H), 1.46 (s, CH_2, 6 H), 1.63 (m, C=C-CH_3, 9 H), 2.1 (m, allyl CH_2, 8 H), 5.0 (m, vinyl, 2 H); mass spectrum *m/e* 315,300. An exact mass determination gave *m/e* 315.2926 (calcd for $C_{22}H_{37}N$: 315.2926).

1-(3-Trimethylsilylpropionyl)-2,2,6,6-tetramethylpiperidine (12a).—Trimethylchlorosilane (0.552 g, 5.2 mmol) was added to 5.20 mmol of the lithio anion of **9**, generated in the usual fashion in 2.0 ml of ether. After the reaction mixture had stirred overnight, 25 ml of pentane was added, the solvent was evaporated, and the residue was dissolved in *n*-hexane and placed on a column of 60 g of activity II acidic alumina (Merck). Elution with 100 ml of hexane gave a forerun of 0.069 g of oil after evaporation. Further elution with 100 ml of ether and evaporation of the solvent gave 0.992 g of oil. Preparative layer chromatography (silica gel; 12:4:1 hexane–methylene chloride–tetrahydrofuran) of 0.950 g of this substance and removal of the uv fluorescent band of R_f 0.4 gave 0.633 g (47%) of **12a** as a white solid: nmr (CCl_4) δ 0.05 [s, $(CH_3)_3Si$, 9 H], 0.8 (m, CH_2Si, 2 H), 1.42 (s, CH_3, 12 H), 1.74 (s, CH_2, 6 H), 2.2 (m, CH_2CO, 2 H); ir λ_{max}^{neat} 6.08 μ [C(O)N]; mass spectrum *m/e* 269, 254, 170, 168, 130, 126, 73, 69. An exact mass determination gave *m/e* 269.2185 (calcd for $C_{15}H_{31}NOSi$: 269.2175). An analytical sample (mp 49–50.5°) was prepared by sublimation at 45° (0.01 mm).

Anal. Calcd for $C_{15}H_{31}NOSi$: C, 66.85; H, 11.59; N, 5.20. Found: C, 66.94; H, 11.56; N, 5.44.

1-(5-Hexenoyl)-2,2,6,6-tetramethylpiperidine (12b).—Allyl iodide (0.222 g, 1.30 mmol) was added to 1.30 mmol of the lithio anion of **9**. After the reaction mixture had stirred overnight, ether was added, and the mixture was passed through a column of 25 g of activity II acidic alumina (Merck) with a total of 100 ml of ether as eluent. Evaporation of the solvent yielded 0.235 g of oil which was purified by plc (silica gel; 18:6:1 hexane–methylene chloride–tetrahydrofuran) to give 0.086 g (28%) of **12b** (R_f 0.4): nmr (CCl_4) δ 1.42 (s, CH_3, 12 H), 2.72 (s and m, CH_2, 8 H), 2.2 (m, allyl CH_2, 4 H), 5.0 (m, vinyl, 2 H), 5.8 (m, vinyl, 1 H); ir λ_{max}^{neat} 6.09 (C(O)N), 10.1, and 10.95 μ (vinyl); mass spectrum *m/e* 237, 222, 126, 70, 69. An exact mass determination gave *m/e* 237.2095 (calcd for $C_{15}H_{27}NO$: 237.2093). An analytical sample was prepared by bulb-to-bulb distillation at 80° (0.01 mm).

Anal. Calcd for $C_{15}H_{27}NO$: C, 75.89; H, 11.46; N, 5.90. Found: C, 75.96; H, 11.52; N, 5.84.

1-Butyryl-2,2,6,6-tetramethylpiperidine (12c).—Reaction of 1.30 mmol of the lithio anion of **9** with 0.185 g (1.30 mmol) of methyl iodide gave, after hydrolysis and purification by plc, 0.060 g (22%) of **12c**: nmr (CCl_4) δ 0.92 (t, J = 7 Hz, CH_3, 3 H), 1.42 (s, CH_3, 12 H), 1.6 (m, CH_2) and 1.72 (s, CH_2) (total 8 H), 2.3 (m, CH_2CO, 2 H); ir λ_{max}^{neat} 6.09 μ [C(O)N]; mass spectrum *m/e* 211, 196, 168, 126. An exact mass determination gave *m/e* 211.1926 (calcd for $C_{13}H_{25}NO$: 211.1936). An analytical sample was prepared by bulb-to-bulb distillation at 80° (0.01 mm).

Anal. Calcd for $C_{13}H_{25}NO$: C, 73.88; H, 11.92; N, 6.63. Found: C, 73.50; H, 11.75; N, 6.74.

1-Heptanoyl-2,2,6,6-tetramethylpiperidine (12d).—Reaction of 1.30 mmol of the lithio anion of **9** with 0.239 g (1.30 mmol) of *n*-butyl iodide gave, after hydrolysis and purification by plc, 0.074 g (22%) of **12d**: nmr (CCl_4) δ 0.9 (m, CH_3, 3 H), 1.3 (m, CH_2) and 1.42 (s, CH_3) (total 20 H), 1.72 (s, CH_2, 6 H), 2.2 (m, CH_2CO, 2 H); ir λ_{max}^{neat} 6.09 μ [C(O)N]; mass spectrum *m/e* 253, 238, 170, 126, 70, 69. An exact mass determination gave *m/e* 253.2408 (calcd for $C_{16}H_{31}NO$: 253.2406). An analytical sample was prepared by bulb-to-bulb distillation at 80° (0.01 mm).

Anal. Calcd for $C_{16}H_{31}NO$: C, 75.83; H, 12.34; N, 5.53. Found: C, 75.80; H, 12.23; N, 5.69.

1-(3-Geranylpropionyl)-2,2,6,6-tetramethylpiperidine (12e).—Geranyl bromide (0.282 g, 1.30 mmol) was treated with 1.30 mmol of the lithio anion of **9**. After the reaction mixture had stirred overnight, 10 ml of pentane was added, the solution was filtered, and the solvent was evaporated. The residue was redissolved in hexane and placed on a column of 25 g of activity II acidic alumina (Merck). The column was washed with hexane until all the hydrocarbon material (0.057 g of **11**) had been eluted. Ether (100 ml) eluted the more polar material, giving 0.244 g of oil after solvent evaporation. This oil was purified by plc (silica gel; 6:2:1 hexane–methylene chloride–tetrahydrofuran; two developments) to yield 0.094 g (22%) of **12e**: nmr (CCl_4) δ 1.41 (s, CH_3, 12 H), 1.6 (m, C=CCH_3, 9 H), 1.72 (s, CH_2, 6 H) superimposed on 1.6 (m, CH_2, 2 H), 2.1 (m, C=CCH_2 and CH_2-CO, 8 H), 5.1 (m, vinyl, 2 H); ir λ_{max}^{neat} 6.09 μ [C(O)N]; mass spectrum *m/e* 333, 318, 264, 196, 183, 168, 164, 140, 127, 126, 125, 124, 109. An exact mass determination gave *m/e* 333.3039 (calcd for $C_{22}H_{39}NO$: 333.3031). An analytical sample was prepared by bulb-to-bulb distillation at 150° (0.01 mm).

Anal. Calcd for $C_{22}H_{39}NO$: C, 79.22; H, 11.79; N, 4.20. Found: C, 79.08; H, 11.69; N, 4.39.

Alkaline Hydrolysis of 1-(3-Geranylpropionyl)-2,2,6,6-tetramethylpiperidine (12a).—Ethylene glycol (5 ml) containing 0.043 g (0.13 mmol) of **12e** and 0.75 g (0.013 mol) of potassium hydroxide was refluxed for 15 hr, whereupon the reaction mixture was diluted with 40 ml of water, acidified with hydrochloric acid, and extracted with three 50-ml portions of ether. The combined ether layers were shaken with 15 ml of saturated aqueous sodium chloride and dried over magnesium sulfate. Evaporation of the solvent gave 0.025 g (90%) of **14**, identical by nmr, ir, and tlc with an authentic sample:[3b] nmr (CCl_4) δ 1.6 (m, C=CCH_3, 9 H), 1.6–2.5 (m, CH_2, 10 H), 5.0 (m, vinyl, 2 H), 11.3 (s, CO_2H, 1 H); ir $\lambda_{max}^{CCl_4}$ 2.8–4.2 (O—H), 5.81 μ (C=O).

Registry No.—**3**, 25665-32-1; **6**, 25665-33-2; **7**, 25665-34-3; **8**, 25665-35-4; **9**, 25665-36-5; **10a**, 25716-08-9; **10b**, 25665-37-6; **10c**, 25665-38-7; **10d**, 25665-39-8; **10e**, 25662-77-5; **12a**, 25665-40-1; **12b**, 25665-41-2; **12c**, 25665-42-3; **12d**, 25665-43-4; **12e**, 25662-78-6; **12f**, 25665-44-5; **15**, 25716-09-0; 2-bromo-3-(N,N-diisopropylamino)propene, 14326-36-4; 2-bromo-3-(2,2,6,6-tetramethylpiperidyl)propene, 25665-46-7; 1-propargyl-2,2,6,6-tetramethylpiperidine, 25665-47-8.

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