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Conversion of 3,3,3-Trisubstituted Prop-1-ynes with *tert*-Butylhydrazine into 3,3,3-Trisubstituted Propionitriles Catalyzed by $TpRh(C_2H_4)_2/P(2\text{-furyl})_3$

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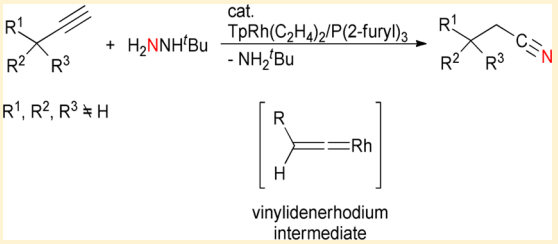
Supporting Information

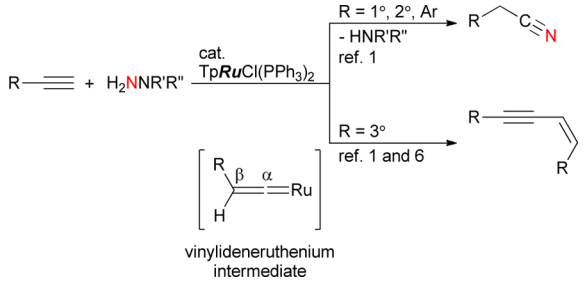
ABSTRACT: The combination of $TpRh(C_2H_4)_2$ (Tp = tris(pyrazol-1-yl)borate) and $P(2\text{-furyl})_3$ catalyzes the reaction of tertiary alkyl-substituted alkynes with *tert*-butylhydrazine, leading to the formation of 3,3,3-trisubstituted propionitrile derivatives. This reaction system is applicable to 1,1-disubstituted propargyl alcohols and amines to afford the corresponding β-cyanohydrins and β-amino nitriles, respectively. The catalytic cycle involves the formation of a vinylidenerhodium complex as a key intermediate.



INTRODUCTION

In 2002, our group developed the reaction of terminal alkynes with *N*-substituted or *N,N*-disubstituted hydrazines, using $TpRuCl(PPh_3)_2$ (Tp = tris(pyrazol-1-yl)borate) as a catalyst, leading to the production of nitriles (Scheme 1).[1] The terminal

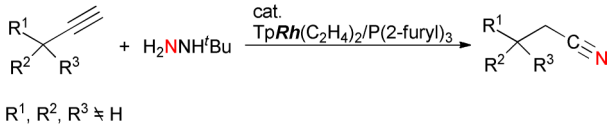
Scheme 1. Previous Reports on the $TpRuCl(PPh_3)_2$-Catalyzed Reaction of Terminal Alkynes with Hydrazines



alkyne carbon is incorporated as a nitrile carbon, and the internal carbon becomes the α-carbon of the nitrile in the product. Among a number of transition metal complexes screened as catalysts, only $TpRuCl(PPh_3)_2$ was found to show good catalytic activity. The catalytic cycle involves the formation of a vinylideneruthenium complex, followed by the nucleophilic attack of a hydrazine nitrogen at the α-carbon of the vinylidene ligand.[2−5] While primary and secondary alkyl- and aryl-substituted alkynes were applicable to the reaction, the reaction of tertiary alkyl-substituted alkynes such as *tert*-butylacetylene under the same reaction conditions afforded dimerization products derived from alkynes and not nitriles. The latter type of reaction was also reported by Kirchner and co-workers, and a vinylideneruthenium complex was proposed as an active precursor.[6]

Herein, we report the conversion of tertiary alkyl-substituted alkynes into 3,3,3-trisubstituted propionitriles using a $TpRh(C_2H_4)_2/P(2\text{-furyl})_3$ catalyst system with *tert*-butylhydrazine (Scheme 2). 1,1-Disubstituted propargyl alcohols

Scheme 2. Conversion of *tert*-Alkyl-Substituted Alkynes into 3,3,3-Trisubstituted Propionitriles Catalyzed by $TpRh(C_2H_4)_2/P(2\text{-furyl})_3$



and amines could also be used to afford β-cyanohydrins and β-amino nitriles, respectively. These moieties are found as structural motifs in several natural products and pharmaceuticals.[7] In addition, the cyano group serves as an important intermediate in organic synthesis for various transformations into other functional groups, such as amines, aldehydes, carboxylic acids, amides, and heterocycles. Therefore, the development of new methods for the synthesis of nitriles is of importance.[8]

RESULTS AND DISCUSSION

The $TpRh(C_2H_4)_2/P(2\text{-furyl})_3$ catalyst system was originally employed for the *anti*-Markovnikov addition of hydrazines to terminal alkynes leading to the production of aldimine-type hydrazones.[5,9,10] The treatment of undec-1-yne (**1a**) with methylhydrazine in the presence of $TpRh(C_2H_4)_2$ and tris(2-furyl)-phosphine in toluene at 100 °C for 6 h gave the hydrazone $\mathbf{2a_{MeH}}$ in 61% yield. In this reaction, a trace amount of undecanenitrile (**3a**) was also detected by ^1H NMR (entry 1 in Table 1). In the course of the study, it was found that the

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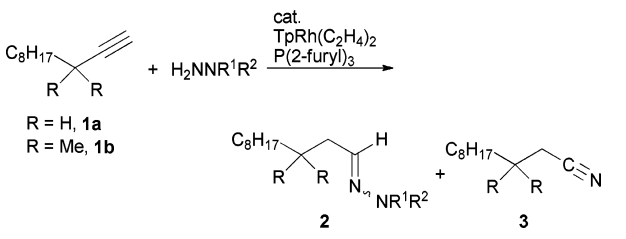
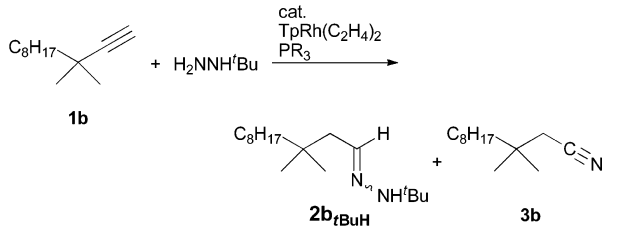
Table 1. $TpRh(C_2H_4)_2/P(2\text{-furyl})_3$-Catalyzed Reaction of Terminal Alkynes with Hydrazines[a]



entry	1	R^1	R^2	2, yield[b] (%) (*E*/*Z*)	3, yield[b] (%)
1	**1a**	H	Me	$\mathbf{2a_{MeH}}$, 61 (81/19)	**3a**, 1
2	**1a**	H	^{t}Bu	$\mathbf{2a_{tBuH}}$, 29 (73/27)	**3a**, 46
3	**1b**	H	Me	$\mathbf{2b_{MeH}}$, 17 (72/28)	**3b**, 48
4	**1b**	H	^{t}Bu	$\mathbf{2b_{tBuH}}$, 8 (71/29)	**3b**, 68
5[c]	**1b**	H	^{t}Bu	$\mathbf{2b_{tBuH}}$, 0	**3b**, 75
6	**1b**	Me	Me	$\mathbf{2b_{Me2}}$, 6 (*E* only)	**3b**, 23

[a]Reaction conditions: alkyne (0.5 mmol), hydrazine (1.5 mmol), $TpRh(C_2H_4)_2$ (0.05 mmol), $P(2\text{-furyl})_3$ (0.1 mmol), in toluene (2 mL), at 100 °C for 6 h. [b]Product yields and *E*/*Z* ratios were determined by ^{1}H NMR spectroscopy with 1,3-dihydroisobenzofuran as the internal standard. [c]In 1,4-dioxane.

Table 2. Screening of Rhodium Complexes and Phosphines[a]



entry	Rh complex	PR_3	yields[b] (%) $\mathbf{2b_{tBuH}}$ (*E*/*Z*)	yields[b] (%) **3b**
1	$TpRh(C_2H_4)_2$	$P(2\text{-furyl})_3$	0	75
2	$TpRh(C_2H_4)_2$	$P(4\text{-}CF_3C_6H_4)_3$	11 (87/13)	27
3	$TpRh(C_2H_4)_2$	PPh_3	8 (85/15)	26
4	$TpRh(C_2H_4)_2$	$P(4\text{-}MeOC_6H_4)_3$	9 (81/19)	13
5	$TpRh(C_2H_4)_2$	PBu_3	0	0
6	$TpRh(C_2H_4)_2$	none	0	0
7	$[RhCl(C_2H_4)_2]_2$	$P(2\text{-furyl})_3$	25 (61/39)	37
8	$[RhCl(cod)]_2$	$P(2\text{-furyl})_3$	25 (55/45)	46

[a]Reaction conditions: **1b** (0.5 mmol), H_2NNH^tBu (1.5 mmol),$TpRh(C_2H_4)_2$ (0.05 mmol), phosphine (0.1 mmol), in 1,4-dioxane (2 mL), at 100 °C for 6 h. [b]Product yields and *E*/*Z* ratios were determined by ^{1}H NMR spectroscopy with 1,3-dihydroisobenzofuran as the internal standard.

product ratio of hydrazone and nitrile depends on the substituent on the hydrazine nitrogen. The reaction with *tert*-butylhydrazine resulted in a decrease in the yield of $\mathbf{2a_{tBuH}}$ to 29%, accompanied by an increase in the yield of **3a** to 46% (entry 2). On the other hand, the alkyne bearing a tertiary alkyl group **1b** reacted with methylhydrazine to afford a mixture of the hydrazone $\mathbf{2b_{MeH}}$ and the nitrile **3b** in 17% and 48% yields, respectively, with no detectable formation of the dimerization product (entry 3). These results prompted us to examine the reaction of **1b** with *tert*-butylhydrazine to afford **3b** in good yield and selectivity. As expected, the yield of **3b** increased to 68%, and the yield of $\mathbf{2b_{tBuH}}$ was lower (entry 4). Finally, **3b** was produced in 75% yield as a sole product when the reaction was carried out in 1,4-dioxane (entry 5). On the other hand, the reaction with *N*,*N*-dimethylhydrazine resulted in a low total yield and a low product selectivity (entry 6). As is the case with the *anti*-Markovnikov hydrohydrazination of terminal alkynes,[5] $P(2\text{-furyl})_3$ was determined to be the ligand of choice (entries 1−6 in Table 2), and Tp ligand was essential for the reaction (entries 1, 7, and 8).

The scope of the catalytic reaction with *tert*-butylhydrazine was next examined with a variety of terminal alkynes (Table 3). When the reaction of the alkyne **1c** was carried out under the standard reaction conditions, 3-methyl-3-phenylbutanenitrile (**3c**) was obtained in 78% isolated yield by silica gel column chromatography (entry 2). 1-Adamantylacetylene (**1d**) was converted into the nitrile **3d** in 48% yield, but some starting alkyne solidified by sublimation on the upper side in the glass vessel during the reaction, and as a result, **1d** was recovered in 25% yield (entry 3). Various 1,1-disubstituted propargyl alcohols and amines were also examined as substrates for this catalytic reaction to afford the corresponding β-cyanohydrins (entries 4−13) and β-amino nitriles (entries 14 and 15). 3-Hydroxy-3-methylundecanenitrile (**3e**) was obtained by the reaction of **1e** under the standard reaction conditions (entry 4). The reaction of ethynyl estradiol (**1n**) produced **3n** in 75% yield with retention of the absolute configuration at the five chiral centers in **1n** (entry 13). In the case of the reaction of propargylamines, a protecting group for amines such as a Boc group was required for **3o** and **3p** to be produced in good yields. The recovery of **1o** in 21% yield can be attributed to the high sublimability of the substrate, as is the case for **1d**. All of the nitriles were not accompanied by the production of hydrazones except for **3g** (hydrazone: 3%), **3h** (hydrazone: <1%), and **3j** (hydrazone: 4%). However, the reaction of the secondary alkyl-substituted alkyne **1q** gave a mixture of the hydrazone $\mathbf{2q_{tBuH}}$ and the nitrile **3q** in yields of 28% and 32%, respectively (Scheme 3).

Although details of the reaction mechanism are currently unclear, a vinylidenerhodium complex (**II**) appears to be involved as a key intermediate in the catalytic cycle, as was reported in our previous study of anti-Markovnikov hydrohydrazination (Scheme 4).[5] The nucleophilic attack of a hydrazine nitrogen at the α-carbon of the vinylidene ligand in **II** affords an α-hydrazinocarbenerhodium complex (**III**). Smaller cone angle and electron-withdrawing ability of $P(2\text{-furyl})_3$[11] might facilitate the nucleophilic attack of the hydrazine. The isomerization of **III** to a zwitterionic complex **V** next occurs, either directly or via the formation of a hydrazinorhodium complex **IV**. Finally, the nitrile is produced as the result of the elimination of *tert*-butylamine from **V**, with regeneration of the rhodium complex **I**. Some stoichiometric reactions of vinylidene−iron[12] and −ruthenium[1,13] complexes with hydrazines to afford nitrile-coordinated metal complexes support the proposed reaction mechanism. On the other hand, reductive elimination from **IV** gives the hydrazone. One possible explanation for the predominant production of nitriles from tertiary alkyl-substituted alkynes when *tert*-butylhydrazine was used is that bulky substituents both on the alkyne and hydrazine would make the formation of the more highly coordinated complex **IV** bearing the bulky Tp ligand difficult, in terms of steric hindrance. The decrease in the total yield of nitrile and hydrazone in the reaction with *N*,*N*-dimethylhydrazine would be attributed to the severe steric hindrance caused by bulkier dimethylamino group, compared to *tert*-butyl group, which complicates the nucleophilic attack of the

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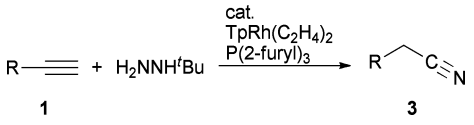
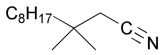
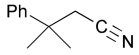
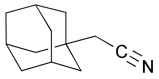
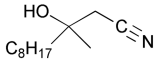
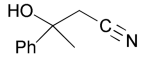
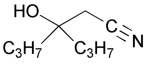
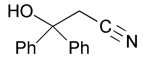
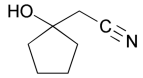
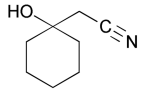
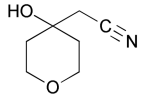
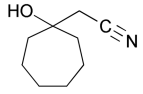
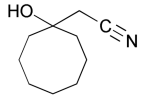
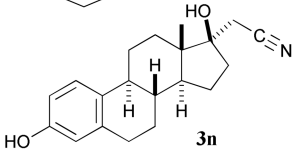
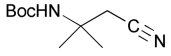
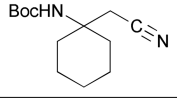
Table 3. Substrate Scope[a]

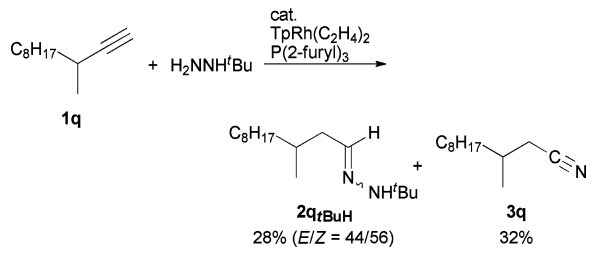


entry	1	product		yield (%)[b]
1	1b		3b	75
2	1c		3c	78
3	1d		3d	48[c]
4	1e		3e	86
5	1f		3f	63
6	1g		3g	80
7	1h		3h	66
8	1i		3i	78
9	1j		3j	81
10	1k		3k	81
11	1l		3l	81
12	1m		3m	86
13	1n		3n	75
14	1o		3o	63[d]
15	1p		3p	76

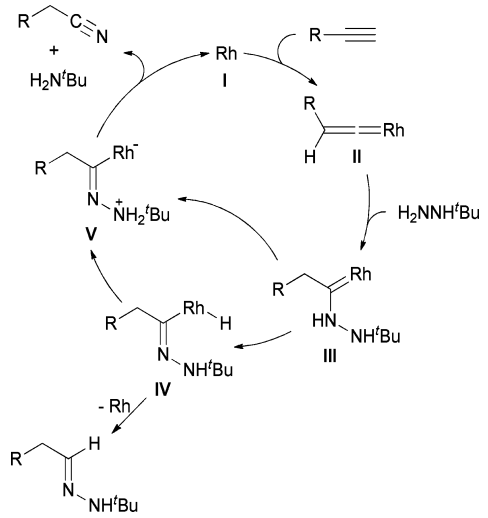
[a]Reaction conditions: alkyne (0.5 mmol), H_2NNH^tBu (1.5 mmol), $TpRh(C_2H_4)_2$ (0.05 mmol), $P(2\text{-furyl})_3$ (0.1 mmol), in 1,4-dioxane (2 mL), at 100 °C for 6 h. [b]Isolated yield. [c]**1d** was recovered in 25% yield. [d]**1o** was recovered in 21% yield.

hydrazine at the α-carbon of the vinylidene ligand. However, the reason for the decrease in selectivity of nitrile is quite unclear at the present stage. An alternative mechanism involving the formation of an ethanimine rhodium complex **VIII** from **II** via zwitterionic complexes **VI** and **VII** followed by tautomerization

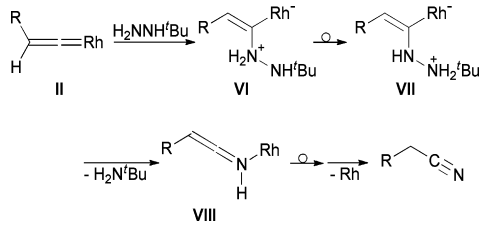
Scheme 3. Reaction of 3-Methylundec-1-yne (1q) with *tert*-Butylhydrazine Catalyzed by $TpRh(C_2H_4)_2/P(2\text{-furyl})_3$



Scheme 4. Plausible Reaction Mechanism



Scheme 5. Alternative Reaction Mechanism



to yield the nitrile would be proposed (Scheme 5).[13] The possibility of such a reaction mechanism cannot be ruled out on the basis of currently available data.

CONCLUSIONS

In conclusion, we demonstrated the $TpRh(C_2H_4)_2/P(2\text{-furyl})_3$-catalyzed reaction of tertiary alkyl-substituted alkynes with *tert*-butylhydrazine to give 3,3,3-trisubstituted propionitriles. This reaction also provides an alternative method for the synthesis of β-cyanohydrins and β-amino nitriles from 1,1-disubstituted propargyl alcohols and amines, respectively. We propose that the reaction mechanism involves the formation of a vinylidenerhodium complex followed by the nucleophilic attack of the hydrazine nitrogen at the α-position of the vinylidene ligand in the catalytic cycle.

EXPERIMENTAL SECTION

General Methods. ^1H and ^{13}C NMR spectra were recorded at 400 and 100 MHz, respectively. Data are reported as follows: chemical shifts in ppm (δ), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, sext = sextet, sept = septet, m = multiplet,

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br = broad singlet, c = complex), coupling constant (Hz), and integration. IR spectra were obtained, and absorption data are reported in reciprocal centimeters with the following relative intensities: s (strong), m (medium), or w (weak). Mass spectra were obtained using a quadruple mass spectrometer with EI source at 70 eV. High-resolution mass spectra (HRMS) were performed on a double-focusing mass spectrometer with EI or CI source at 70 eV. Optical rotations were determined at 589 nm in a thermostated conventional 10 cm cell. Toluene was purified by passage through activated Al_2O_3. Anhydrous grade 1,4-dioxane was purchased and used without further purification. Alkynes **1a**, **1f**, **1h**, **1i**, **1j**, and **1n**, methylhydrazine, and undecanal were purchased and distilled over CaH_2 prior to use. Compounds **1b**, **1e**, **1g**, **1m**, **1o**, and **1q** were prepared as described below. Compounds **1c**,[14] **1d**,[15] **1k**,[16] **1l**,[17] and **1p**[18,19] were prepared following procedures described in the literature. *tert*-Butylhydrazine was obtained by treatment of *tert*-butylhydrazine hydrochloride with powdered KOH and subsequent double distillation of the resulting liquid, the last of which was done over CaH_2. P(2-furyl)$_3$ was commercially available and was purified by recrystallization from hexane prior to use. TpRh$(C_2H_4)_2$ was prepared according to the procedure following a literature procedure.[20]

Alternative Sample Preparation of Hydrazones $2a_{MeH}$, $2a_{tBuH}$, $2b_{MeH}$, $2b_{tBuH}$, $2b_{Me2}$, and $2q_{tBuH}$ with the Conventional Reaction. Authentic samples of all hydrazones $2a_{MeH}$, $2a_{tBuH}$, $2b_{MeH}$, $2b_{tBuH}$, $2b_{Me2}$, and $2q_{tBuH}$ were prepared by the conventional reaction of undecanal (for $2a_{MeH}$ and $2a_{tBuH}$), 3-methylundecanal (for $2q_{tBuH}$), or 3,3-dimethylundecanal (for $2b_{MeH}$, $2b_{tBuH}$, and $2b_{Me2}$) with the corresponding hydrazines according to a previously reported procedure[21] and were used to identify the formation of those compounds from the present reaction. 3-Methylundecanal was prepared as described below. 3,3-Dimethylundecanal[22] was prepared following a procedure reported by Wakatsuki and co-workers.[23]

General Procedure for the Reaction of Terminal Alkynes with *tert*-Butylhydrazine Catalyzed by the TpRh$(C_2H_4)_2$/P(2-furyl)$_3$ System. A 25 mL Schlenk tube was flame-dried and then cooled to room temperature under N_2. TpRh$(C_2H_4)_2$ (18.5 mg, 0.05 mmol), P(2-furyl)$_3$ (23.2 mg, 0.10 mmol), and 1,4-dioxane (1 mL) were added to the tube. The mixture was stirred for 3 min at room temperature. To the resulting yellow solution were added hydrazine (1.5 mmol), alkyne (0.5 mmol), and 1,4-dioxane (1 mL). The reaction mixture was then heated at 100 °C for 6 h. After the mixture was cooled to room temperature, the volatiles were removed in vacuo. Product yields were determined by ^{1}H NMR spectroscopy with 1,3-dihydroisobenzofuran as the internal standard. The products were isolated by flash column chromatography on SiO_2.

*Preparation of 3,3-Dimethylundec-1-yne (**1b**).* The procedure reported by Gagosz et al.[14] was modified by using 2,2-dimethyldecanal[24] (5.53 g, 30.0 mmol) to produce **1b**, which was isolated by flash column chromatography on SiO_2 (R_f = 0.60 in hexane) in 57% yield (3.08 g, 17.1 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H), 1.19 (s, 6H), 1.23−1.44 (c, 14H), 2.06 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 14.1, 22.6, 25.2, 29.1, 29.3, 29.5, 30.0, 30.9, 31.9, 43.1, 67.4, 92.1. IR (ATR): 3312 w, 2961 m, 2926 s, 2855 w, 1468 w cm^{-1}. MS: m/z (relative intensity): 165 (85), 137 (100), 124 (60), 107 (71), 94 (67), 78 (46), 58 (46). HRMS (CI) calcd for $C_{13}H_{25}$ (M^+ + 1): 181.1956, found 181.1951.

*Preparation of 3-Hydroxy-3-methylundec-1-yne (**1e**).* The procedure reported by Kato et al.[17] was modified by using decan-2-one (3.20 g, 20.5 mmol) in place of stanolone to produce **1e**, which was isolated by flash column chromatography on SiO_2 (R_f = 0.20 in hexane/EtOAc = 10/1) in 79% yield (2.95 mg, 16.2 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H), 1.27−1.30 (c, 10H), 1.43−1.51 (c, 5H), 1.66 (c, 2H), 2.04 (bs, 1H), 2.43 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 14.0, 22.6, 24.5, 29.2, 29.4, 29.6, 29.7, 31.8, 43.4, 68.0, 71.1, 87.7. IR (ATR): 3389 w, 3310 w, 2925 m, 2855 m, 1463 w, 1372 w, 1131 w cm^{-1}. MS: m/z (relative intensity): 167 (83), 111 (100), 83 (85), 65 (86), 54 (91). HRMS (CI) calcd for $C_{12}H_{23}O$ (M^+ + 1): 183.1749, found 183.1750.

*Preparation of 3-Hydroxy-3-propylhex-1-yne (**1g**).* The procedure reported by Kato et al.[17] was modified by using heptan-4-one (2.31g, 20.3 mmol) in place of stanolone to produce **1g**, which was isolated by flash column chromatography on SiO_2 (R_f = 0.20 in hexane/EtOAc = 10/1) in 83% yield (2.36 g, 16.8 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.95 (t, J = 6.8 Hz, 6H), 1.48−1.64 (c, 8H), 2.23 (bs, 1H), 2.43 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 14.1, 17.3, 44.0, 70.9, 72.0, 87.9. IR (ATR): 3388 w, 3309 w, 2959 m, 2874 m, 1465 w, 1142 m, 977 m cm^{-1}. MS: m/z (relative intensity): 112 (74), 99 (20), 91 (92), 78 (100), 54 (96). HRMS (CI) calcd for $C_9H_{17}O$ (M^+ + 1) 141.1279, found 141.1280.

*Preparation of 1-Ethynylcyclooctan-1-ol (**1m**).* The procedure reported by Kato et al.[17] was modified by using cyclooctanone (2.53 g, 20.1 mmol) in place of stanolone to produce **1m**, which was isolated by flash column chromatography on SiO_2 (R_f = 0.14 in hexane/EtOAc = 10/1) in 80% yield (2.45 g, 16.1 mmol) as a white solid. Mp = 44−45 °C. ^{1}H NMR ($CDCl_3$): δ 1.40−1.71 (c, 10H), 1.95 (m, 4H), 2.44 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 21.9, 24.3, 27.8, 37.9, 71.0, 71.2, 88.5. IR (ATR): 3303 m, 3289 w, 2915 s, 2850 w, 2360 w, 1686 m, 1447 m, 1067 s, 981 s cm^{-1}. MS: m/z (relative intensity): 151 (45), 137 (52), 123 (57), 119 (45), 109 (100), 68 (96). HRMS (CI) calcd for $C_{10}H_{17}O$ (M^+ + 1): 153.1279, found 153.1277.

*Preparation of tert-Butyl (2-Methylbut-3-yn-2-yl)carbamate (**1o**).* The procedure reported by Britton et al.[18] was modified by using 2-methylbut-3-yn-2-amine (1.09 g, 13.1 mmol) in place of 1-ethynylcyclohexan-1-amine to produce **1o**, which was isolated by flash column chromatography on SiO_2 (R_f = 0.26 in hexane/EtOAc = 10/1) in 95% yield (2.28 g, 12.4 mmol) as a white solid. Mp = 59−60 °C. ^{1}H NMR ($CDCl_3$): δ 1.45 (s, 9H), 1.58 (s, 6H), 2.30 (s, 1H), 4.69 (s, 6H). ^{13}C NMR ($CDCl_3$): δ 28.3, 29.4, 46.9, 68.6, 79.7, 87.4, 154.0. IR (ATR): 3355 w, 2984 w, 1681 s, 1514 s, 1246 s, 1153 s, 1081 s cm^{-1}. MS: m/z (relative intensity): 168 (18), 127 (100), 112 (41). HRMS (CI) calcd for $C_{10}H_{18}NO_2$ (M^+ + 1): 184.1338, found 184.1337.

*Preparation of 3-Methylundec-1-yne (**1q**).* The procedure reported by Gagosz et al.[14] was modified by using 2-methyldecanal[25] (7.23 g, 42.5 mmol) to produce **1q**, which was isolated by flash column chromatography on SiO_2 (R_f = 0.57 in hexane) in 46% yield (3.25 g, 19.5 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.86 (t, J = 7.2 Hz, 3H), 1.16 (d, J = 6.8 Hz, 3H), 1.20−1.30 (c, 10H), 1.36−1.47 (c, 4H), 2.01 (d, J = 2.0 Hz, 1H), 2.40 (c, 1H). ^{13}C NMR ($CDCl_3$): δ 14.1, 20.9, 22.6, 25.6, 27.2, 29.2, 29.4, 29.5, 31.8, 36.7, 67.9, 89.3. IR (ATR): 3312 w, 2958 m, 2925 s, 2855 w, 1461 w cm^{-1}. MS: m/z (relative intensity): 151 (21), 137 (22), 123 (46), 110 (100), 97 (97), 83 (73), 58 (46), 44 (87), 30 (34). HRMS calcd for $C_{12}H_{23}$ (M^+ + 1): 167.1800; found: 167.1796.

(E)- and (Z)-1-Methyl-2-undecylidenehydrazine ($2a_{MeH}$, E/Z = 82/18). Undecanal (3.34 g, 19.6 mmol) was reacted with methylhydrazine in CH_2Cl_2 to produce $2a_{MeH}$. After evaporation of volatiles, a colorless oil (3.62 mg) was obtained. ^{1}H NMR ($CDCl_3$): δ 0.87 (t, J = 6.8 Hz, 3H, *E*- and *Z*-isomers), 1.19−1.39 (c, 14H, *E*- and *Z*-isomers), 1.43−1.54 (c, 2H, *E*- and *Z*-isomers), 2.05 (td, J = 7.3 Hz, 5.0 Hz, 2H, *Z*-isomer), 2.20 (c, 2H, *E*-isomer), 2.79 (s, 3H, *E*-isomer), 2.94 (s, 3H, *Z*-isomer), 6.46 (t, J = 5.0 Hz, 1H, *Z*-isomer), 6.91 (t, J = 5.5 Hz, 1H, *E*-isomer). However, $2a_{MeH}$ in analytically pure form could not be obtained because of the instability. Therefore, $2a_{MeH}$ was converted into **4a** according to the procedure described in the literature.[26]

(E)- and (Z)-1-tert-Butyl-2-undecylidenehydrazine ($2a_{tBuH}$, E/Z = 77/23). Undecanal (3.32 g, 19.4 mmol) was reacted with *tert*-butylhydrazine in CH_2Cl_2 to produce $2a_{MeH}$. After evaporation of volatiles, a colorless oil (3.57 g) was obtained. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 6.8 Hz, 3H, *E*- and *Z*-isomers), 1.16 (s, 9H, *E*-isomer), 1.19 (s, 9H, *Z*-isomer), 1.20−1.39 (c, 14H, *E*- and *Z*-isomers), 1.46 (quint, J = 7.6 Hz, 2H, *E*-isomer), 1.53 (quint, J = 7.7 Hz, 2H, *Z*-isomer), 2.02 (td, J = 7.7 Hz, 5.0 Hz, 2H, *Z*-isomer), 2.17 (td, J = 7.6 Hz, 5.5 Hz, 2H, *E*-isomer), 6.48 (t, J = 5.0 Hz, 1H, *Z*-isomer), 7.01 (t, J = 5.5 Hz, 1H, *E*-isomer). However, $2a_{tBuH}$ in analytically pure form could not be obtained because of the instability. Therefore, $2a_{tBuH}$ was converted into $2a_{tBuMe}$ according to the procedure described in the literature.[27]

(E)-1-tert-Butyl-1-methyl-2-undecylidenehydrazine ($2a_{tBuMe}$). $2a_{tBuMe}$ was prepared from the crude reaction mixture (3.57 g)

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containing $\mathbf{2a}_{tBuH}$ and isolated by HPLC (Phenomenex Luna 5u NH_2 100 × 21.20 mm column with hexane as an eluent) as a colorless oil (1.20 g). ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 6.8 Hz, 3H), 1.18 (s, 9H), 1.26−1.33 (c, 14H), 1.48 (quint, J = 7.3 Hz, 2H), 2.22 (dq, J = 5.0 Hz, 7.3 Hz, 2H), 2.55 (s, 3H), 6.65 (t, J = 5.0 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 14.1, 22.6, 26.8, 27.5, 29.2, 29.3, 29.5, 29.6 × 2, 31.9, 32.0, 33.5, 58.0, 137.4 (C═N). IR (ATR): 2957 m, 2923 s, 2853 m, 1462 w, 1360 w, 1246 w cm^{-1}. MS *m/z* (relative intensity): 254 (11), 239 (100), 72 (26), 57 (9). HRMS (CI): calcd for $C_{16}H_{34}N_2$ (M^+ + 1) 254.2722, found 254.2724.

(E)- and (Z)-1-(3,3-Dimethylundecylidene)-2-methylhydrazine ($\mathbf{2b}_{MeH}$, E/Z = 84/16). 3,3-Dimethylundecanal (218 mg, 1.10 mmol) was reacted with methylhydrazine in CH_2Cl_2 to produce $\mathbf{2b}_{MeH}$. After evaporation of volatiles, a colorless oil (236 mg) was obtained. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.3 Hz, 3H, *E*- and *Z*-isomers), 0.90 (s, 6H, *E*-isomer), 0.95 (s, 6H, *Z*-isomer), 1.18−1.32 (c, 14H, *E*- and *Z*-isomers), 1.93 (d, J = 5.3 Hz, 2H, *Z*-isomer), 2.09 (d, J = 6.2 Hz, 2H, *E*-isomer), 2.82 (s, 3H, *Z*-isomer), 2.95 (s, 3H, *E*-isomer), 6.60 (t, J = 5.3 Hz, 1H, *Z*-isomer), 6.95 (t, J = 6.2 Hz, 1H, *E*-isomer). However, $\mathbf{2b}_{MeH}$ in analytically pure form could not be obtained because of the instability. Therefore, $\mathbf{2b}_{MeH}$ was converted into **4b** according to the procedure described in the literature.[26]

(E)- and (Z)-1-tert-Butyl-2-(3,3-dimethylundecylidene)hydrazine ($\mathbf{2b}_{tBuH}$, E/Z = 84/16). 3,3-Dimethylundecanal (406 mg, 2.05 mmol) was reacted with *tert*-butylhydrazine in CH_2Cl_2 to produce $\mathbf{2b}_{tBuH}$. After evaporation of volatiles, a colorless oil (542 mg) was obtained. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H, *E*- and *Z*-isomers), 0.89 (s, 9H, *E*-isomer), 1.19 (s, 9H, *Z*-isomer), 1.21−1.31 (c, 14H, *E*- and *Z*-isomers), 1.91 (d, J = 5.8 Hz, 2H, *Z*-isomer), 2.07 (d, J = 6.4 Hz, 2H, *E*-isomer), 6.61 (t, J = 5.8 Hz, 1H, *Z*-isomer), 7.05 (t, J = 6.4 Hz, 1H, *E*-isomer). However, $\mathbf{2b}_{tBuH}$ in analytically pure form could not be obtained because of the instability. All attempts to convert $\mathbf{2b}_{tBuH}$ into other compounds were also unsuccessful.

(E)-2-(3,3-Dimethylundecylidene)-1,1-dimethylhydrazine ($\mathbf{2b}_{Me2}$). 3,3-Dimethylundecanal (1.09 g, 5.50 mmol) was reacted with *N*,*N*-dimethylhydrazine in CH_2Cl_2 to produce $\mathbf{2b}_{Me2}$, which was isolated by flash column chromatography on SiO_2 (R_f = 0.15 in hexane) in 72% (952 mg, 3.96 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H), 0.90 (s, 6H), 1.18−1.30 (c, 14H), 2.12 (d, J = 6.0 Hz, 2H), 2.73 (s, 6H), 6.70 (t, J = 6.0 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 14.1, 22.6, 23.8, 27.0, 29.3, 29.6, 30.4, 31.8, 33.3, 42.3, 43.5, 44.7, 137.9. IR (ATR): 2954 m, 2925 s, 2853 m, 2825 w, 1603 w, 1468 m, 1014 m cm^{-1}. MS: *m/z* (relative intensity): 240 (M^+, 11), 86 (93), 87 (100), 44 (46). HRMS (EI) calcd for $C_{15}H_{32}N_2$ (M^+): 240.2565; found: 240.2564.

(E)- and (Z)-1-tert-Butyl-2-(3-methylundecylidene)hydrazine ($\mathbf{2q}_{tBuH}$). *i. Preparation of Ethyl 3-Methylundecanoate.* The procedure reported by Cahiez et al.[28] was modified by using ethyl crotonate (TCI, 5.74 g, 50.3 mmol) to produce ethyl 3-methylundecanoate, which was isolated by distillation (bp =90 °C/0.3 mmHg) in 84% yield (9.65 g, 42.2 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H), 0.92 (d, J = 6.4 Hz, 3H), 1.14−1.35 (c, 17H), 1.94 (m, 1H), 2.08 (dd, J = 7.8, 14.7 Hz, 1H), 2.28 (dd, 1H, J = 5.9, 14.7 Hz), 4.12 (q, J = 7.3 Hz, 2H). ^{13}C NMR ($CDCl_3$): δ 14.0, 14.2, 19.7, 22.6, 26.8, 29.2, 29.5, 29.7, 30.3, 31.8, 36.7, 41.9, 60.0, 173.3. IR (ATR): 2957 w, 2923 m, 2854 m, 1736 s, 1462 w, 1372 w, 1183 m, 1033 m cm^{-1}. MS: *m/z* (relative intensity): 229 (12), 183 (23), 115 (25), 88 (100). HRMS (EI) calcd for $C_{14}H_{28}O_2$ (M^+): 228.2089, found 228.2092.

ii. Preparation of 3-Methylundecanal. The procedure reported by Tochtrop et al.[29] was modified by using ethyl 3-methylundecanoate (9.65 g, 42.2 mmol) to produce 3-methylundecanal, which was isolated by flash column chromatography on SiO_2 (R_f = 0.28 in hexane/EtOAc = 20/1) in 64% yield (4.98 g, 27.0 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.3 Hz, 3H), 0.95 (d, J = 6.9 Hz, 3H), 1.18−1.36 (c, 14H), 2.05 (m, 1H), 2.23 (ddd, J = 2.3, 6.2, 14.6 Hz, 1H), 2.38 (ddd, J = 2.3, 6.2, 12.0 Hz, 1H), 9.75 (t, J = 2.3 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 14.0, 19.9, 22.6, 26.9, 28.1, 29.2, 29.5, 29.6, 31.8, 36.8, 51.0, 203.0. IR (ATR): 2956 w, 2923 s, 2854 m, 2711 w, 1725 s, 1462 w, 1378 w cm^{-1}. MS: *m/z* (relative intensity): 140 (53), 111 (36), 97 (45), 81 (31), 71 (100), 57 (46), 55 (56). HRMS (CI) calcd for $C_{12}H_{25}O$ (M^+ + 1): 185.1905, found 185.1909.

iii. (E)- and (Z)-1-tert-Butyl-2-(3-methylundecylidene)hydrazine ($\mathbf{2q}_{tBuH}$, E/Z = 66/34). 3-Methylundecanal (562 g, 3.05 mmol) was reacted with *tert*-butylhydrazine in CH_2Cl_2 to produce $\mathbf{2q}_{tBuH}$. After evaporation of volatiles, a colorless oil (812 mg) was obtained. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 6.8 Hz, 3H, *E*- and *Z*-isomers), 0.89 (d, J = 6.8 Hz, 3H, *E*-isomer), 0.95 (d, J = 6.8 Hz, 3H, *Z*-isomer), 1.16 (s, 9H, *E*-isomer), 1.19 (s, 9H, *Z*-isomer), 1.21−1.31 (c, 14H, *E*- and *Z*-isomers), 1.68 (c, 1H, *E*-isomer), 1.85 (c, 1H, *Z*-isomer), 2.00 (c, 2H, *E*-isomer), 2.17 (c, 1H, *Z*-isomer), 6.52 (t, J = 5.0 Hz, 1H, *Z*-isomer), 7.01 (t, J = 5.5 Hz, 1H, *E*-isomer). However, $\mathbf{2q}_{tBuH}$ in analytically pure form could not be obtained due to the instability. All attempts to convert $\mathbf{2q}_{tBuH}$ into other compounds were also unsuccessful.

*Undecanenitrile (**3a**).* Compound **3a** was isolated by flash column chromatography on SiO_2 (R_f = 0.48 in hexane/EtOAc = 10/1) in 42% yield (35.0 mg, 0.210 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H), 1.20−1.36 (c, 12H), 1.43 (quint, J = 7.2 Hz, 2H), 1.65 (quint, J = 7.2 Hz, 2H), 2.33 (t, J = 7.2 Hz, 2H). ^{13}C NMR ($CDCl_3$): δ 14.1, 17.1, 22.6, 25.3, 28.6, 28.7, 29.2, 29.3, 29.4, 31.8, 119.8. These spectral data were in complete agreement with the published data.[30]

*3,3-Dimethylundecanenitrile (**3b**).* Compound **3b** was isolated by flash column chromatography on SiO_2 (R_f = 0.24 in hexane/EtOAc = 10/1) in 75% yield (73.2 mg, 0.375 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H), 1.04 (s, 6H), 1.20−1.36 (c, 14H), 2.21 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 14.1, 22.6, 24.0, 26.7, 29.2, 29.5, 30.1, 30.4, 31.8, 33.0, 41.5, 118.5. IR (ATR): 2958 m, 2926 s, 2855 m, 2927 w, 2246 w, 1468 m cm^{-1}. MS: *m/z* (relative intensity): 180 (6), 166 (3), 152 (7), 138 (14), 124 (21), 111 (23), 96 (23), 82 (68), 57 (100). HRMS (CI) calcd for $C_{13}H_{26}N$ (M^+ + 1): 196.2065, found 196.2066.

*3-Methyl-3-phenylbutanenitrile (**3c**).* Compound **3c** was isolated by flash column chromatography on SiO_2 (R_f = 0.36 in hexane/EtOAc = 10/1) in 78% yield (61.6 mg, 0.390 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 1.51 (s, 6H), 2.61 (s, 2H), 7.23−7.27 (c, 1H), 7.33−7.38 (c, 4H). ^{13}C NMR ($CDCl_3$): δ 28.2, 32.5, 36.8, 118.1, 125.0, 126.7, 128.5, 145.7. IR (ATR): 2969 w, 2249 w, 764 s, 698 s cm^{-1}. MS: *m/z* (relative intensity): 159 (61, M^+), 144 (51), 127 (30), 120 (100), 102 (38), 92 (63), 80 (32), 58 (73). HRMS (EI) calcd for $C_{11}H_{13}N$ (M^+): 159.1048, found 159.1047.

*2-(Adamantan-1-yl)acetonitrile (**3d**).* Compound **3d** was isolated by flash column chromatography on SiO_2 (R_f = 0.38 in hexane/EtOAc = 10/1) in 48% yield (42.0 mg, 0.240 mmol) as a white solid. Mp = 75−76 °C. ^{1}H NMR ($CDCl_3$): δ 1.62 (c, 6H), 1.65−1.74 (c, 6H), 2.03 (m, 3H), 2.10 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 28.1, 32.0, 32.1, 36.1, 41.6, 117.8. IR (ATR): 2898 s, 2848 m, 2238 w, 1444 m cm^{-1}. MS: *m/z* (relative intensity): 135 (100), 107 (13), 93 (26), 79 (29), 67 (10). HRMS (CI) calcd for $C_{12}H_{18}N$ (M^+ + 1): 176.1439, found 176.1438.

*3-Hydroxy-3-methylundecanenitrile (**3e**).* Compound **3e** was isolated by flash column chromatography on SiO_2 (R_f = 0.13 in hexane/EtOAc = 5/1) in 86% yield (84.8 mg, 0.430 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H), 1.27−1.32 (c, 12H), 1.36 (s, 3H), 1.61 (m, 2H), 1.78 (bs, 1H), 2.49 (d, J = 16.5 Hz, 1H), 2.51 (d, J = 16.5 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 13.9, 22.5, 23.7, 26.4, 29.0, 29.3, 29.7, 31.0, 31.7, 41.4, 70.9, 117.7. IR (ATR): 3446 w, 2925 s, 2855 m, 2253 w, 1464 m, 1379 m, 1132 m cm^{-1}. MS: *m/z* (relative intensity): 182 (45), 180 (6), 157 (100), 141 (56), 136 (35), 123 (43), 109 (34), 86 (32), 66 (25). HRMS (CI) calcd for $C_{12}H_{24}NO$ (M^+ + 1): 198.1858, found 198.1857.

*3-Hydroxy-3-phenylbutanenitrile (**3f**).* Compound **3f** was isolated by flash column chromatography on SiO_2 (R_f = 0.50 in hexane/EtOAc = 1/1) in 63% yield (50.7 mg, 0.315 mmol) as a colorless oil. ^{1}H NMR ($CDCl_3$): δ 1.75 (s, 3H), 2.45 (bs, 1H), 2.79 (d, J = 16.4 Hz, 1H), 2.84 (d, J = 16.4 Hz, 1H), 7.30−7.34 (c, 1H), 7.37−7.41 (c, 2H), 7.46−7.49 (c, 2H). ^{13}C NMR ($CDCl_3$): δ 28.9, 33.4, 72.3, 117.3, 124.3, 127.8, 128.5, 144.5. IR (ATR): 3442 w, 2978 w, 2255 w, 765 m, 699 s cm^{-1}. MS: *m/z* (relative intensity): 143 (5), 121 (100),

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105 (34), 91 (12), 77 (16), 60 (10). HRMS (CI) calcd for $C_{10}H_{12}NO$ ($M^+ + 1$): 162.0919, found 162.0919.

*3-Hydroxy-3-propylhexanenitrile (**3g**).* Compound **3g** was isolated by flash column chromatography on SiO_2 (R_f = 0.14 in hexane/EtOAc = 5/1) in 80% yield (62.0 mg, 0.40 mmol) as a colorless oil. ^1H NMR ($CDCl_3$): δ 0.94 (t, J = 7.2 Hz, 6H), 1.31−1.40 (m, 4H), 1.52−1.62 (m, 4H), 2.00 (s, 1H), 2.50 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 14.2, 16.7, 29.1, 41.2, 72.9, 117.7. IR (ATR): 3457 w, 2960 s, 2935 m, 2874 m, 2253 w, 1465 m, 1140 m cm^{-1}. MS: m/z (relative intensity): 112 (29), 97 (3), 71 (100), 55 (18). HRMS (CI) calcd for $C_9H_{18}NO$ ($M^+ + 1$): 156.1388, found 156.1387.

*3-Hydroxy-3,3-diphenylpropanenitrile (**3h**).* Compound **3h** was isolated by flash column chromatography on SiO_2 (R_f = 0.11 in hexane/EtOAc = 5/1) in 66% yield (73.7 mg, 0.330 mmol) as a white solid. Mp = 134−135 °C. ^1H NMR ($CDCl_3$): δ 2.81 (bs, 1H), 3.27 (s, 2H), 7.29−7.41 (c, 10H). ^{13}C NMR ($CDCl_3$): δ 32.5, 76.4, 117.1, 125.7, 128.2, 128.6, 143.7. These spectral data were in complete agreement with the published data.[31]

*2-(1-Hydroxycyclopentyl)acetonitrile (**3i**).* Compound **3i** was isolated by flash column chromatography on SiO_2 (R_f = 0.19 in hexane/EtOAc = 5/1) in 78% yield (48.8 mg, 0.390 mmol) as a colorless oil. ^1H NMR ($CDCl_3$): δ 1.66−1.92 (c, 8H), 2.66 (s, 2H), 2.82 (bs, 1H). ^{13}C NMR ($CDCl_3$): δ 23.4, 29.6, 38.9, 79.0, 118.1. IR (ATR): 3437 m, 2961 m, 2875 w, 2253 w, 1735 w, 1014 s cm^{-1}. MS: m/z (relative intensity): 96 (61), 85 (79), 83 (40), 67 (69), 55 (100). HRMS (CI) calcd for $C_7H_{12}NO$ ($M^+ + 1$): 126.0919, found 126.0919.

*2-(1-Hydroxycyclohexyl)acetonitrile (**3j**).* Compound **3j** was isolated by flash column chromatography on SiO_2 (R_f = 0.16 in hexane/EtOAc = 5/1) in 81% yield (56.4 mg, 0.405 mmol) as a colorless oil. ^1H NMR ($CDCl_3$): δ 1.24−1.75 (c, 10H), 2.52 (s, 2H), 2.60 (bs, 1H). ^{13}C NMR ($CDCl_3$): δ 21.6, 24.9, 31.6, 36.6, 69.8, 117.6. These spectral data were in complete agreement with the published data.[32]

*2-(4-Hydroxytetrahydro-2H-pyran-4-yl)acetonitrile (**3k**).* Compound **3k** was isolated by flash column chromatography on SiO_2 (R_f = 0.16 in hexane/EtOAc = 1/1) in 81% yield (57.2 mg, 0.405 mmol) as a white solid. Mp = 78−79 °C. ^1H NMR ($CDCl_3$): δ 1.67−1.83 (m, 4H), 2.36 (bs, 1H), 2.56 (s, 2H), 3.74−3.83 (m, 4H). ^{13}C NMR ($CDCl_3$): δ 32.6, 36.8, 63.2, 67.4, 116.7. IR (ATR): 3372 m, 2964 w, 2940 w, 2880 w, 2244 w, 1089 s, 838 s cm^{-1}. MS: m/z (relative intensity): 123 (28), 96 (96), 69 (100), 54 (94). HRMS (CI) calcd for $C_7H_{12}NO_2$ ($M^+ + 1$): 142.0868, found 142.0867.

*2-(1-Hydroxycycloheptyl)acetonitrile (**3l**).* Compound **3l** was isolated by flash column chromatography on SiO_2 (R_f = 0.10 in hexane/EtOAc = 5/1) in 81% yield (62.1 mg, 0.405 mmol) as a colorless oil. ^1H NMR ($CDCl_3$): δ 1.39−1.87 (c, 12H), 2.16 (bs, 1H), 2.52 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 21.9, 29.1, 32.6, 40.6, 73.8, 118.8. These spectral data were in complete agreement with the published data.[33]

*2-(1-Hydroxycyclooctyl)acetonitrile (**3m**).* Compound **3m** was isolated by flash column chromatography on SiO_2 (R_f = 0.16 in hexane/EtOAc = 5/1) in 86% (71.9 mg, 0.430 mmol) yield as a colorless oil. ^1H NMR ($CDCl_3$): δ 1.26−1.74 (c, 12H), 1.87−1.94 (m, 2H), 2.28 (bs, 1H), 2.52 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 21.9, 24.4, 27.7, 31.3, 36.7, 73.3, 117.7. IR (ATR): 3444 w, 2922 s, 2855 m, 2251 w, 1473 m, 1013 s cm^{-1}. MS: m/z (relative intensity): 152 (18), 127 (100), 120 (66), 109 (76), 96 (83), 82 (60), 57 (65). HRMS (CI) calcd for $C_{10}H_{18}NO$ ($M^+ + 1$): 168.1388, found 168.1388.

*2-((8R,9S,13S,14S,17R)-3,17-Dihydroxy-13-methyl-7,8,9,11,12,13,14,15,16,17-decahydro-6H-cyclopenta[a]-phenanthren-17-yl)acetonitrile (**3n**).* Compound **3n** was isolated by flash column chromatography on SiO_2 (R_f = 0.12 in hexane/EtOAc = 2/1) in 75% yield (116.8 mg, 0.375 mmol) as a white solid. Mp = 227−228 °C. $[a]^{22.0}_D$ +46.44 (c 5.0 × 10^{-1}, pyridine); authentic samples: $[\alpha]^{22.0}_D$ +50 (c 5.0 × 10^{-1}, pyridine),[34] $[a]^{25.0}_D$ +46 (c 1.0, pyridine).[35] ^1H NMR (DMSO-d_6): δ 0.79 (s, 3H), 1.19−1.40 (c), 1.59 (c), 1.80 (c), 2.05 (c), 2.23 (c), 2.50−2.75 (c) 4.95 (s, 1H), 6.42(s, J = 2.2 Hz, 1H), 6.50 (dd, J = 2.2, 8.4 Hz, 1H), 7.03 (d, J = 8.4 Hz, 1H), 9.00 (s, 1H). ^{13}C NMR (DMSO-d_6): δ 14.1, 22.5, 25.9, 27.1, 27.9, 29.2, 31.3, 35.6, 39.8, 43.0, 46.2, 49.7, 80.7, 112.7, 114.9, 120.1, 126.0, 130.2, 137.1, 155.0. These spectral data were in complete agreement with the published data.[36]

*tert-Butyl (1-Cyano-2-methylpropan-2-yl)carbamate (**3o**).* Compound **3o** was isolated by flash column chromatography on SiO_2 (R_f = 0.24 in hexane/EtOAc = 5/1) in 63% yield (62.4 mg, 0.315 mmol) as a white solid. Mp = 64−65 °C. ^1H NMR ($CDCl_3$): δ 1.41 (s, 9H), 1.44 (s, 6H), 2.93 (s, 2H), 4.64 (bs, 1H). ^{13}C NMR ($CDCl_3$): δ 27.1, 28.2, 28.4, 50.7, 79.8, 117.7, 154.2. IR (ATR): 3356 w, 2984 w, 2249 w, 1682 s, 1515 s, 1458 m, 1365 m, 1292 m, 1247 s, 1167 s, 1153 s, 1082 s cm^{-1}. MS m/z (relative intensity): 158 (28), 143 (20), 109 (40), 84 (100), 81 (21), 68 (45). HRMS (CI) calcd for $C_{10}H_{19}N_2O_2$ ($M^+ + 1$): 199.1447, found 199.1446.

*tert-Butyl (1-(Cyanomethyl)cyclohexyl)carbamate (**3p**).* Compound **3p** was isolated by flash column chromatography on SiO_2 (R_f = 0.15 in hexane/EtOAc = 5/1) in 76% yield (90.5 mg, 0.380 mmol) as a white solid. Mp = 72−73 °C. ^1H NMR ($CDCl_3$): δ 1.25−1.62 (c, 10H), 1.44 (s, 9H), 2.05 (bs, 2H), 4.55 (bs, 1H). ^{13}C NMR ($CDCl_3$): δ 21.2, 25.0, 27.8, 28.3, 34.4, 52.7, 79.7, 117.6, 154.2. IR (ATR): 3373 w, 3332 w, 2979 w, 2939 w, 2859 w, 2245 w, 1679 m, 1523 m, 1251 m, 1163 s, 1094 m, 981 m cm^{-1}. MS: m/z (relative intensity): 198 (12), 142 (54), 124 (37), 98 (65), 95 (36), 81 (39), 57 (100). HRMS (CI) calcd for $C_{13}H_{23}N_2O_2$ ($M^+ + 1$): 239.1760, found 239.1758.

*3-Methylundecanenitrile (**3q**).* Compound **3q** was isolated by flash column chromatography on SiO_2 (R_f = 0.23 in hexane/EtOAc = 10/1) in 32% yield (29.0 mg, 0.160 mmol) as a colorless oil. ^1H NMR ($CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3H), 1.08 (d, J = 6.4 Hz, 3H), 1.24−1.44 (c, 14H), 1.83 (m, 1H), 2.23 (dd, J = 6.8, 17.2 Hz, 1H) 2.31 (dd, J = 5.0, 17.2 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 14.0, 19.4, 22.6, 24.4, 26.8, 29.2, 29.4, 29.5, 30.4, 31.8, 35.8, 118. IR (ATR): 2957 m, 2925 s, 2854 m, 2247 w, 1462 m cm^{-1}. MS: m/z (relative intensity): 180 (31), 166 (80), 152 (81), 139 (79), 125 (100), 109 (50), 94 (44), 72 (40). HRMS (CI) calcd for $C_{12}H_{24}N$ ($M^+ + 1$): 182.1909, found 182.1907.

*N-Phenyl-((E)-1-methyl-2-undecylidenehydrazine)-1-carboxamide (**4a**).* Compound **4a** was prepared from the crude reaction mixture (3.50 g) containing $\mathbf{2a_{MeH}}$ and isolated by NH_2 modified column chromatography on SiO_2 (R_f = 0.08 in hexane) as a white solid (4.70 g). Mp = 45−46 °C. ^1H NMR ($CDCl_3$): δ 0.88 (t, J = 6.8 Hz, 3H), 1.20−1.44 (c, 14H), 1.57 (quint, J = 6.8 Hz, 2H), 2.36 (dq, J = 6.8, 5.2 Hz, 2H), 3.24 (s, 3H), 6.90 (t, J = 5.2 Hz, 1H), 7.03 (t, J = 7.2 Hz, 1H), 7.30 (t, J = 7.2 Hz, 2H), 7.51 (c, 2H). 8.67 (bs, 1H). ^{13}C NMR ($CDCl_3$): δ 14.0, 22.6, 26.9, 27.4, 29.1, 29.2, 29.4, 29.5, 29.5, 31.8, 32.8, 119.1, 122.8, 128.8, 138.6, 140.6, 153.0. IR (ATR): 3360 w, 2919 m, 2850 w, 1681 s, 1591 m, 1528 s, 1442 m, 1325 w, 1308 m, 1122 m, 1015 m. MS: m/z (relative intensity): 177 (11), 176 (100), 93 (17), 72 (40), 71 (11), 57 (12), 55 (14). HRMS (CI) calcd for $C_{19}H_{32}N_3O$ ($M^+ + 1$): 318.2545, found 318.2552.

*N-Phenyl-((E)-2-(3,3-dimethylundecylidene)-1-methylhydrazine)-1-carboxamide (**4b**).* Compound **4b** was prepared from the crude reaction mixture (236 mg) containing $\mathbf{2b_{MeH}}$ and isolated by NH_2 modified column chromatography on SiO_2 (R_f = 0.03 in hexane) as a colorless oil (99 mg). ^1H NMR ($CDCl_3$): δ 0.87 (t, J = 6.9 Hz, 3H), 0.96 (s, 6H), 1.18−1.32 (c, 14H), 2.25 (d, J = 6.1 Hz, 2H), 3.26 (s, 3H), 6.90 (t, 1H, J = 6.1 Hz), 7.03 (t, J = 7.3 Hz, 1H), 7.30 (c, 2H), 7.51 (d, 2H, J = 1.6 Hz). 8.69 (bs, 1H). ^{13}C NMR ($CDCl_3$): δ 14.0, 22.6, 23.9, 27.2, 27.5, 29.2, 29.6, 30.4, 31.8, 33.7, 42.2, 44.6, 119.1, 122.8, 128.8, 138.6, 138.8, 153.0. IR (ATR): 3380 w, 2925 m, 2854 w, 1694 m, 1592 w, 1521 s, 1442 m, 1122 m, 1011 m cm^{-1}. MS: m/z (relative intensity): 167 (29), 149 (100), 72 (38), 71 (22), 57 (39), 43 (22), 41 (11). HRMS (EI) calcd for $C_{21}H_{35}N_3O$ (M^+): 345.2780, found 345.2778.

■ ASSOCIATED CONTENT

Supporting Information

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NMR spectra of all new compounds (PDF)

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Notes

The authors declare no competing financial interest.

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