Synthetic Utility of Organometallic Reagents Derived from Group IV Metal Tetrachlorides and CH_3Li. A Direct Synthesis of 2-(2-Keto-1-alkylidene)tetrahydropyrroles from 4-Alkynylamines and Acyl Cyanides

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The non-Cp-bearing titanium alkyls $(CH_3)_2TiCl_2 \cdot L_2$ (**1a**) and $(CH_3)_2Ti(OTFE)Cl \cdot L_2$ (**1b**) and their Zr(IV) analogues have been shown to mediate efficient aminoalkyne cyclizations to provide azatitanium intermediates that undergo facial C-acylation in the presence of acyl cyanides.

Group IV metallocene complexes have continued to play a preeminent role as catalysts for alkene polymerization.[1] Recently, interest has intensified in group IV metal complexes containing amido[2] as well as other heteroatom (i.e., amidinato[3]) bearing ligands as polymerization catalysts. In addition, inexpensive non-Cp-containing isopropoxytitanium complexes have been found to mediate highly selective C−C bond formation in a manner reminiscent of group IV metallocene derivatives.[4] Studies in these laboratories have revealed that transient imido complexes generated by treatment of $CpTi(CH_3)_2Cl$ with alkynylamines undergo facile intramolecular [2+2] cycloaddition to provide intermediates that subsequently engage in selective nucleophilic coupling with acyl cyanides.[5,6] In this article, we show that organotitanium derivatives of the type $(CH_3)_2TiCl_2 \cdot L_2$ (**1a**), which can be directly prepared by treating inexpensive $TiCl_4$·1,2-DME (**2**) with 2 equiv of CH_3Li, participate admirably in the aminoalkyne cyclization/acyl cyanide coupling sequence. In addition, the corresponding zirconium alkyls have been found to perform in an analogous manner. Whereas $(CH_3)_2TiCl_2$ is predisposed toward disproportionation at ambient temperatures,[7a] the corresponding complexes with chelating ethers (i.e., dioxane) have been described as comparatively stable.[7b] In light of these observations, $TiCl_4$·1,2-DME (**2**) was selected as an appropriate Ti(IV) source for initial examination.[8]

Results and Discussion

The alkynylamines that were utilized in this study were prepared by the general routes described previously.[6] We commenced the present investigation by exploring the ability of $(CH_3)_2TiCl_2 \cdot L_2$ (**1a**) to cyclize representative alkynylamines (Scheme 1). In a typical procedure, addition of 2 equiv of CH_3Li to **2** in THF at 0 °C generated a light orange solution of the active reagent **1a**. Subsequent addition of the appropriate alkynylamine **3** at 0 °C resulted in an immediate evolution of CH_4 with the homogeneous solution assuming a rich burgundy color. After stirring at ambient temperature for an additional 3 h, protonolysis of the putative azatitanetine **4** (5% NaOH in MeOH) afforded the corresponding Δ^1-pyrrolines **5a**−**c** in the indicated yields after purification (Table 1). In the cases of **3b** and **3c**, protodesilyation occurred upon quenching to provide the corresponding Δ^1-pyrrolines **5b** and **5c**. We have previously shown that $CpTiCl_3$ is a very effective catalyst for the cyclization of 1-amino-4-alkynes to Δ^1-pyrrolines.[6c] It is therefore of interest that **2** is relatively inactive as a catalyst for this interconversion.[9]

The reaction of the organometallic species derived from **1a** and 1-amino-4-alkynes with acyl cyanides was subsequently examined. To this end, simple addition of an acyl cyanide (1 equiv) to the preformed azatitanium intermediate at 0 °C, followed by stirring at ambient temperature for 72 h and final quenching (CH_3OH), furnished the anticipated 2-(2-keto-1-alkylidene)tetrahydropyrroles (**6b**−**i**) in good to excellent isolated yield (Scheme 2). The results of a series of aminoalkyne

(1) Mitchell, J. P.; Hajela, S.; Brookhart, S. K.; Hardcastle, K. I.; Henling, L. M.; Bercaw, J. E. *J. Am. Chem. Soc.* **1996**, *118*, 1045−1053, and references therein.

(2) (a) Scollard, J. D.; McConville, D. H. *J. Am. Chem Soc.* **1996**, *118*, 10008−10009. (b) Tinkler, S.; Deeth, R. J.; Duncalf, D. J.; McCamley, A. *J. Chem. Soc., Chem. Commun.* **1996**, 2623−2624.

(3) Hagadorn, J. R.; Arnold, J. *J. Chem. Soc., Dalton Trans.* **1997**, 3087−3096, and references therein.

(4) Okamoto, S.; Iwakubo, M.; Kobayashi, K.; Sato, F. *J. Am. Chem. Soc.* **1997**, *119*, 6984−6990, and references therein.

(5) For a comprehensive review in the area of aminoalkyne cyclizations see: Muller, E. T.; Beler, M. *Chem. Rev.* **1998**, *98*, 676.

(6) (a) Fairfax, D.; Stein, M.; Livinghouse, T.; Jensen, M. *Organometallics* **1997**, *16*, 1523−1525. (b) McGrane, P. L.; Livinghouse, T. *J. Am. Chem. Soc.* **1993**, *115*, 11485−11489. (c) McGrane, P. L.; Jensen, M. D.; Livinghouse, T. *J. Am. Chem. Soc.* **1992**, *114*, 5459−5460. (d) McGrane, P. L.; Livinghouse, T. *J. Org. Chem.* **1992**, *57*, 1323−1324.

(7) (a) deButts, E. H. U.S. Patent 3,021,349, 1962. (b) Beerman, C.; Beastian, H. *Angew. Chem.* **1959**, *71*, 618−623.

(8) (a) Evaluation of $TiCl_4$·1,4-dioxane as a Ti(IV) source revealed that this complex possessed no advantages relative to **2**. (b) Ti(III) complexes are not efficacious in the ac/acc sequence. Accordingly, the use of $TiCl_3$·2THF in place of **2** led to aminoalkyne cyclization with concomitant generation of an azatitanium intermediate that was lethargic toward acyl cyanide interception.

(9) (a) Although **2** proved quite effective as a catalyst for the cyclization of highly reactive aminoalkynes possessing a 5-trimethylsilyl substituent,[9b] comparatively less reactive substrates bearing 5-alkyl or 5-aryl substituents cyclized inefficiently.[9c] (b) Li, Y.; Marks, T. J. *J. Am. Chem. Soc.* **1996**, *118*, 9295−9306. (c) We wish to acknowledge the early contribution of Dr. Phil Ho Lee, of these laboratories, who first demonstrated the use of **1a** for the cyclization of **3b** to **5b**.

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Scheme 1

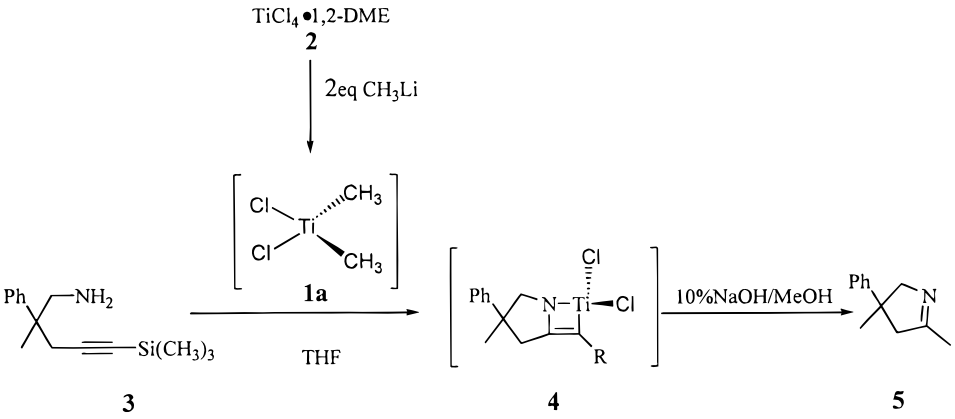
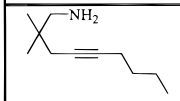
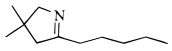
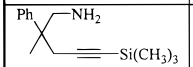
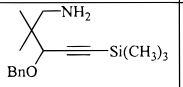
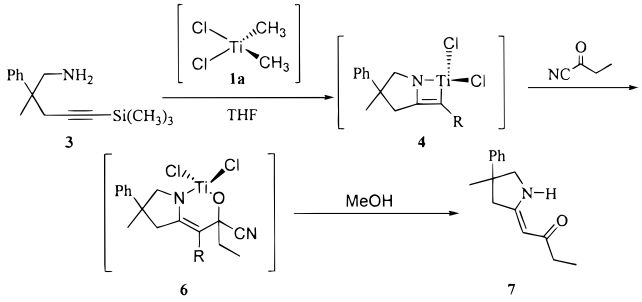


Table 1. Aminoalkyne Cyclization Reactions Promoted by Complex 1a

Aminoalkyne	Ti(IV) Complex	α[1]-Pyrroline	(%) Yield
 3a	1a	 5a	84
 3b	1a	 5b	93
 3c	1a	 5c	84

Scheme 2



cyclization/acyl cyanide coupling (ac/acc) reactions are assembled in Table 2.

Several of the above results are worthy of comment. Whereas the Ti(IV) complex **1a** is capable of eliciting sequential ac/acc reactions involving 1-amino-4-alkynes bearing aryl or trimethylsilyl substitution at the 5-position (entries 2−9), 1-amino-4-alkynes possessing 5-alkyl substituents undergo facile cyclization *without successful acylation* when **1a** is employed (entries 1 and 10). By way of contrast, the reagent generated via sequential treatment of **2** with CH_3Li (3 equiv) followed by CF_3CH_2OH (TFEOH, 1 equiv), $(CH_3)_2Ti(OTFE)Cl{\cdot}L_2$ (**1b**),[10] is capable of engaging in efficient ac/acc reactions with the latter substrates (entries 11 and 12). As expected, $(CH_3)TiCl_3{\cdot}L_2$ (**1c**), generated by treatment of **2** with only 1 equiv of CH_3Li, gives rise to efficient cyclization with minimal subsequent acyl cyanide interception (entries 13 and 14).[11] As had been previously observed, protodesilyation could be effected by using a slightly modified quenching procedure to afford the corresponding heterocycles **7** in high yield (entries 2, 3, 5, 6, 8, 9).

After the foregoing studies, a variety of alternative, non-Cp-bearing, complexes of both Ti(IV) and Zr(IV) were generated by an analogous procedure and evaluated in representative ac/acc sequences (Table 3). As is evident from these examples, yields obtained for complexes derived form Zr(IV) are comparable, or sometimes superior, to their Ti(IV) counterparts. It should be noted that group IV complexes possessing comparatively electron deficient ligands (e.g., **1a**, **b**, **d**, **e**, **f**, and **h**) are generally quite effective for the transformations of interest. By way of contrast, Ti(IV) complexes bearing conventional alkoxide (*i*-PrO, EtO), thioalkoxide (*t*-BuS), fluoride, or ≥3 CH_3 substituents are not useful for the ac/acc sequence. As is expected from these trends, the catechol-bearing zirconium alkyl **1j** is considerably less effective for the ac/acc reaction than its tetrachloro counterpart **1h**.

We have previously shown that the presumed azatitanetine intermediate derived by the treatment of **3g** with $CpTi(CH_3)_2Cl$ (**8**) could be efficiently trapped by propionitrile (**7**) at slightly elevated temperatures.[6c] In accord with this observation, sequential exposure of **3e** to **1a** (0 °C → ambient) followed by **9** (1 equiv, 60 °C, 4 weeks) provided **7k** in 84% isolated yield after quenching (HCl_{aq}) (Scheme 3).[12] The foregoing results are consistent with the intermediacy of an azatitanetine (i.e., **4**) in those reactions leading to efficient *C*-acylation. As we have previously noted for azatitanium intermediates derived from **8**,[6a] *N*-acylation is the preferred reaction mode when acyl chlorides are used as trapping reagents (Scheme 4).

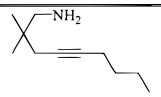
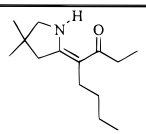
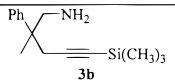
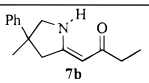
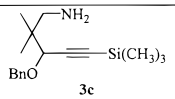
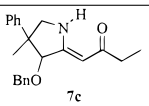
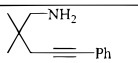
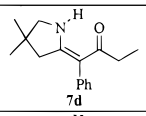
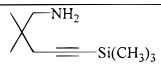
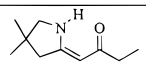
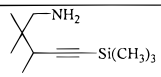
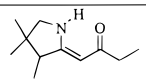
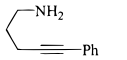
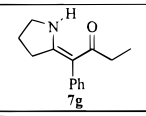
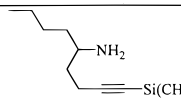
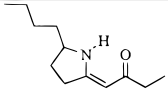
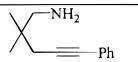
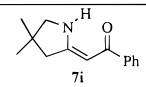
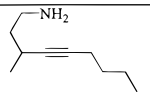
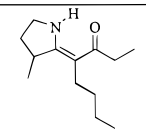
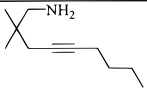
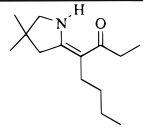
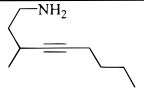
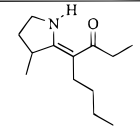
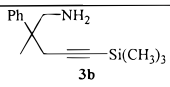
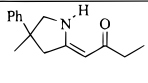
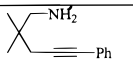
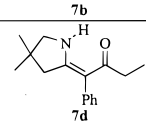
In summation, we have shown that simple, non-Cp-bearing organometallics of the type $(CH_3)_2TiL_1Cl{\cdot}2L_2$ (L_1 = Cl, **1a;** OTFE, **1b**) and the corresponding zirconium complexes **1d, 1e,** and **1h** are highly effective reagents for the aminoalkyne cyclization/acyl cyanide coupling

(10) For an additional example of transition metal modification by trifluoroethoxy ligand substitution, see: Ryter, K.; Livinghouse, T. *J. Am. Chem. Soc.* **1998**, *120*, 2658−2659.

(11) In consonance with these observations, a stoichiometric quantity of $CpTi(CH_3)Cl_2$ was found to promote the efficient cyclization of **5b**, leading to an azatitanium intermediate that failed to undergo clean *C*-acylation in the presence of propanoyl cyanide.

(12) In a control experiment, the attempted condensation of **3e** with **9** mediated by $TiCl_4{\cdot}$DME (**2**) (THF, 60 °C, 4 weeks) failed to produce observable quantities of **7k**.

Table 2. Aminoalkyne Cyclization/Acyl Cyanide Coupling Reactions Promoted by Non-Cp-Bearing Ti(IV) Complexes

Entry	Aminoalkyne	Ti(IV) complex	Vinylogous Amide	(%) Yield
1	 **3a**	1a	 **7a**	0[a]
2	 **3b**	1a	 **7b**	87
3	 **3c**	1a	 **7c**	73
4	 **3d**	1a	 **7d**	72
5	 **3e**	1a	 **7e**	83
6	 **3f**	1a	 **7f**	71
7	 **3g**	1a	 **7g**	83
8	 **3h**	1a	 **7h**	79
9	 **3d**	1a	 **7i**	62
10	 **3j**	1a	 **7j**	0
11	 **3a**	1b	 **7a**	71
12	 **3j**	1b	 **7j**	62
13	 **3b**	1c	 **7b**	0[b]
14	 **3d**	1c	 **7d**	0[b]

[a] Δ^1-Pyrrolines **5a** and **5j** (R^1 = *n*-C_4H_9, R^2 = CH_3, R^3 = R^4 = R^5 = H) were obtained as the exclusive products in 84% (isolated) and 89% (GC) yield, respectively. [b] Δ^1-Pyrrolines **5b** and **5d** (R^1 = Ph, R^2 = H, R^3 = R^4 = CH_3, R^5 = H) were obtained as the exclusive products in 93% (isolated) and 78% (GC) yield, respectively.

sequence. The active species **1a** and **1b** are highly economical to prepare, and their use typically results in superior product conversion than observed for CpTi-$(CH_3)_2$Cl (**8**).[6a,d]

Experimental Section[13]

Dimethyltitanium Dichloride (1a) or Dimethylzirconium Dichloride (1d) Complex in THF. A flame-dried 5 mL test tube equipped with a magnetic Teflon-coated spinvane was charged with $TiCl_4$·DME (**2**) (56 mg, 0.20 mmol) or $ZrCl_4$ (47 mg, 0.20 mmol) and fitted with a rubber septum. The test tube was purged with argon, and THF (2 mL) was subsequently added. The reaction mixture was cooled to 0 °C, and methyllithium (0.25 mL of 1.6 M in Et_2O, 0.40 mmol, 2.0 equiv) was added dropwise via syringe. The solution was stirred for 15 min at 0 °C to produce a homogeneous orange solution for the titanium complex and a clear homogeneous solution for the zirconium complex.

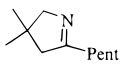
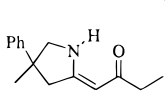
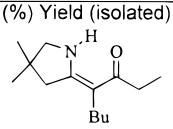
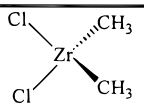
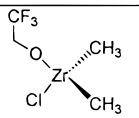
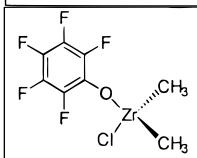
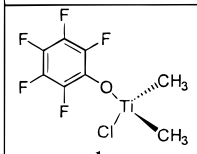
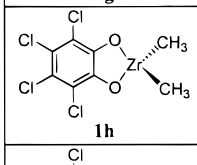
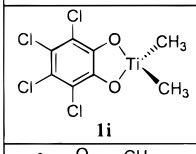
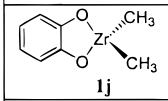
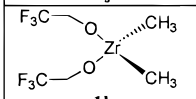
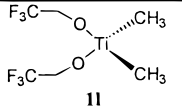
Dimethyl(trifluoroethoxy)titanium Chloride (1b) or Dimethyl(trifluoroethoxy)zirconium (1e) Chloride Complex in THF. A flame-dried 5 mL test tube equipped with a magnetic Teflon-coated spinvane was charged with $TiCl_4$·DME (**2**) (56 mg, 0.20 mmol) or $ZrCl_4$ (47 mg, 0.20 mmol) and fitted with a rubber septum. The test tube was purged with argon, and THF (2 mL) was subsequently added. The reaction mixture was cooled to 0 °C, and methyllithium (0.38 mL of 1.6 M in Et_2O, 0.60 mmol, 3.0 equiv) was added dropwise via syringe. The reaction mixture was stirred for 15 min at 0 °C followed by the addition of trifluoroethanol (20 mg, 0.20 mmol) dissolved in THF (1 mL) and stirred for an additional 15 min at 0 °C to produce a dark homogeneous solution for the titanium complex and a clear homogeneous solution for the zirconium complex.

2,2-Dimethylnon-4-ynylamine (3a). A 50 mL flame-dried round-bottomed flask equipped with a Teflon-coated magnetic stirring bar was charged with a suspension of lithium aluminum hydride (0.23 g, 6.1 mmol) in Et_2O (25 mL) and fitted with a rubber septum. The suspension was cooled to 0 °C and treated with 2,2-dimethylnon-4-yne nitrile (1.0 g, 6.1 mmol) dropwise over a 5 min period. Once the addition was complete, the reaction mixture was warmed to ambient temperature and stirred for an additional 8 h. The reaction mixture was cooled to 0 °C, and a saturated ammonium chloride solution (5 mL) was added to quench the unreacted lithium aluminum hydride, followed by the addition of Et_2O (20 mL). The organic phase was decanted from the aluminum salts, washed with brine, dried over magnesium sulfate, filtered, and concentrated under reduced pressure to give the crude product as a yellow oil. The crude product was subjected to flash chromatography on silica gel (5% EtOAc/hexane, then 15% MeOH/CH_2Cl_2 for elution) to furnish the title amine (1.0 g, 97%) as a clear yellow liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.47 (s, 2H, $-CH_2NH_2$), 2.08 (m, 2H, $-CH_2C{\equiv}C-$), 1.98 (t, 2H, J = 1.9 Hz, CCH_2CH_2), 1.43 (m, 4H, $-CH_2CH_2-$), 1.2 (bs, 2H, CH_2NH_2), 0.84 (s, 9H, $-Si(CH_3)_2$. ^{13}C NMR (75 MHz, $CDCl_3$): δ 81.82, 77.48, 52.19, 35.74, 31.21, 29.51, 24.49, 21.80, 18.22, 13.39. IR (film): 2959, 2932, 1579, 1466, 1402, 1332, 1011 (cm^{-1}).

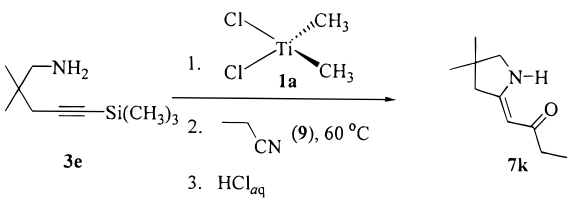
2-Methyl-2-phenyl-5-(trimethylsilyl)pent-4-ynylamine (3b). Subjecting 2-methyl-2-phenyl-5-(trimethylsilyl)-pent-4-yne nitrile (5.0 g, 21 mmol) and lithium aluminum hydride (0.79 g, 21 mmol) to the general procedure described for **3a** provided the title amine (3.7 g, 73%) as a yellow liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.34 (m, 4H, Ar*H*), 7.18 (m, 1H, Ar*H*), 3.07 (d, 1H, J = 13.2 Hz, $-CHHNH_2$), 2.86 (d, 1H, J = 13.2 Hz, $-CHHNH_2$), 2.62 (d, 1H, J = 16.7 Hz, $-CHHC{\equiv}$

(13) General experimental details may be found in ref 14.
(14) Lee, C. H.; Westling, M.; Livinghouse, T.; Williams, A. C. *J. Am. Chem. Soc.* **1992**, *114*, 4089.

Table 3. Aminoalkyne Cyclization/Acyl Cyanide Coupling Reactions Promoted by Alternative Non-Cp-Bearing Ti(IV) and Zr(IV) Complexes

Metal Complex	(%) Yield (GC)  **5b**	(%) Yield (GC)  **5a**	(%) Yield (isolated)  **7b**	(%) Yield (isolated)  **7a**
 **1d**	97%	98%	89%	81%
 **1e**	-	96%	-	59%
 **1f**	ND	92%	61%	44%
 **1g**	97%	91%	61%	0%
 **1h**	ND	94%	80%	61%
 **1i**	95%	100%	74%	0%
 **1j**	98%	96%	63%	22%
 **1k**	ND	92%	66%	36%
 **1l**	0%	0%	0%	0%

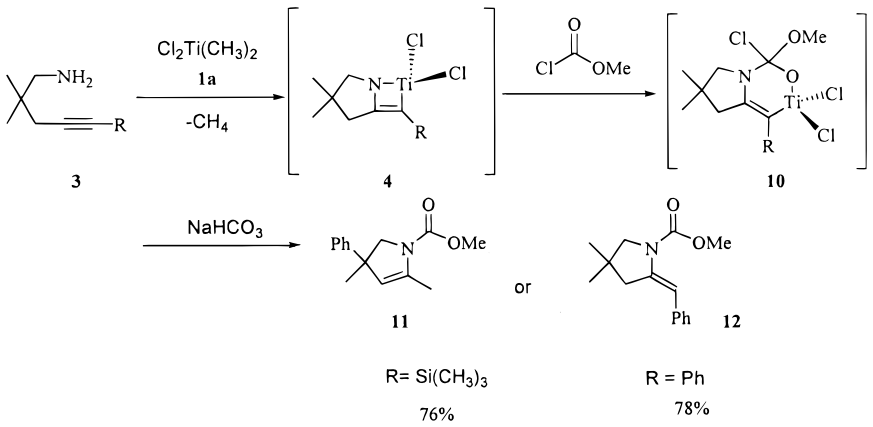
Scheme 3



$CSi(CH_3)_3$), 2.48 (d, 1H, J = 16.7 Hz, $-CHHC{\equiv}CSi(CH_3)_3$), 1.34 (s, 3H, $-CH_3$), 1.09 (s, 2H, $-NH_2$), 0.68 (s, 9H, $-Si(CH_3)_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 139.09, 128.77, 128.16, 125.68, 122.57, 100.35, 89.81, 41.65, 34.02, 25.51, −0.23. IR (film): 3088, 3059, 3025, 2959, 2173, 1249, 1026, 842 (cm^{-1}).

3-Hydroxy-2,2-dimethylpent-4-ynylnitrile. A 100 mL flame-dried round-bottomed flask equipped with rubber septum and a Teflon-coated magnetic stirring bar was charged with a solution of LDA (prepared from diisopropylamine (2.97, 0.03 mol) and *n*-BuLi (17.61 mL of 1.59 M in hexane, 0.03 mol)) in THF. The solution was cooled to 0 °C and treated with isopropylnitrile (1.94 g, 0.03 mol). The reaction mixture was stirred at 0 °C for 30 min and cooled to −78 °C, whereupon 3-(trimethylsilyl)-2-propyn-1-al (7.5 g, 0.03 mol) in THF (50 mL) was added dropwise over a 10 min period. The reaction mixture was stirred for 3 h at −78 °C and then slowly warmed to ambient temperature over a 2 h period. The solution was cooled to 0 °C, a saturated ammonium chloride solution (25 mL) was added, and the mixture was stirred for an additional

Scheme 4



30 min. The reaction mixture was extracted with Et_2O (3 × 25 mL), and the combined organic extracts were washed with brine, dried over magnesium sulfate, and concentrated. The residue was dissolved in methanol (10 mL) and treated with a 5% NaOH/MeOH solution (5 mL). After stirring for 30 min the solution was concentrated, triturated with Et_2O (10 mL), and filtered through a pad of basic alumina. The filtrate was concentrated, and the residue was subjected to flash chromatography on silica gel (20% ethyl acetate/hexane for elution) to furnish the title nitrile (3.14 g, 88%) as a clear liquid. ^{1}H NMR (250 MHz, $CDCl_3$): δ 4.24 (s, 1H, C*H*OH), 2.92 (bs, 1H, −O*H*), 2.56 (s, 1H, −C≡C*H*), 1.44 (s, 6H, −C(C*H*$_3$)$_2$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 119.5, 85.1, 75.2, 68.6, 34.8, 16.0. IR (film): 3412, 3273, 2983, 2245, 2124 (cm^{-1}).

3-Benzyloxy-2,2-dimethylpent-4-ynylnitrile. A 50 mL flame-dried round-bottomed flask equipped with a Teflon-coated magnetic stirring bar was charged with a suspension of NaH (0.65 g, 16.10 mmol) in THF (20 mL) and fitted with a rubber septum. The reaction mixture was cooled to 0 °C and treated with 3-hydroxy-2,2-dimethylpent-4-ynylnitrile (1.0 g, 8.12 mmol) dissolved in THF (5 mL) over a 10 min period. Once the addition was complete, the reaction mixture was stirred for 2 h at ambient temperature and then treated with benzyl bromide (2.78 g, 16.24 mmol). After stirring for 12 h, a saturated K_2CO_3 solution (5 mL) was added, and the mixture was extracted with Et_2O (3 × 25 mL). The combined organic extracts were washed with brine, dried over magnesium sulfate, and concentrated. The residue was subjected to flash chromatography on silica gel (20% ethyl acetate/hexane for elution) to furnish the title compound (1.19 g, 69%) as a clear liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.34 (m, 5H, Ar *H*), 4.90 (d, 1H, J = 12.0 Hz, ArC*H*HO), 4.86 (d, 1H, J = 12.0 Hz, ArCH*H*O), 3.98 (d, 1H, J = 2.1 Hz, BnOC*H*C═), 2.59 (d, 1H, J = 2.1 Hz, −C═C*H*), 1.43 (s, 3H, −C(C*H*$_3$)(CH$_3$)), 1.41 (s, 3H, −C(CH$_3$)(C*H*$_3$)). ^{13}C NMR (75 MHz, $CDCl_3$): δ 137.1, 128.9, 128.5, 128.4, 123.4, 78.4, 73.2, 71.5, 38.1, 23.6, 22.7. IR (film): 3280, 2975, 2855, 2234, 2114 (cm^{-1}).

3-Benzyloxy-2,2-dimethyl-5-(trimethylsilyl)pent-4-ynylnitrile. A 50 mL flame-dried round-bottomed flask equipped with a rubber septum and a Teflon-coated magnetic stirring bar was charged with a solution of LDA (prepared from diisopropylamine (0.47 g, 4.69 mol) and *n*-BuLi (2.95 mL of 1.59 M in hexane, 4.69 mmol)) in THF (20 mL). The solution was cooled to 0 °C, and 3-benzyloxy-2,2-dimethylpent-4-ynylnitrile (1.20 g, 4.69 mmol) was added dropwise over a 10 min period. The reaction mixture was stirred at 0 °C for 1 h and cooled to −78 °C, whereupon chlorotrimethylsilane (0.54 g, 5.00 mmol) in THF (5 mL) was added. The reaction mixture was stirred for 3 h at −78 °C and then slowly warmed to ambient temperature over a 2 h period. The mixture was cooled to 0 °C, and a saturated ammonium chloride solution (25 mL) was added with subsequent stirring for an additional 30 min. The reaction mixture was extracted with Et_2O (3 × 25 mL), and the combined organic extracts were washed with brine, dried over magnesium sulfate, and concentrated to give a yellow oil. The residue was subjected to flash chromatography on silica gel (20% ethyl acetate/hexane for elution) to furnish the title compound as a colorless oil (1.31 g, 98%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.36 (m, 5H, Ar *H*), 4.87 (d, 1H, J = 12.0 Hz, ArC*H*HO), 4.57 (d, 1H, J = 12.0 Hz, ArCH*H*O), 3.97 (s, 1H, BnOC*H*C═), 1.41 (s, 3H, −C(C*H*$_3$)(CH$_3$)), 1.39 (s, 3H, −C(CH$_3$)(C*H*$_3$)), 0.19 (s, 9H, Si(C*H*$_3$)$_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 137.6, 128.8, 128.3, 127.8, 122.9, 10.7, 94.4, 74.2, 71.5, 37.9, 23.2, 22.5, −0.1. IR (film): 2959, 2239, 2173 (cm^{-1}).

3-Benzyloxy-2,2-dimethyl-5-(trimethylsilyl)pent-4-ynylamine (3c). Subjecting 3-benzyloxy-2,2-dimethyl-5-(trimethylsilyl)pent-4-ynenitrile (0.80 g, 2.8 mmol) and lithium aluminum hydride (0.11 g, 2.8 mmol) to the general procedure described for **3a** provided the title amine (0.72 g, 69%) as a viscous colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.36−7.29 (m, 5H, Ar *H*), 4.82 (d, 1H, J = 11.9 Hz, OC*H*HPh), 4.45 (d, 1H, J = 11.9 Hz, OCH*H*Ph), 3.84 (s, 1H, C*H*OCH$_2$Ph) 2.67 (d, 1H, J = 13.3 Hz, CH*H*NH$_2$), 2.57 (d, 1H, J = 13.3 Hz, C*H*HNH$_2$), 1.41 (bs, 2H, −N*H*$_2$), 0.95 (s, 3H, C(C*H*$_3$)(CH$_3$)), 0.92 (s, 3H, C(CH$_3$)(C*H*$_3$)), 0.18 (s, 9H, Si(CH$_3$)$_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 11.04, 85.24, 51.02, 37.16, 33.51, 22.20, 21.63, 15.25, 0.53, 0.18. IR (film): 3396, 3064, 2957, 2887, 2167, 1652, 1608, 1496, 1454, 1386, 1249, 1069, 840, 759, 697 (cm^{-1}).

2,2-Dimethyl-5-phenyl-4-pentynylamine (3d). Subjecting 5-phenyl-2,2-dimethyl-5-phenylpent-4-ynenitrile (1.0 g, 5.5 mmol) and lithium aluminum hydride (0.21 g, 5.5 mmol) to the general procedure described for **3a** provided the title amine (0.87 g, 84%) as clear yellow liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.37 (m, 2H, Ar*H*), 7.15 (m, 3H, Ar*H*), 2.60 (s, 2H, −C*H*$_2$NH$_2$), 2.31 (s, 2H, C*H*$_2$C≡CPh), 1.37 (bs, 2H, −NH$_2$), 0.99 (s, 6H, −C(C*H*$_3$)$_2$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 131.95, 128.59, 127.96, 126.4, 52.49, 35.96, 30.45, 25.11. IR (film): 3280, 3067, 2953, 2859, 1599, 1575, 750, 681 (cm^{-1}).

2,2-Dimethyl-5-(trimethylsilyl)pent-4-ynylamine (3e). Subjecting 2,2-dimethyl-5-(trimethylsilyl)pent-4-ynenitrile (0.41 g, 3.0 mmol) and lithium aluminum hydride (0.11 g, 3.0 mmol) to the general procedure described for **3a** provided the title amine (0.36 g, 76%) as a yellow liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.48 (s, 2H, −C*H*$_2$NH$_2$), 2.05 (s, 2H, −C*H*$_2$C≡C), 1.31 (bs, 2H, −CH$_2$N*H*$_2$), 0.86 (s, 6H, C(CH$_3$)$_2$), 0.08 (s, 9H, −C≡CSi(C*H*$_3$)$_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 105.0, 86.2, 51.8, 30.4, 25.2, 24.4, 0.0. IR (film): 2959, 2173, 1579, 1469, 1249, 1038, 842 (cm^{-1}).

2,2,3-Trimethyl-5-(trimethylsilyl)pent-4-ynylamine (3f). Subjecting 3,2,2-trimethyl-5-(trimethylsilyl)pent-4-ynenitrile (0.84 g, 4.3 mmol) and lithium aluminum hydride (0.17 g, 4.3 mmol) to the general procedure described for **3a** provided the title amine (0.74 g, 87%) as a viscous colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.65 (d, 1H, J = 12.8 Hz, C*H*HNH$_2$), 2.56 (q, 1H, J = 7.1 Hz, C*H*CH$_3$), 2.45 (d, 1H, J = 12.8 Hz, CH*H*NH$_2$), 1.10 (d, 3H, J = 7.1 Hz, CHC*H*$_3$), 0.97 (s, 3H,

C(CH_3)(CH_3)), 0.95 (bs, 2H, $-NH_2$), 0.85 (s, 3H, C(CH_3)(CH_3)), 0.24 (s, 9H, Si(CH_3)$_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 111.04, 85.24, 51.02, 37.16, 33.51, 22.20, 21.63, 15.25, 0.53, 0.18. IR (film): 2963, 2203, 1599, 1461, 1252, 1049, 1038, 854, 751, 694 (cm^{-1}).

5-Phenylpent-4-ynylamine (3 g). A 50 mL flame-dried round-bottomed flask equipped with a Teflon-coated magnetic stirring bar was charged with a suspension of potassium phthalimide (1.4 g, 7.4 mmol) in dimethylformamide (25 mL) and fitted with a rubber septum. The reaction mixture was treated with 1-iodo-5-phenyl-4-pentyne (2.0 g, 7.4 mmol) and heated at 60 °C with stirring for 12 h. Dimethylformamide was removed under reduced pressure, and the resulting residue was triturated with 10% aqueous potassium hydroxide (2 × 25 mL) to afford a white solid after filtration (1.53 g, 71%). The white solid was dissolved in ethanol (100%, 25 mL) and treated with hydrazine monohydrate (0.27 g, 5.29 mmol). The reaction flask was fitted with a reflux condenser, and the solution was heated at reflux for 8 h, during which time a white solid precipitated. Upon cooling to ambient temperature, the solid was collected by filtration and washed several times with Et_2O (3 × 50 mL). The filtrate was concentrated under reduced pressure to give a cloudy oil, which was purified by bulb-to-bulb distillation (110 °C at 0.25 mmHg) to furnish the title compound (0.79 g, 64%) as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.35 (m, 2H, Ar*H*), 7.24 (m, 3H, Ar*H*), 2.83 (t, 2H, J = 6.80 Hz, $-NCH_2$), 2.45 (t, 2H, J = 7.0 Hz, $-CH_2C{\equiv}$CPh), 1.71 (m, 2H, $-CH_2CH_2CH_2$), 1.16 (bs, 2H, $-NH_2$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 131.55, 128.17, 127.53, 124.00, 89.61, 80.97, 41.36, 32.60, 16.88. IR (film): 3298, 3056, 2938, 2866, 2228, 1598, 1570, 1560, 1490, 1442, 756 (cm^{-1}).

1-Butyl-5-(trimethylsilyl)pent-4-ynylamine (3h). A 250 mL flame-dried round-bottomed flask equipped with a magnetic Teflon-coated stirring bar was charged with diisopropylamine (2.6 g, 20 mmol) dissolved in THF (100 mL) and fitted with a rubber septum. The mixture was cooled to 0 °C and treated with *n*-BuLi (10.4 mL of 2.21 M in hexane, 20 mmol) dropwise over a 5 min period. The reaction was cooled to −50 °C, and 9-(trimethylsilyl)non-8-yn-5-one-*O*−(tetrahydropyran-2-yl)oxime[6b] (3.0 g, 15 mmol) in THF (10 mL) was added and stirred for an additional 4 h. 3-(Trimethylsilyl)propargyl bromide (2.9 g, 15 mmol) was added, and the reaction mixture was allowed to warm to ambient temperature over a 5 h period. A solution of saturated aqueous ammonium chloride (50 mL) and Et_2O (50 mL) was successively added to the reaction mixture, which was stirred for an additional 20 min. The biphasic mixture was transferred to a separatory funnel, and the phases were separated. The aqueous phase was re-extracted with Et_2O (2 × 50 mL), and the combined organic extracts were washed with brine, dried over magnesium sulfate, filtered, and concentrated. The residue was dissolved in Et_2O (50 mL) and added via cannula to a suspension of lithium aluminum hydride (0.56 g, 7.8 mmol) in Et_2O (50 mL) at −78 °C. Once the addition was complete, the reaction mixture was allowed to warm to ambient temperature and stirred for an additional 8 h. The reaction mixture was cooled to 0 °C, and a solution of saturated ammonium chloride (NH_4-Cl) was added to quench the unreacted lithium aluminum hydride, followed by the addition of Et_2O (50 mL). The organic phase was decanted from the aluminum salts, washed with brine, dried over magnesium sulfate, filtered, and concentrated under reduced pressure to give the crude product as a yellow oil. The crude product was subjected to flash chromatography on silica gel (5% EtOAc/hexane, then 15% MeOH/CH_2Cl_2 for elution) to furnish the title amine (1.0 g, 77%) as a clear yellow liquid. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.57 (m, 1H, CH_2CHNH_2), 2.26 (t, J = 7.2 Hz, 2H, $CH_2C{\equiv}C-$), 1.72 (bs, 2H, $-NH_2$), 1.35−1.72 (m, 8H, 4-CH_2), 0.87 (m, 3H, CH_2CH_3), 1.41 (s, 9H, Si(CH_3)$_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 107.11, 84.70, 50.39, 37.53, 36.52, 32.36, 28.15, 22.63, 22.06, 16.78, 13.90, 0.14. IR (neat): 3320, 3285, 2959, 2861, 2173, 1590, 1460, 1370, 825 cm^{-1}.

3,3-Dimethyl-5-pentyl-3,4-dihydro-2*H*-pyrrole (5a).[6a] Subjecting **3a** (38 mg, 0.20 mmol) to the general procedure for **5b** provided the title compound (36 mg, 84%) as a yellow oil with no additional purification required. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.49 (s, 2H, $=NCH_2$), 2.26 (t, 2H, J = 1.5 Hz, $=CCH_2CH_3$), 2.21 (s, 2H, $=CCH_2C$), 1.51 (m, 2H, $CH_2CH_2CH_2$), 1.31 (m, 4H, $CH_2CH_2CH_2$), 1.02 (s, 6H, C(CH_3)$_2$), 0.83 (m, 3H, $-CH_2CH_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 178.13, 74.24, 52.26, 38.31, 34.70, 28.08, 26.00, 22.43, 13.92. IR (film): 2956, 2926, 28.56, 1651, 1576, 1463, 1256 cm^{-1}.

3-Methyl-3-phenyl-3,4-dihydro-2*H*-pyrrole (5b).[6a] A flame-dried 5 mL test tube with a magnetic Teflon-coated spinvane was charged with $TiCl_4$·DME (**2**) (56 mg, 0.20 mmol) and fitted with a rubber septum. The test tube was purged with argon, and THF (2 mL) was subsequently added. The solution was cooled to 0 °C, and methyllithium (0.27 mL of 1.5 M in Et_2O, 0.40 mmol, 2.0 equiv) was added dropwise via syringe. Once the addition was complete, the reaction mixture was stirred for 30 min at 0 °C and then treated with 2-methyl-2-phenyl-5-(trimethylsilyl)pent-4-ynylamine (**3b**) (49 mg, 0.20 mmol). The test tube was wrapped in aluminum foil and allowed to warm to ambient temperature and stirred for 3 h. A 5% sodium hydroxide/methanol solution (1 mL) was added to the reaction mixture, which was stirred for an additional 20 min. The reaction mixture was filtered through a small pad of silica gel (Et_2O for elution) and concentrated in vacuo to provide the title compound as a yellow oil (32 mg, 93%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.33 (m, 3H, Ar*H*), 7.21 (m, 2H, Ar*H*), 3.97 (s, 2H, $=NCH_2$), 2.90 (d, 1H, J = 16.9 Hz, $=CCHH$), 2.66 (d, 1H, J = 16.9 Hz, $=CCHH$), 2.06 (s, 3H, $=CCH_3$), 1.34 (s, 3H, $-CCH_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 174.71, 149.13, 128.87, 126.32, 126.22, 74.50, 53.83, 47.26, 30.30, 20.6. IR (neat): 2956, 2921, 2861, 1646, 1495, 1430, 1377, 1309, 1029, 762, 700 cm^{-1}.

4-Benzyloxy-3,3,5-trimethyl-3,4-dihydro-5-methyl-2*H*-pyrrole (5c). Subjecting **3c** (38 mg, 0.20 mmol) to the general procedure for **5b** provided the title compound (36 mg, 84%) as a yellow oil with no additional purification required. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.30 (m, 5H, Ar*H*), 4.74 (d, 1H, J = 11.7 Hz, PhC*H*HO), 4.59 (d, 1H, J = 11.7 Hz, PhCH*H*O), 3.94 (s, 1H, OC*H*C=), 3.51 (d, 1H, J = 10.1 Hz, $=NCHH$), 3.39 (d, 1H, J = 10.1 Hz, $NCHH-$), 1.99 (s, 3H, $=CCH_3$), 1.19 (s, 3H, C(CH_3)(CH_3)), 1.01 (s, 3H, C(CH_3)(CH_3)). ^{13}C NMR (75 MHz, $CDCl_3$): δ 176.15, 138.4, 128.86, 128.30, 128.24, 93.06, 73.99, 72.18, 26.97, 21.80, 18.24. IR (film): 3334, 2981, 2361, 1626, 1481, 1377, 1309, 754, 730 cm^{-1}. HRMS (CI): *m*/*z* 218.1534 (calculated for (M + 1) $C_{14}H_{20}NO$, 218.1544).

4-(4,4-Dimethyl-pyrrolidine-2-ylidene)octan-3-one (7a).[6a]
Method A. A flame-dried 5 mL test tube with a magnetic Teflon-coated spinvane was charged with $TiCl_4$·DME (**2**) (56 mg, 0.20 mmol) and fitted with a rubber septum. The test tube was purged with argon, and THF (2.0 mL) was subsequently added. The reaction mixture was cooled to 0 °C and treated with methyllithium (0.40 mL of 1.5 M in Et_2O, 0.60 mmol, 3.0 equiv) dropwise over a 2 min period. The reaction was stirred for 15 min at 0 °C followed by the addition of 2,2,2-trifluoroethanol (20 mg, 0.20 mmol) and was subsequently stirred for an additional 15 min at 0 °C. 2,2-Dimethylnon-4-ynylamine (**3a**) (34 mg, 0.20 mmol) was added, and the test tube was wrapped in aluminum foil and allowed to warm to ambient temperature with stirring for an additional 3 h. The reaction mixture was cooled to 0 °C and treated with propanoylnitrile (17 mg, 0.20 mmol). The reaction mixture was allowed to warm to ambient temperature and stirred for 72 h. Methanol (1.0 mL) was added, and the reaction mixture was stirred for 20 min. The solution was filtered through a pad of silica gel (Et_2O for elution) and concentrated in vacuo. The residue was subjected to column chromatography (30% ethyl acetate/

hexane for elution) to provide the title compound as a slightly yellow oil (32 mg, 71%).

Method B. Subjecting **3a** (38 mg, 0.20 mmol) to the general procedure for **7a** [except $ZrCl_4$ (76 mg, 0.2 mmol) was used instead of $TiCl_4$·DME (**2**)] provided the title compound as a slightly yellow oil (37 mg, 81%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 10.21 (bs, 1H, −N*H*), 3.25 (s, 2H, −NCH_2), 2.41 (s, 2H, =CCH_2), 2.39 (q, 2H, J = 7.4 Hz, −OCCH_2CH$_3$), 2.11 (t, 2H, J = 7.5 Hz, =C−CH_2CH$_2$−), 1.29 (m, 4H, −CH_2CH_2−), 1.12 (s, 6H, C(CH_3)$_2$), 1.07 (t, 3H, J = 7.4 Hz, −OCCH$_2$CH_3), 0.89 (t, 3H, J = 6.7 Hz, −CH$_2$CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 199.00, 166.44, 101.71, 60.54, 46.37, 36.90, 34.55, 31.42, 29.09, 27.48, 23.21, 14.42, 10.01. IR (film): 2957, 2929, 2870, 1617, 1539, 1180 cm^{-1}.

1-(4-Methyl-4-phenyl-pyrrolidine-2-ylidene)butane-2-one (7b).[6a] A flame-dried 5 mL test tube equipped with a Teflon-coated magnetic spinvane was charged with $TiCl_4$·DME (**2**) (56 mg, 0.20 mmol) and fitted with a rubber septum. The test tube was purged with argon, and THF (2.0 mL) was subsequently added. The reaction mixture was cooled to 0 °C and treated with methyllithium (0.27 mL of 1.5 M in Et_2O, 0.40 mmol, 2.0 equiv) to give an orange, homogeneous solution. The reaction mixture was stirred for 30 min at 0 °C and treated with 2-methyl-2-phenyl-5-(trimethylsilyl)pent-4-ynylamine (49 mg, 0.20 mmol). The test tube was wrapped in aluminum foil and allowed to warm to ambient temperature with vigorous stirring for 3 h. The reaction mixture was cooled to 0 °C and treated with propanoyl nitrile (17 mg, 0.20 mmol). The reaction mixture was allowed to warm to ambient temperature and stirred for 72 h. Methanol (1.0 mL) was added, and the reaction mixture was stirred for an additional 20 min, filtered through a pad of silica gel (Et_2O for elution), and concentrated in vacuo. The residue was subjected to column chromatography (30% ethyl acetate/hexane for elution) to provide the title compound as a slightly yellow oil (40 mg, 87%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 9.72 (bs, 1H, −N*H*), 7.35−7.29 (m, 2H, Ar*H*), 7.25−7.18 (m, 3H, Ar*H*), 5.16 (s, 1H, C=C*H*), 3.81 (d, 1H, J = 10.4 Hz, −NC*H*H), 3.66 (d, 1H, J = 10.4 Hz, −NCH*H*), 3.01 (d, 1H, J = 16.1 Hz, =CC*H*H), 2.69 (d, 1H, J = 16.1 Hz, =CCH*H*), 2.31 (q, 2H, J = 7.5 Hz, −CH_2CH$_3$), 1.4 (s, 3H, −CH_3), 1.09 (t, 3H, J = 7.5 Hz, −CH$_2$CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 199.82, 166.63, 146.93, 129.08, 126.96, 126.02, 89.83, 59.79, 46.28, 44.78, 35.16, 29.40, 10.51. IR (film): 3310, 2964, 2931, 1627, 1557, 1225, 1017 cm^{-1}.

1-(3-Benzyloxy-4,4-dimethyl-pyrrolidin-2-ylidene)-butan-2-one (7c). Subjecting **3c** (232 mg, 0.800 mmol)) to the general procedure for **7b** provided the title compound as a white solid (160 mg, 73%) after the crude material was subjected to flash chromatography (20% ethyl acetate/hexane for elution). Mp: 110−112 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 9.28 (bs, 1H, −N*H*), 7.35 (m, 5H, Ar *H*), 5.20 (s, 1H, =C*H*CO−), 4.74 (d, 1H, J = 11.8 Hz, PhC*H*HO−), 4.64 (d, 1H, J = 11.8 Hz, PhCH*H*O−), 3.88 (s, 1H, OCHC=), 3.31 (d, 1H, J = 10.5 Hz, C*H*HNH), 3.17 (d, 1H, J = 10.5 Hz, CH*H*NH), 2.36 (q, 2H, J = 7.6 Hz, COCH_2CH$_3$), 1.09 (t, 3H, J = 7.6 Hz, OCCH$_2$CH_3), 1.15 (s, 3H, C(CH_3)CH$_3$), 1.07 (s, 3H, C(CH$_3$)-CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 209.47, 165.14, 138.25, 128.84, 128.25, 90.23, 87.59, 73.48, 58.13, 41.80, 35.44, 25.45, 20.37, 10.29, −0.84. IR (KBr): 3308, 2960, 1635, 1567, 1497, 1457, 1343, 1284, 1218, 1128, 1026 cm^{-1}. HRMS (EI): *m*/*z* 273.1733 (calculated for $C_{17}H_{23}NO_2$, 273.1729).

1-(4,4-Dimethylpyrrolidine-2-ylidene)-1-phenylbutane-2-one (7d).[6a] Subjecting **3d** (38 mg, 0.20 mmol) to the general procedure for **7b** provided the title compound as a white crystalline solid (35 mg, 72%) after the crude material was subjected to flash chromatography (30% ethyl acetate/hexane for elution). Mp: 82−84 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 10.13 (bs, 1H, −N*H*), 7.33−7.22 (m, 3H, Ar*H*), 7.15−7.12 (m, 2H, Ar*H*), 3.34 (s, 2H, −NCH_2), 2.11 (s, 2H, =CCH_2), 2.09 (q, 2H, J = 7.5 Hz, OCCH_2CH$_3$), 1.06 (s, 6H, C(CH_3)$_2$), 0.96 (t, 3H, J = 7.5 Hz, OCCH$_2$CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 198.34, 166.66, 140.54, 132.30, 128.73, 126.75, 106.57, 60.94, 47.59, 36.98, 33.16, 27.28, 9.92. IR (KBr): 3446, 2958, 2869, 2364, 2344, 1632, 1567, 1459, 1420, 1185, 1019 cm^{-1}.

1-(4,4-Dimethylpyrrolidine-2-ylidene)butane-2-one (7e).[6a] Subjecting **3e** (37 mg, 0.20 mmol) to the general procedure for **7b** provided the title compound as a yellow oil (28 mg, 83%) after the crude material was subjected to flash chromatography (20% ethyl acetate/hexane for elution). ^{1}H NMR (300 MHz, C_6D_6): δ 9.62 (bs, 1H, −N*H*), 5.03 (s, 1H, C=C*H*), 3.26 (bs, 2H, −CH_2N−), 2.34 (s, 2H, C=CH_2), 2.25 (q, 2H, J = 7.6 Hz, OCCH_2CH$_3$) 1.12 (s, 3H, C(CH_3)(CH$_3$)), 1.11 (s, 3H, C(CH$_3$)(CH_3)), 1.08 (t, 3H, J = 7.6 Hz, OCCH$_2$CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 199.1, 167.1, 89.1, 60.2, 47.0, 36.7, 34.7, 26.8, 10.1. IR (film): 2959, 2931, 2870, 1624, 1560, 1502, 1465 cm^{-1}.

1-(3,4,4-Trimethylpyrrolidine-2-ylidene)butane-2-one (7f). Subjecting **3f** (118 mg, 0.600 mmol) to the general procedure for **7b** provided the title compound as a white solid (77.0 mg, 71%) after the crude material was subjected to flash chromatography (20% ethyl acetate/hexane for elution). Mp: 81−83 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 9.55 (bs, 1H, −N*H*), 4.99 (s, 1H, C=C*H*), 3.21 (bs, 2H, −CH_2N−), 2.37 (q, 1H, J = 7.2 Hz, CH$_3$C*H*−), 2.29 (q, 2H, J = 7.6 Hz, OCCH_2CH$_3$), 1.09 (s, 3H, C(CH_3)(CH$_3$)), 1.09 (t, 3H, J = 7.6 Hz, OCCH$_2$CH_3), 1.02 (d, 3H, J = 7.2 Hz, CH_3CH−), 0.89 (s, 3H, C(CH_3)(CH$_3$)). ^{13}C NMR (75 MHz, $CDCl_3$): δ 199.90, 171.45, 88.38, 59.45, 48.90, 35.28, 25.81, 21.56, 11.15, 10.57. IR (KBr): 3335, 2962, 2870, 1731, 1623, 1560, 1494, 1458, 1370, 1279, 1200, 1151, 1019 cm^{-1}. HRMS (EI): *m*/*z* 181.1462 (calculated for $C_{17}H_{23}$-NO_2, $C_{11}H_{19}NO$, 181.1467).

1-(Pyrrolidine-2-ylidene)butane-1-phenyl-2-one (7g).[6a] Subjecting **3g** (32 mg, 0.20 mmol) to the general procedure for **7b** provided the title compound as a yellow oil (36 mg, 83%) after the crude material was subjected to flash chromatography (30% ethyl acetate/hexane for elution). ^{1}H NMR (300 MHz, $CDCl_3$): δ 10.45 (bs, 1H, −N*H*), 7.34−7.17 (m, 3H, Ar*H*), 7.16−7.14 (m, 2H, Ar*H*), 3.63 (t, 2H, J = 7.2 Hz, −NCH_2), 2.35 (t, 2H, J = 7.8 Hz, =CCH_2CH$_2$−), 2.13 (q, 2H, J = 7.4 Hz, OCCH_2-CH$_3$), 1.88 (q, 2H, J = 7.8 Hz, −CH$_2$CH_2CH$_2$−), 0.99 (t, 3H, J = 7.4 Hz, OCCH$_2$CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 197.74, 166.49, 140.27, 131.85, 128.30, 126.35, 105.7247.84, 32.62, 29.66, 21.40, 9.52. IR (film): 3277, 2925, 1615, 1538, 1198 cm^{-1}.

1-(5-Butyl-pyrrolidine-2-ylidene)butane-2-one (7h).[6a] Subjecting **3h** (42 mg, 0.20 mmol) to the general procedure (except the cyclization step required stirring for 24 h at ambient temperatures in order to complete cyclization) for **7b** provided the title compound as a yellow oil (31 mg, 79%) after the crude material was subjected to flash chromatography (20% ethyl acetate/hexane for elution). ^{1}H NMR (300 MHz, C_6D_6): δ 10.35 (bs, 1H, −N*H*), 5.14 (s, 1H, =C*H*CO−), 3.19 (m, 1H, −C*H*N−), 2.48 (q, 2H, J = 7.6 Hz, OCCH_2CH$_3$), 2.21 (m, 2H, CH_2C=), 1.36 (t, 3H, J = 7.6 Hz, OCCH$_2$CH_3), 1.13−1.04 (m, 8H, CH_2 pocket), 0.82 (t, 3H, J = 7.21 Hz, CH$_2$CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 198.14, 165.65, 88.86, 60.09, 36.10, 35.33, 31.84, 28.81, 28.01, 23.00, 14.24, 10.64. IR (film): 2960, 2933, 2871, 1621, 1934, 1180, 1015 cm^{-1}.

1-Phenyl-2-(4-methyl-4-phenyl-pyrrolidine-2-ylidene)-ethanone (7i). Subjecting **3b** (0.49 g, 2.0 mmol) to the general procedure for **6b** (except benzoyl nitrile was used as the trapping reagent) provided the title compound as a white solid (0.34 g, 62%) after the crude material was subjected to flash chromatography (20% ethyl acetate/hexane for elution). Mp: 64−66 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 10.45 (bs, 1H, −N*H*), 8.32 (m, 2H, Ar*H*), 7.33−7.07 (m, 6H, Ar*H*), 6.93 (m, 2H, Ar*H*), 5.96 (s, 1H, C=C*H*), 3.24 (d, 1H, J = 10.5 Hz, CHH_2NH), 2.96 (d, 1H, J = 10.5 Hz, CHH_2NH), 2.69 (d, 1H, J = 16.0 Hz, CC*H*HC=), 2.35 (d, 1H, J = 16.0 Hz, CCH*H*C=), 1.09 (s, 3H, CPh(CH_3)). ^{13}C NMR (75 MHz, $CDCl_3$): 188.35, 167.16, 147.08, 141.37, 130.85, 128.91, 128.63, 126.75, 126.01, 87.45, 59.45, 59.24, 46.28, 44.25, 28.69. IR (KBr): 3317, 2936, 2931, 1617,

1527, 1245, 1017, 754 cm^{-1}. HRMS (EI): *m/z* 277.1460 (calculated for $C_{14}H_{17}NO$, 277.1467).

4-(3-Methylpyrrolidine-2-ylidene)octan-3-one (7j).[6a] Subjecting 3-methylnon-4-ynylamine (26 mg, 0.17 mmol) to the general procedure for **7a** provided the title compound as a yellow oil (26 mg, 62%) after the crude material was subjected to flash chromatography (20% ethyl acetate/hexane for elution). ^{1}H NMR (300 MHz, $CDCl_3$): δ 10.42 (bs, 1H, −N*H*), 3.96 (m, 1H, −NC*H*), 2.67 (m, 2H, =CCH_2), 2.39 (q, 2H, J = 7.39 Hz, OCCH_2CH$_3$), 2.10 (m, 2H, =CCH_2CH$_2$−), 1.47 (m, 1H, −C*H*CH$_3$), 1.28 (m, 4H, −CH_2CH_2−), 1.21 (d, 3H, J = 6.3 Hz, −CHCH_3), 1.07 (t, 3H, J = 7.4 Hz, OCCH$_2$CH_3), 0.89 (t, 3H, J = 7.1 Hz, −CH$_2$CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 198.39, 165.39, 100.54, 55.44, 33.88, 31.13, 30.89, 29.72, 28.52, 22.80, 21.66, 13.90, 9.45. IR (film): 3246, 2961, 2931, 2871, 1616, 1535, 1187 cm^{-1}.

1-(4,4-Dimethylpyrrolidine-2-ylidene)-3-methylbutan-2-one (7k). A flame-dried 5 mL test tube with a screw top equipped with a Teflon-coated magnetic spinvane was charged with $TiCl_4$·DME (**2**) (56 mg, 0.20 mmol) and fitted with a rubber septum. The test tube was purged with argon, and THF (2 mL) was subsequently added. The reaction mixture was cooled to 0 °C, and methyllithium (0.27 mL of 1.5 M in Et_2O, 0.40 mmol, 2.0 equiv) was added dropwise via syringe. Once the addition was complete, the reaction mixture was stirred for 30 min at 0 °C. 2,2-Dimethyl-5-(trimethylsilyl)pent-4-ynylamine (**3b**) (37 mg, 0.20 mmol) was then added via syringe. The test tube was wrapped in aluminum foil and allowed to warm to ambient temperature with stirring for 3 h. The reaction mixture was cooled to 0 °C, and isobutyronitrile (10 mg, 0.20 mmol) was added dropwise via syringe. The rubber septum was replaced with a plastic screw cap, and the reaction mixture was heated at 60 °C for 4 weeks. Aqueous hydrochloric acid (20%, 1.0 mL) was added, and the resulting mixture was stirred an additional 4 h at 60 °C. The reaction mixture was cooled to ambient temperature, and Et_2O (2.0 mL) was added. The biphasic mixture was separated, and the aqueous phase was extracted with Et_2O (2 × 2.0 mL). The combined organic extracts were dried over magnesium sulfate, filtered, and concentrated in vacuo. The residue was subjected to column chromatography (20% ethyl acetate/hexane for elution) to provide the title compound as a slightly yellow oil (30 mg, 84%). Spectral data are identical with those of **7e**.

3,5-Dimethyl-3-phenyl-2,3-dihydropyrrole-1-carboxylic Acid Methyl Ester (11). A flame-dried 5 mL test tube with a Teflon-coated magnetic spinvane was charged with $TiCl_4$·DME (**2**) (56 mg, 0.20 mmol) and fitted with a rubber septum. The test tube was purged with argon, and THF (2.0 mL) was subsequently added. The reaction mixture was cooled to 0 °C and then treated with methyllithium (0.27 mL of 1.5 M in Et_2O, 0.40 mmol, 2.0 equiv) to give an orange, homogeneous solution. The reaction mixture was stirred for 30 min at 0 °C and then treated with 2-methyl-2-phenyl-5-(trimethylsilyl)pent-4-ynylamine (49 mg, 0.20 mmol). The test tube was wrapped in aluminum foil and allowed to warm to ambient temperature with vigorous stirring for 3 h. The reaction mixture was cooled to 0 °C and treated with methyl chloroformate (19 mg, 0.20 mmol). The reaction mixture was allowed to warm to ambient temperature and was stirred for 18 h. Methanol (10 μL) and hexane (2 mL) were added to the mixture, which was stirred for an additional 20 min, filtered through a pad of silica gel (Et_2O for elution), and concentrated in vacuo. The residue was subjected to column chromatography (10% ethyl acetate/hexane for elution) to provide the title compound as a slightly yellow oil (35 mg, 76%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.30−7.19 (m, 5H, Ar*H*), 4.95 (d, 1H, J = 1.3 Hz, C*H*=C), 3.88 (d, 1H, J = 11.2 Hz, NC*H*H), 3.85 (d, 1H, J = 11.2 Hz, NCH*H*), 3.67 (s, 3H, OCH_3), 2.18 (d, 3H, J = 1.3 Hz, CH=CCH_3), 1.46 (s, 3H, ArCCH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 153.9, 148.5, 129.1, 129.0, 128.8, 126.6, 126.2, 125.9, 116.7, 63.5, 52.5, 47.2, 35.4, 28.7, 15.9. IR (film) 2956, 2858, 1716, 1696, 1651 cm^{-1}. HRMS (EI): *m/z* 231. 1263 (calculated for $C_{14}H_{17}NO_2$, 231.1259).

2-Benzylidene-4,4-dimethylpyrrolidine-1-carboxylic Acid Methyl Ester (12). Subjecting 2,2-dimethyl-5-phenyl-4-pentynylamine (**3d**) (37 mg, 0.20 mmol) to the general procedure for **11** provided the title compound as a clear oil (38 mg, 78%) after the crude material was subjected to flash chromatography (20% ethyl acetate/hexane for elution). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.29−7.18 (m, 5H, Ar*H*), 7.11 (app t, 1H, J = 1.9 Ar−C*H*=), 3.76 (s, 3H, OCH_3), 3.39 (s, 2H, CH_2N), 2.58 (d, 2H, J = 1.9 Hz CH_2CH=), 1.06 (s, 6H, C(CH_3)$_2$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 154.5, 140.8, 139.1, 129.9, 128.6, 128.4, 127.5, 125.6, 110.1, 61.4, 52.8, 52.6, 45.0, 35.3, 26.6, 25.9. IR (film): 2948, 2871, 1722, 1713, 1645 cm^{-1}. HRMS (EI): *m/z* 245.1416 (calculated for $C_{15}H_{19}NO_2$, 245.1416).

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