Palladium-Catalyzed Cross-Coupling Syntheses of Benzotriazolyl Enynes and a General Route to Enynyl Ketones and Alkynyl Ketones

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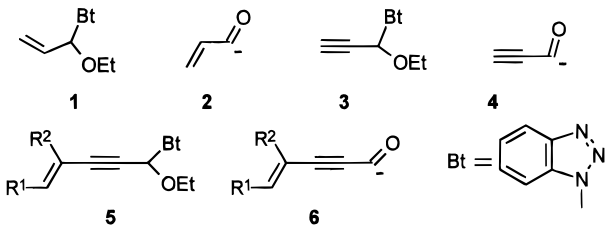
Received July 8, 1997[⊗]

A new general route to conjugated enynyl ketones was developed based on a two-step procedure. First, palladium-catalyzed cross-coupling reactions of 1-(benzotriazol-1-yl)propargyl ethyl ether (**3**) and vinyl triflates or vinyl bromides afforded the key intermediates [1-(benzotriazol-1-yl)-1-enynyl]-methyl ethyl ethers **5a**−**d** in good yields. Then reactions of compounds **5** with primary halides gave intermediates **8**, which were hydrolyzed by dilute acid to enynyl ketones **9a**−**g**. Similar palladium-catalyzed coupling reactions of **3** with various aryl iodides followed by an analogous sequence afforded aryl-substituted propargyl ethers **12a**−**d** and thence alkynyl ketones **13a**,**b**.

Introduction

Enynyl ketones are important intermediates in the syntheses of various natural products and their analogues.[1−4] Common routes to enynyl ketones are based on reactions of enynyl organometallic reagents (e.g., those of magnesium,[5,6] lithium,[3,7] copper,[8] and silicon[9]) with carboxylic acid chlorides, esters, or anhydrides. However, such reactions of enynyllithium or magnesium reagents with carboxylic acid derivatives are not always satisfactory.[5] Reactions between enynylsilanes and acid chlorides require 1 equiv of titanium tetrachloride as Lewis acid, and only two examples have been reported.[9] The cuprous-catalyzed reaction of acid chlorides and enynes can afford enynyl ketones in good yields in the presence of triethylamine as the base,[10] but this method is not applicable to primary acid chlorides, such as acetyl, propanoyl, and butanoyl chlorides, which react readily with triethylamine.[11] Other routes to enynyl ketones include oxidations of the corresponding alcohols by CrO_3,[5] PDC,[4] or Swern reagents[12] in moderate yields: the alcohols were prepared through the palladium-catalyzed coupling reactions between vinyl bromides and 3-hydroxyalkynylstannanes. However, all of the aforementioned preparations of enynyl ketones show some problems in the availability of starting materials and/or lack of generality. Recent work in this group has demonstrated that 1-benzotriazolyl-1-ethoxymethyl derivatives are useful acyl anion synthon equivalents for



the syntheses of various classes of ketones. For example, 1-(benzotriazol-1-yl)allyl ethyl ether (**1**)[13] and 1-(benzotriazol-1-yl)propargyl ethyl ether (**3**)[14] are useful equivalents for propenoyl anion **2** in the synthesis of vinyl ketones and propynoyl anion **4** in the preparation of alkynyl ketones, respectively. Now we report that this methodology can be extended to various 1-(benzotriazol-1-yl)-1-enynylmethyl ethyl ethers of general structure **5**, which provide general and versatile (enynyl)acyl anion synthon equivalents **6** for the synthesis of diverse enynyl ketones.

Results and Discussion

Palladium-Catalyzed Coupling Reactions between Vinyl Triflates or Bromides and 1-(Benzotriazol-1-yl)propargyl Ethyl Ether (3) for the Synthesis of Enynyl Benzotriazoles 5a−d and Enynyl Ketones 9a−g. Palladium−copper-catalyzed reactions of 1-alkynes and vinyl halides or vinyl triflates are commonly used to introduce enynyl groups in organic synthesis.[15,16] We have now coupled 1-(benzotriazol-1-yl)propargyl ethyl ether (**3**) with vinyl triflates and vinyl bromides for the synthesis of 1-(benzotriazol-1-yl)enynyl ethyl ethers **5**. Under the general palladium−copper-catalyzed conditions,[17,18] compound **3** reacted with 1-cy-

[⊗] Abstract published in *Advance ACS Abstracts,* October 15, 1997.

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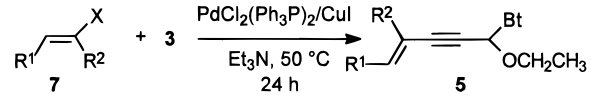
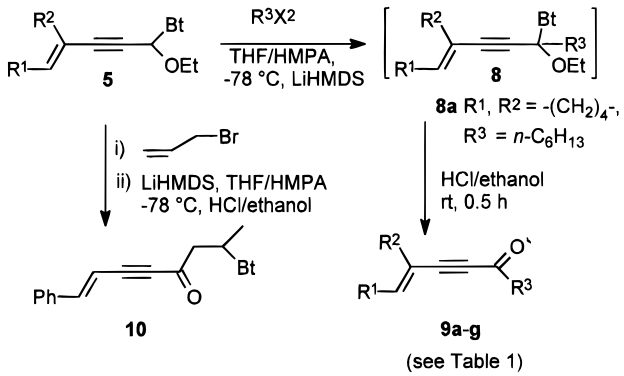
Scheme 1



7a R^1, R^2 = -$(CH_2)_4$-, X = OTf
7b R^1 = C_6H_5, R^2 = H, X = Br
7c R^1 = $(CH_3)_3Si$, R^2 = H, X = Br
7d R^1, R^2 = -$(CH_2)_3$-, X = OTf

5a R^1, R^2 = -$(CH_2)_4$-, 70%
5b R^1 = C_6H_5, R^2 = H, 75%
5c R^1 = $(CH_3)_3Si$, R^2 = H, 85%
5d R^1, R^2 = -$(CH_2)_3$-, 50%

Scheme 2



8a R^1, R^2 = -$(CH_2)_4$-, R^3 = *n*-C_6H_{13}

Table 1. Preparation of Enynyl Ketones

products	R^1	R^2	R^3	X^2	yield (%)
9a	$-(CH_2)_4-$		*n*-C_6H_{13}	Br	60
9b	C_6H_5	H	CH_3	I	42
9c	C_6H_5	H	CH_3CH_2	Br	50
9d	C_6H_5	H	*n*-C_4H_9	Br	60
9e	C_6H_5	H	*n*-$C_{10}H_{21}$	Br	50
9f	Me_3Si	H	$C_6H_5CH_2$	Cl	67
9g	Me_3Si	H	*n*-C_7H_{15}	Br	75

clohexenyl triflate (**7a**), *β*-bromostyrene (**7b**), (2-bromovinyl)trimethylsilane (**7c**), and 1-cyclopentenyl triflate (**7d**) to afford the desired products **5a**−**d**, respectively, in good yields (Scheme 1).

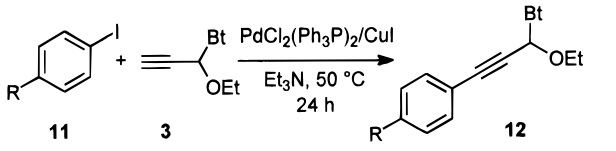
The reactions probably proceed through the commonly accepted mechanism.[11,17] However, as the benzotriazolyl group present in the substrate is a good coordinator, it affects the electronic and steric environment of palladium.

In the presence of lithium hexamethyldiazasilane as base, compounds **5** reacted with various primary halides as expected to introduce an alkyl group at the α-position to the benzotriazolyl group (e.g., **8a**, Scheme 2). Hydrolysis of **8a** under acidic conditions afforded the desired enynyl ketone **9a** in 60% overall yield (two steps from **5a**). Similarly, **9b**−**g** were prepared without the isolation of the alkylated intermediates (Table 1).

When allyl bromide was used as the electrophile, *β*-benzotriazolyl enynyl ketone **10** was isolated in 70% yield. This is due to the double-bond (from allyl bromide) migration from *β*,*γ* to α,*β* of the carbonyl group under acidic conditions and subsequent Michael addition of benzotriazole to the α,*β*-unsaturated ketone (Scheme 2).[19]

The use of lithium hexamethyldiazasilane and the one-step procedure now described were crucial for the present reactions. The stepwise procedure (lithiation of **5** with *n*-BuLi or *s*-BuLi followed by addition of the electrophile) of previous reports[13,14] failed for the present reactions. In comparison with the carbanions from 1-(benzotriazol-1-yl)allyl ethyl ether (**1**)[13] and 1-(benzotriazol-1-yl)propargyl ethyl ether (**3**),[14] the carbanions of compounds **5** appear to be less stable.

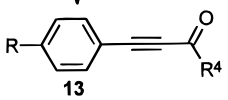
Scheme 3



11a R = H
11b R = CH_3
11c R = OCH_3
11d R = NO_2

12a R = H, 80%
12b R = CH_3, 85%
12c R = OCH_3, 80%
12d R = NO_2, 76%

i) *n*-BuLi, -78 °C
ii) CH_3I or *n*-$C_6H_{13}Br$
iii) HCl/ethanol



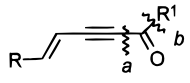
13a R = CH_3, R^4 = *n*-C_6H_{13}, 80%
13b R = OCH_3, R^4 = CH_3, 70%

Palladium-Catalyzed Coupling Reactions between Aryl Iodides and 1-(Benzotriazol-1-yl)propargyl Ethyl Ether (3) for the Synthesis of 1-(Benzotriazol-1-yl)-3-arylpropargyl Ethyl Ethers 12a−d and Alkynyl Ketones 13a,b. We previously reported that 3-substituted 1-(benzotriazol-1-yl)propargyl ethyl ether (**3**) can be prepared from the corresponding substituted propargyl aldehyde acetals, as useful synthons for the synthesis of various alkynyl ketones.[14] However, except for 3-phenylpropargyl aldehyde acetal, no aryl-substituted propargyl aldehyde acetal is commercially available. We have now developed a general route to 3-aryl-1-(benzotriazol-1-yl)propargyl ethyl ethers **12a**−**d** by palladium−copper-catalyzed coupling reactions of compound **3** with aryl halides. Both electron-rich and electron-deficient aryl iodides gave good yields (Scheme 3).

As expected based upon previous work on compound **12a**,[14] compound **12b**, after lithiation by *n*-BuLi, subsequent reaction with 1-bromohexane, and hydrolysis under acidic conditions, gave alkynyl ketone **13a** in 80% yield (Scheme 3). Similarly, compound **12c**, which bears an electron-donating group (4-methoxy), reacted with *n*-BuLi and iodomethane to afford alkynyl ketone **13b** in 70% yield after acid hydrolysis. Unlike the reactions of **5**, reactions of **12** can be run stepwise using *n*-BuLi as the base, apparently because their carbanion intermediates are more stable that those of lithiated **5**.

Conclusions

In conclusion, we developed a novel route for the synthesis of enynyl ketones **9**, utilizing palladium-catalyzed coupling reactions between 1-(benzotriazol-1-yl)propargyl ethyl ether (**3**) and vinyl bromides or vinyl triflates to give new enynyl acyl anion synthons **5** in moderate to good yields. It is noteworthy that whereas all previously reported routes to enynyl ketones were based on the formation of bond a, the present method is based on the formation of bond b in structure **14**.



14

We also explored the palladium-catalyzed coupling reaction of aryl iodides with compound **3**, which provides

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an alternative route to various aryl-substituted 1-(benzotriazol-1-yl)propargyl ethyl ethers **12**.

Experimental Section

General Comments. Melting points were measured on a hot-stage microscope and are uncorrected. ^{1}H and ^{13}C NMR data were collected on a 300 MHz NMR spectrometer (300 and 75 MHz, respectively) using $CDCl_3$ as solvent.

Compounds **3**[14] and **7a**,**d**[20] were prepared by the literature methods. All of the other starting materials were supplied by Aldrich Chemical Co. or Fisher and used without further purification.

General Procedure for the Preparation of Compounds 5 and 12. A mixture of vinyl triflates, vinyl halides, or aryl iodides (1.1 mmol), 1-(benzotriazol-1-yl)propargyl ethyl ether (**3**) (0.2 g, 1.0 mmol), $PdCl_2(PPh_3)_2$ (20 mg, 0.028 mmol), CuI (10 mg, 0.037 mmol), Et_3N (4 mL), and toluene (2 mL) was stirred at 50 °C for 1 day. After evaporation of the solvent under vacuum, the residue was dissolved in CH_2Cl_2 (40 mL) and sequentially washed with saturated Na_2CO_3 solution (5 mL) and saturated NH_4Cl solution (5 mL). The organic layer was dried over $MgSO_4$ and evaporated *in vacuo* to give a residue which was purified by column chromatography (eluent: hexane−ethyl acetate) to afford the desired product.

1-(Benzotriazol-1-yl)-3-(1-cyclohexenyl)propargyl ethyl ether (5a): colorless oil; ^{1}H NMR δ 1.15 (t, 3H, J = 6.9 Hz), 1.56−1.61 (m, 4H), 2.07−2.11 (m, 4H), 3.35−3.50 (m, 1H), 3.60−3.75 (m, 1H), 6.22 (s, 1H), 6.92 (s, 1H), 7.43 (t, 1H, J = 7.2 Hz), 7.53 (t, 1H, J = 7.2 Hz), 7.99 (d, 1H, J = 8.4 Hz), 8.08 (d, 1H, J = 8.7 Hz); ^{13}C NMR δ 14.5, 21.1, 21.9, 25.5, 28.4, 64.2, 78.8, 79.0, 90.0, 111.6, 119.0, 119.8, 124.2, 127.5, 131.2, 137.8, 146.7; MS *m*/*z* 281 (M^+, 75), 77 (100); HRMS (EI) calcd for $C_{17}H_{19}N_3O$ 281.1528, found 281.1525.

1-(Benzotriazol-1-yl)-1-ethoxy-5-phenyl-4-penten-2-yne (5b): colorless oil; ^{1}H NMR δ 1.18 (t, 3H, J = 6.9 Hz), 3.40−3.46 (m, 1H), 3.64−3.70 (m, 1H), 6.16 (dd, 1H, J = 1.5, 16.2 Hz), 6.98 (d, 1H, J = 1.2 Hz), 7.02 (d, 1H, J = 16.5 Hz), 7.26−7.38 (m, 5H), 7.43 (t, 1H, J = 7.8 Hz), 7.57 (t, 1H, J = 7.2 Hz), 7.99 (d, 1H, J = 8.4 Hz), 8.09 (d, 1H, J = 8.1 Hz); ^{13}C NMR δ 14.6, 64.4, 79.0, 82.9, 87.5, 105.8, 111.6, 120.0, 124.4, 126.5, 127.8, 128.7, 129.2, 131.2, 135.4, 144.1, 146.8. Anal. Calcd for $C_{19}H_{17}N_3O$: C, 75.21; H, 5.65; N, 13.86. Found: C, 74.92; H, 5.84; N, 13.87.

1-(Benzotriazol-1-yl)-1-ethoxy-5-(trimethylsilyl)-4-penten-2-yne (5c): colorless oil; ^{1}H NMR δ −0.01 (s, 9H), 1.07 (t, 3H, J = 7.2 Hz), 3.28−3.38 (m, 1H), 3.50−3.60 (m, 1H), 5.88 (d, 1H, J = 19.2 Hz), 6.57 (d, 1H, J = 19.2 Hz), 6.85 (s, 1H), 7.35 (t, 1H, J = 7.2 Hz), 7.45 (t, 1H, J = 7.2 Hz), 7.88 (d, 1H, J = 8.4 Hz), 8.99 (d, 1H, J = 8.1 Hz); ^{13}C NMR δ −1.9, 14.5, 64.3, 78.9, 81.4, 88.1, 111.5, 119.9, 121.2, 124.3, 127.7, 130.9, 146.7, 149.5; MS *m*/*z* 299 (M^+, 5), 181 (100). Anal. Calcd for $C_{16}H_{21}N_3OSi$: C, 64.18; H, 7.07; N, 14.04. Found: C, 64.06; H, 7.25; N, 14.01.

1-(Benzotriazol-1-yl)-3-(1-cyclopentenyl)propargyl ethyl ether (5d): colorless oil; ^{1}H NMR δ 1.16 (t, 3H, J = 6.6 Hz), 1.84−1.94 (m, 2H), 2.38−2.52 (m, 4H), 3.39−3.44 (m, 1H), 3.62−3.68 (m, 1H), 6.18 (d, 1H, J = 1.5 Hz), 6.94 (s, 1H), 7.41 (t, 1H, J = 7.2 Hz), 7.53 (t, 1H, J = 7.2 Hz), 7.98 (d, 1H, J = 8.4 Hz), 8.09 (d, 1H, J = 8.1 Hz); ^{13}C NMR δ 14.5, 23.1, 23.3, 35.8, 64.3, 78.9, 82.4, 85.8, 111.6, 119.9, 122.6, 124.3, 127.7, 131.2, 141.2, 146.7; HRMS (EI) calcd for $C_{16}H_{17}N_3O$ 267.1372, found 267.1372.

1-(Benzotriazol-1-yl)-3-phenylpropargyl ethyl ether (12a):[14] white solid, mp 69−70 °C (lit.[14] mp 69−70 °C); ^{1}H NMR 1.19 (t, 3H, J = 9.0 Hz), 3.40−3.50 (m, 1H), 3.65−3.75 (m, 1H), 7.04 (s, 1H), 7.30−7.50 (m, 6H), 7.54 (t, 1H, J = 7.1 Hz), 8.04 (d, 1H, J = 8.3 Hz), 8.09 (d, 1H, J = 8.3 Hz).

1-(Benzotriazol-1-yl)-3-(4-methylphenyl)propargyl ethyl ether (12b): colorless oil; ^{1}H NMR δ 1.19 (t, 3H, J = 6.8 Hz), 2.34 (s, 3H), 3.46−3.49 (m, 1H), 3.67−3.70 (m, 1H), 7.02 (s, 1H), 7.12 (d, 2H, J = 8.1 Hz), 7.35 (d, 2H, J = 7.8 Hz), 7.43 (t, 1H, J = 6.9 Hz), 7.55 (t, 1H, J = 7.5 Hz), 8.04 (d, 1H, J = 8.4 Hz), 8.10 (d, 1H, J = 8.4 Hz); ^{13}C NMR δ 14.6, 21.4, 64.5, 78.5, 80.8, 88.4, 111.6, 117.9, 120.0, 124.4, 127.8, 129.1, 131.3, 131.8, 139.7, 146.8; MS *m*/*z* 291 (M^+, 6), 276 (6), 173 (100). Anal. Calcd for $C_{18}H_{17}N_3O$: C, 74.20; H, 5.88; N, 14.42. Found: C, 73.86; H, 6.01; N, 14.42.

1-(Benzotriazol-1-yl)-3-(4-methoxyphenyl)propargyl ethyl ether (12c): colorless oil; ^{1}H NMR δ 1.08 (t, 3H, J = 6.5 Hz), 3.41−3.51 (m, 1H), 3.65−3.75 (m, 1H), 3.82 (s, 3H), 6.83 (d, 2H, J = 8.3 Hz), 7.02 (s, 1H), 7.39−7.46 (m, 3H), 7.55 (t, 1H, J = 7.5 Hz), 8.02 (d, 1H, J = 8.4 Hz), 8.06 (d, 1H, J = 8.4 Hz); ^{13}C NMR δ 14.5, 55.2, 64.4, 79.0, 80.1, 88.3, 111.5, 112.7, 113.9, 119.9, 124.4, 127.7, 131.2, 133.4, 146.7, 160.4; MS *m*/*z* 307 (M^+, 8), 189 (100). Anal. Calcd for $C_{18}H_{17}N_3O_2$: C, 70.34; H, 5.58; N, 13.67. Found: C, 70.08; H, 5.77; N, 13.52.

1-(Benzotriazol-1-yl)-3-(4-nitrophenyl)propargyl ethyl ether (12d): yellow plates, mp 90−91 °C; ^{1}H NMR δ 1.22 (t, 3H, J = 6.9 Hz), 3.43−3.53 (m, 1H), 3.66−3.76 (m, 1H), 7.06 (s, 1H), 7.46 (t, 1H, J = 7.14 Hz), 7.58 (t, 1H, J = 7.4 Hz), 7.62 (d, 2H, J = 8.8 Hz), 7.96 (d, 1H, J = 8.5 Hz), 8.13 (d, 1H, J = 8.2 Hz), 8.2 (d, 2H, J = 8.8 Hz); ^{13}C NMR δ 14.5, 64.7, 78.6, 85.6, 86.0, 111.0, 120.2, 123.6, 124.6, 127.4, 128.1, 131.1, 132.8, 146.7, 147.8; MS *m*/*z* 278 (M − NO_2, 8), 176 (100). Anal. Calcd for $C_{17}H_{14}N_4O_3$: C, 63.35; H, 4.38; N, 17.38. Found: C, 63.31; H, 4.41; N, 17.05.

1-(1-Cyclohexenyl)-3-(benzotriazol-1-yl)-3-ethoxy-1-nonyne (8a). A mixture of **5a** (0.5 g, 1.6 mmol) and 1-bromohexane (0.32 g, 1.9 mmol) in THF (20 mL) and HMPA (4 mL) was cooled to −78 °C, and LiHMDS (1.9 mL, 1.9 mmol in hexane) was added. After 15 min at this temperature, water (10 mL) was added to quench the reaction, which was then extracted with ether. After evaporating the solvent, the residue was purified by column chromotography (eluent: hexane−ethyl acetate = 100:3) to give **8a** as a colorless oil: ^{1}H NMR δ 0.81 (t, 3H, J = 6.6 Hz), 1.14 (t, 3H, J = 7.2 Hz), 1.16−1.20 (m, 8H), 1.58−1.68 (m, 4H), 2.12−2.14 (m, 4H), 2.39 (t, 2H, J = 6.9 Hz), 3.12−3.17 (m, 1H), 3.78−3.84 (m, 1H), 6.32 (m, 1H), 7.35 (t, 1H, J = 8.1 Hz), 7.45 (t, 1H, J = 7.2 Hz), 7.95 (d, 1H, J = 8.4 Hz), 8.05 (d, 1H, J = 8.1 Hz).

General Procedure for the Preparation of Compounds 9a−g and 10. The corresponding intermediate **8** was prepared using the procedure for **8a**. Then crude **8** was dissolved in ethanol (20 mL), and concentrated HCl (1 mL) was added. The solution was stirred at rt for 30 min. Again, after water (20 mL) was added, the solution was extracted with ether (3 × 100 mL), washed with saturated NaCl (10 mL) solution, and dried over $MgSO_4$. Chromatography on silica gel (eluent: hexane−ethyl acetate) afforded the desired product.

1-(1-Cyclohexenyl)-1-nonyn-3-one (9a): colorless oil; ^{1}H NMR δ 0.89 (t, 3H, J = 6.9 Hz), 1.29−1.32 (m, 6H), 1.61−1.67 (m, 6H), 2.15−2.19 (m, 4H), 2.55 (t, 2H, J = 7.5 Hz), 6.43−6.46 (m, 1H); ^{13}C NMR δ 13.9, 21.1, 21.9, 22.4, 24.2, 26.0, 28.3, 28.6, 31.5, 45.4, 86.1, 93.1, 118.9, 142.1, 188.5; HRMS (EI) calcd for $C_{15}H_{22}O$ 218.1670, found 218.1693.

1-Phenyl-1-hexen-3-yn-5-one (9b): colorless oil; ^{1}H NMR δ 2.0 (s, 3H), 5.84 (d, 1H, J = 16.2 Hz), 6.83 (d, 1H, J = 16.5 Hz), 6.95−7.10 (m, 5H); ^{13}C NMR δ 32.6, 90.0, 90.2, 105.1, 126.9, 128.9, 130.0, 135.0, 147.7, 184.4; MS *m*/*z* 170 (M^+, 30), 127 (100); HRMS (EI) calcd for $C_{12}H_{10}O$ 170.0732, found 170.0733.

1-Phenyl-1-hepten-3-yn-5-one (9c): colorless oil; ^{1}H NMR δ 1.2 (t, 3H, J = 7.5 Hz), 2.64 (q, 2H, J = 7.5 Hz), 6.23 (d, 1H, J = 16.2 Hz), 7.21 (d, 1H, J = 15.6 Hz), 7.36−7.56 (m, 5H); ^{13}C NMR δ 8.2, 38.7, 78.6, 89.6, 105.3, 110.6, 126.9, 128.9, 129.9, 135.2, 147.5, 190.1; HRMS (EI) calcd for $C_{13}H_{12}O$ 184.0889, found 184.0920.

1-Phenyl-1-nonen-3-yn-5-one (9d): colorless oil; ^{1}H NMR δ 0.95 (t, 3H, J = 7.5 Hz), 1.35−1.43 (m, 2H), 1.68−1.73 (m, 2H), 2.62 (t, 2H, J = 7.2 Hz), 6.24 (d, 1H, J = 16.2 Hz), 7.21 (d, 1H, J = 16.5 Hz), 7.36−7.46 (m, 5H); ^{13}C NMR δ 13.9, 22.2, 26.3, 45.2, 89.9, 90.3, 105.3, 126.9, 128.9, 130.0, 135.2, 147.6, 188.2; MS *m*/*z* 212 (M^+, 10), 127 (100); HRMS (EI) calcd for $C_{15}H_{16}O$ 212.1201, found 212.1197.

1-Phenyl-1-pentadecen-3-yn-5-one (9e): colorless oil; ^{1}H NMR δ 0.88 (t, 3H, J = 6.04 Hz), 1.26−1.30 (m, 14H), 1.68−1.70 (m, 2H), 2.63 (t, 2H, J = 7.42 Hz), 6.24 (d, 1H, J = 16.2 Hz), 7.22 (d, 1H, J = 16.4 Hz), 7.34−7.44 (m, 5H); ^{13}C NMR δ

(20) Stang, P. J.; Treptow, W. *Synthesis* **1980**, 283.

14.2, 22.7, 24.3, 29.1, 29.4, 29.5, 29.6, 31.9, 45.5, 89.9, 90.3, 105.3, 127.0, 129.0, 130.1, 135.2, 147.6, 188.2; MS *m/z* 212 (M^+, 10), 127 (100); HRMS (EI) calcd for $C_{21}H_{28}O$ 296.2140, found 296.2130.

1-(Trimethylsilyl)-6-phenyl-1-hexen-3-yn-5-one (9f): colorless oil; ^{1}H NMR δ 0.10 (s, 9H), 3.86 (s, 2H), 5.99 (d, 1H, J = 19.5 Hz), 6.74 (d, 1H, J = 19.5 Hz), 7.24−7.35 (m, 5H); ^{13}C NMR δ −2.0, 52.1, 87.3, 91.9, 120.6, 127.3, 128.7, 129.7, 133.0, 154.2, 185.1; MS *m/z* 241 ($M^+ - 1$, 12), 123 (100); HRMS (EI) calcd for $C_{15}H_{18}O$ 242.1127, found 242.1101.

1-(Trimethylsilyl)-1-dodecen-3-yn-5-one (9g): colorless oil; ^{1}H NMR δ 0.19 (s, 9H), 0.96 (t, 3H, J = 7.5 Hz), 1.21−1.62 (m, 10H), 2.49 (t, 2H, J = 7.5 Hz), 6.10 (d, 1H, J = 19.8 Hz), 6.85 (d, 1H, J = 19.5 Hz); ^{13}C NMR δ −1.9, 14.0, 22.6, 24.0, 28.8, 31.5, 45.4, 87.5, 89.9, 120.8, 153.3, 188.2; HRMS (EI) calcd for $C_{15}H_{26}OSi$ + H 251.1831, found 251.1831.

1-Phenyl-7-(benzotriazol-1-yl)-1-octen-3-yn-5-one (10): colorless oil; ^{1}H NMR δ 1.75 (d, 3H, J = 6.9 Hz), 3.36 (dd, 1H, J = 6.0, 17.5 Hz), 3.72 (dd, 1H, J = 7.5, 17.5 Hz), 5.45−5.52 (m, 1H), 6.16 (d, 1H, J = 16.2 Hz), 7.16 (d, 1H, J = 16.2 Hz), 7.35−7.45 (m, 6H), 7.52 (t, 1H, J = 7.2 Hz), 7.64 (d, 1H, J = 8.1 Hz), 8.05 (d, 1H, J = 8.7 Hz); ^{13}C NMR δ 22.6, 52.0, 52.6, 90.9, 93.9, 106.2, 111.2, 121.5, 125.6, 128.6, 128.8, 130.5, 134.1, 136.5, 147.5, 150.1, 184.8; HRMS (EI) calcd for $C_{20}H_{17}N_3O$ 315.1372, found 315.1436.

General Procedure for the Preparation of 13. Compound **12b** or **12c** (1.0 mmol) in THF (20 mL) was cooled to −78 °C, and *n*-BuLi (0.8 mL, 1.2 mmol in hexane) was added over 5 min. After 10 min, an alkyl halide was added and the mixture was stirred at this temperature for 10 min. Water (10 mL) was added to quench the reaction. The crude product obtained was dissolved in ethanol (20 mL) with concentrated HCl (1 mL), and the mixture was stirred at rt for 30 min. After ether extraction and chromatography on silica gel, pure compounds **13** were obtained.

1-(4-Methylphenyl)-1-nonyn-3-one (13a): colorless oil; ^{1}H NMR δ 0.89 (t, 3H, J = 6.9 Hz), 1.24−1.78 (m, 8H), 2.39 (s, 3H), 2.65 (t, 2H, J = 7.5 Hz), 7.19 (d, 2H, J = 6.9 Hz), 7.46 (d, 2H, J = 6.9 Hz); ^{13}C NMR δ 14.0, 21.6, 22.4, 24.2, 28.7, 31.5, 45.5, 87.8, 91.2, 117.8, 129.4, 133.0, 141.3, 188.2; HRMS (EI) calcd for $C_{16}H_{20}O$ + H 229.1592, found 229.1653.

1-(4-Methoxyphenyl)-1-butyn-3-one (13b):[21] colorless oil; ^{1}H NMR δ 2.43 (s, 3H), 3.84 (s, 3H), 6.88 (d, 2H, J = 8.4 Hz), 7.52 (d, 2H, J = 8.4 Hz); ^{13}C NMR δ 32.5, 55.3, 88.2, 91.4, 111.5, 114.3, 135.0, 161.6, 184.6.

Supporting Information Available: ^{1}H and ^{13}C NMR and HRMS spectra for products **5a**,**d**, **8a**, **9a**−**g**, **10**, and **13a** (32 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

JO971234C

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