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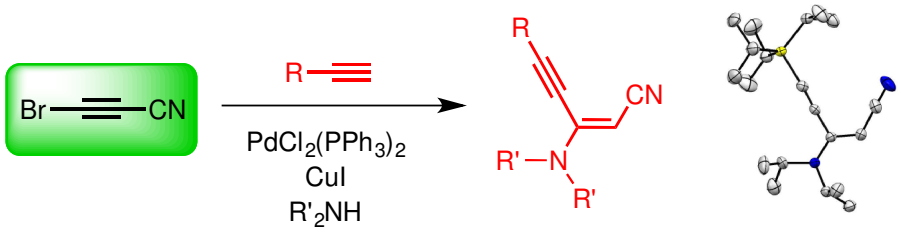


Bromocyanoacetylene is able to provide conjugated enynenitriles stereoselectively in one step from alkynes, secondary amines and co-catalysts.

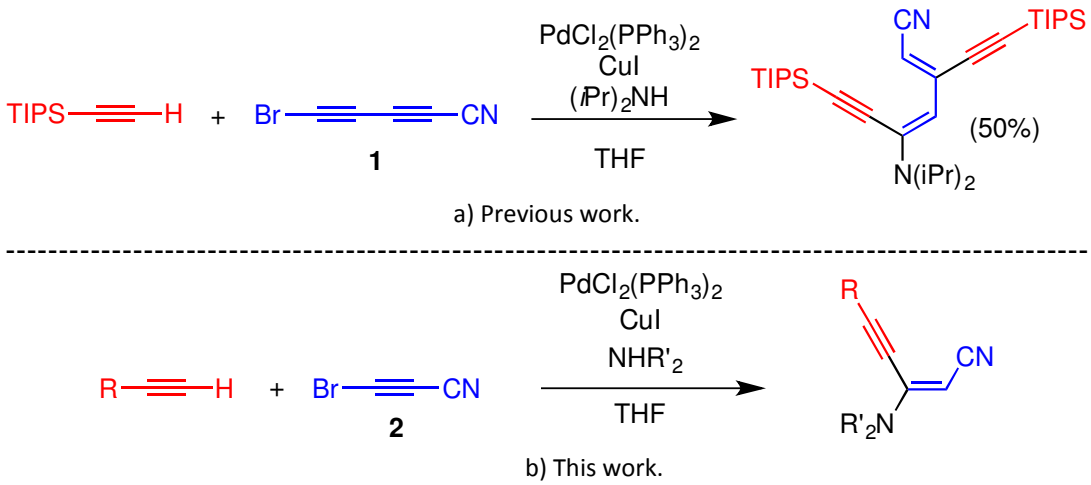
The chemical reactivity of bromocyanoacetylene has been evaluated for the first time by making it react with terminal alkynes and secondary amines in the presence of bis(triphenylphosphine)palladium dichloride and copper iodide as co-catalysts. This reaction provided new conjugated enynenitriles stereoselectively in one step in variable yields.

The synthesis of 1,3-enynes is of particular interest in different fields such as biology, electronics and photonics.[1] Numerous recent publications report new ways to overcome the problem of synthesizing 1,3-enynes in a controlled manner, especially concerning the configuration of the C=C double bond.[2] In most cases, the synthesis of 1,3-enynes proceeds in two steps by first forming a functionalized alkene having the desired configuration and then coupling a terminal alkyne following a Sonogashira or a Negishi-like coupling.[3] Alternatively, the addition of the alkyne may be performed first and the C=C double bond is formed subsequently.[4] More rarely, we can find in the literature elegant methods using a one-pot procedure for the formation of the alkene and the addition of the alkyne[5] or direct formation of the 1,3-enyne by alkyne cross-coupling.[6]

Our laboratory recently reported on the particular reactivity of bromocyanobutadiyne BrC_5N **1** with triisopropylsilylacetylene in the presence of palladium(II) complexes and copper(I) as co-catalysts, as well as diisopropylamine. We showed the formation of an unexpected dienyne in a stereoselective fashion (Scheme 1a).[7] Inspired by this work, we wondered whether the smaller homologous counterpart

bromocyanoacetylene BrC_3N **2** could react the same way or would lead to a more standard reactivity such as a Cadiot-Chodkiewicz coupling as does the corresponding ester.[8] If the reactivity would be the same as BrC_5N, BrC_3N should be a precursor of conjugated enynenitriles (Scheme 1b). Surprisingly, to the best of our knowledge, the chemical reactivity of BrC_3N in solution has never been investigated whereas its halogen-free counterpart HC_3N has largely been documented.[9]

In this article, we report the stereoselective synthesis of conjugated enynenitriles in moderate to good yields in one step from BrC_3N, a terminal alkyne and an amine using bis(triphenylphosphine)palladium dichloride and copper iodide as co-catalysts.

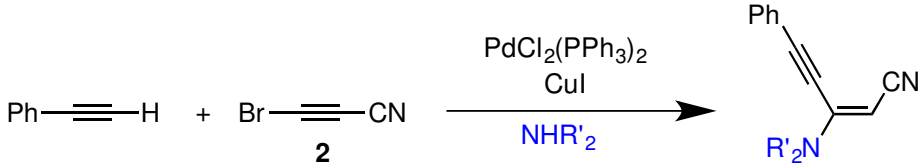


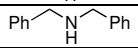
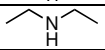
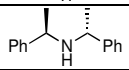
Scheme 1 a) Previous work: reactivity of BrC_5N; b) This work: reactivity of BrC_3N.

First, the reactivity of BrC_3N, which was synthesized according to a described procedure,[10] was evaluated with different amines (5 equiv) and phenylacetylene (2 equiv). Bis(triphenylphosphine)palladium dichloride (10 mol%) and copper iodide (10 mol%) were used as co-catalysts and the reaction was run each time in THF overnight at room temperature under inert atmosphere. Four amines were tested: the reaction only led to degradation with morpholine or dibenzylamine, but enynenitriles **5**, **6** and **7** were obtained in 34% yield with diethylamine, 82% yield with diisopropylamine and 42% yield with diethylbenzylamine (Table 1). The *E*-configuration of the CC double bond was clearly established by 2D-NMR spectroscopy and no traces of the *Z*-isomer could be observed.

The fact that the reaction did not work with morpholine could be explained by a stronger nucleophilicity that would imply potential multiple additions on BrC_3N before phenylacetylene could react.[11] Concerning dibenzylamine, the reasons are more obscure. Steric hindrance cannot be invoked since enynenitrile **7** could be obtained with diethylbenzylamine. Given these five results, diisopropylamine was chosen to evaluate the scope of this reaction with different alkynes.

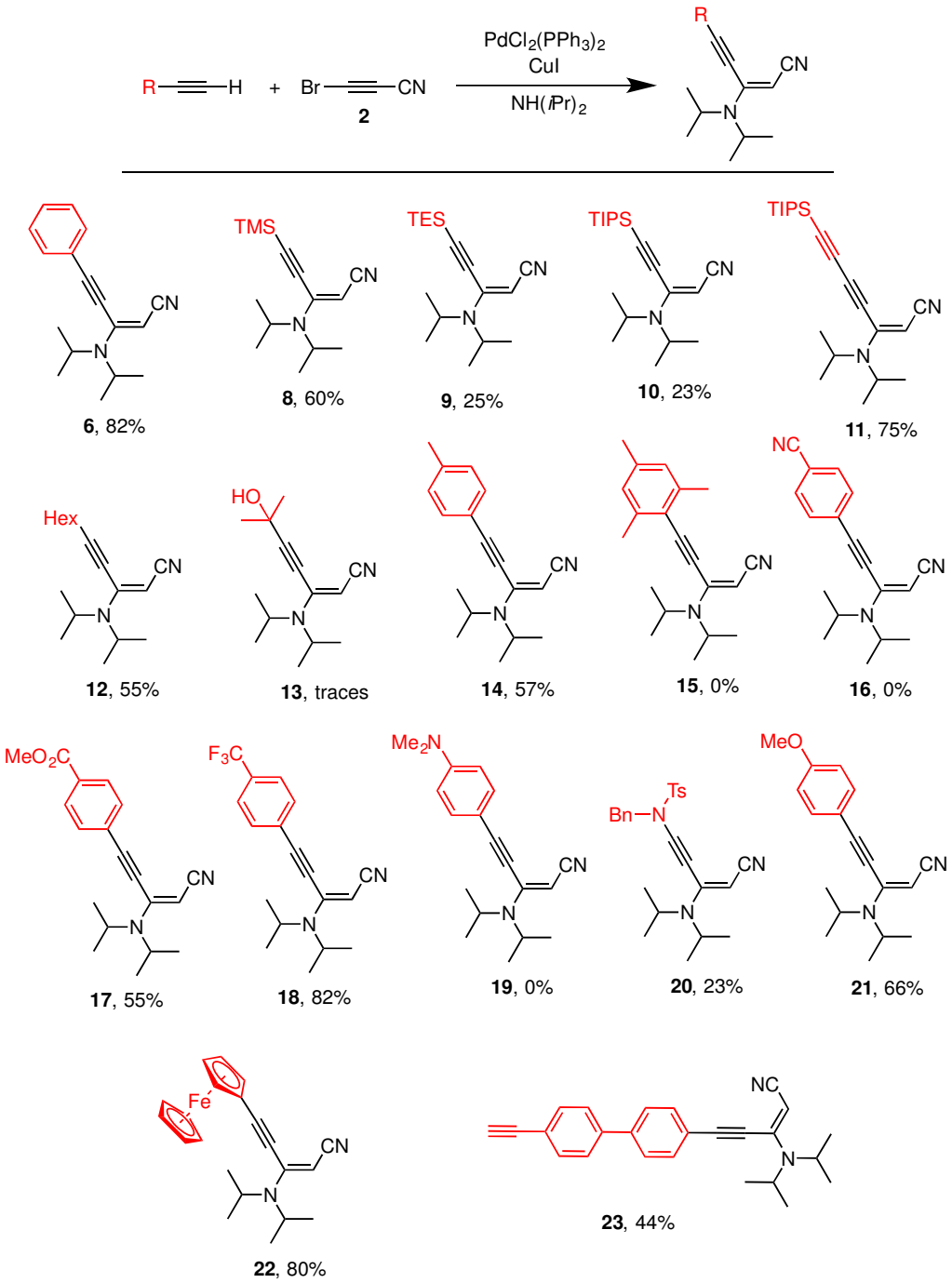
Table 1 Formation of enynenitriles with different amines.[a]



Entry	NHR'_2	Product	Yield [b]
1		**3**	0%
2		**4**	0%
3		**5**	34%
4		**6**	82%
5		**7**	42%

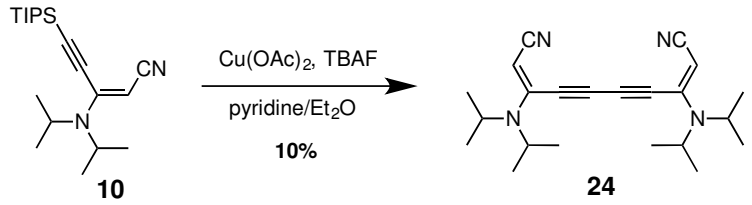
[a] Reaction conditions: bromocyanoacetylene (0.2 M in THF), phenylacetylene (2 equiv. *vs.* BrC_3N), $PdCl_2(PPh_3)_2$ (0.1 equiv. *vs.* BrC_3N), CuI (0.1 equiv. *vs.* BrC_3N), NHR'_2 (5 equiv. *vs.* BrC_3N), r.t., 17h. [b] Isolated yield.

In the same conditions as previously described, the reactivity of BrC_3N was evaluated by reacting it with different terminal alkynes (scheme 2). Using trimethylsilylacetylene instead of phenylacetylene slightly lowers the yield to 60% (compound **8**). However, the use of triethylsilylacetylene or triisopropylsilylacetylene dramatically affects the reaction and leads to the corresponding enynes in 25 and 23% yield respectively (compounds **9** and **10**). Steric hindrance is probably responsible for this drop of yield. This interpretation is confirmed by using 2,4,6-trimethylphenylacetylene that completely inhibits the reaction (compound **15**). Moreover, when using triisopropylsilylbutadiyne, the obtained yield is 75% (compound **11**), which confirms that taking away a bulky group is better for the reaction. The use of 1-octyne and *para*-methylphenylacetylene leads to the corresponding products **12** and **14** in acceptable yields of 55 and 57% respectively, whereas only traces of enyne **13** were obtained from 2-methyl-but-3-yn-2-ol. It is important to notice that all the indicated yields were calculated from products isolated after column chromatography. When using para-cyanophenylacetylene, no corresponding enyne **16** could be obtained but only an insoluble product was isolated which structure was assigned to the product of homocoupling of the terminal acetylene (Glaser-type coupling) according to ^{1}H-NMR spectroscopy.[12] Nevertheless, electron-deficient alkynes are not prohibited since para-methylbenzoateacetylene and para-trifluoromethylphenylacetylene led to enynes **17** and **18** in 55 and 82% yields, respectively. Concerning electron-rich alkynes, no enyne could be isolated from the reaction with 4-ethynyl-*N*,*N*-dimethylbenzenamine. However, enynes **20, 21** and **22** were obtained from the corresponding ynamide[13], para-methoxyphenylacetylene and ethynylferrocene in 23, 66 and 80% yields respectively. Interestingly, when using a reactant bearing two terminal acetylenes separated by a biphenyl unit,[14] only one CC triple bond reacted to afford compound **23** in 44% yield. This observation opens possibilities to further functionalize this kind of compounds.



Scheme 2 Reactivity of BrC_3N using different terminal alkynes. Reaction conditions: bromocyanoacetylene (0.2 M in THF), alkyne (2 equiv. *vs.* BrC_3N), $PdCl_2(PPh_3)_2$ (0.1 equiv. *vs.* BrC_3N), CuI (0.1 equiv. *vs.* BrC_3N), diisopropylamine (5 equiv. *vs.* BrC_3N), r.t., 17h.

The reactivity of enyne **10** was evaluated by a one-pot deprotection-Eglington coupling reaction in the presence of TBAF and $Cu(OAc)_2$ in a mixture pyridine and diethyl ether leading to diyne **24** in 10% yield (scheme 3). Despite the very modest yield obtained for this sequence, it shows the possibility these enynes may offer in the future for diverse applications such as the construction of π-conjugated systems.[15]



Scheme 3 Synthesis of diyne **24** from enyne **10**

Crystals suitable for X-ray diffraction were obtained for compounds **2** and **10** (Figure 1). The structure of compound **2** shows a particularly short C-C single bond (1.38 Å), showing thus a significant double bond character. This is most probably due to the conjugation of the C≡C and the C≡N triple bonds.[16] The other distances are in agreement with usual bonds of their kinds (C-Br: 1.79 Å; C≡C: 1.19 Å; C≡N: 1.15 Å). The structure of compound **10** confirmed the *E*-configuration of the double bond. The two C-C single bonds linked to the C=C double bond are significantly shorter than usual C-C single bonds: 1.44 Å for the one next to the C≡C triple bond and 1.41 Å for the one next to the nitrile group. Likewise, the C=C double bond is slightly longer than usual: 1.37 Å. These distances are most probably due to the push-pull structure of the edifice with one electron-withdrawing group (the nitrile) conjugated to two electron-donating groups (the amine and the C≡C triple bond).

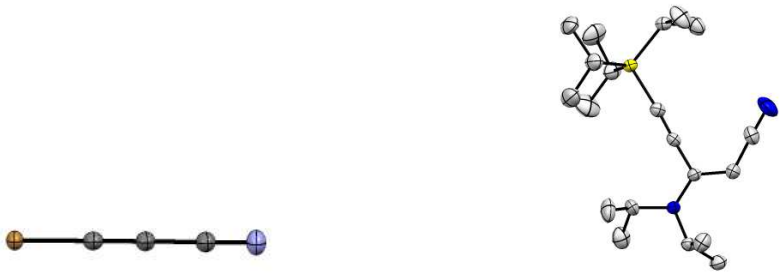


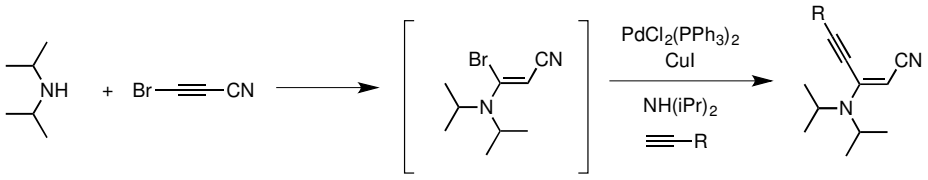
Figure 1 X-ray structures of compounds **2** (left) and **10** (right). Thermal ellipsoids are drawn with 50% probability. Concerning compound **10**, H-atoms were omitted for clarity.[17]

In order to rationalize the formation of enynenitriles from such conditions, we postulate that the first step is the addition of the amine. This step would direct the *E*-configuration of the CC double bond for steric reasons as indicated below. Then, a Sonogashira coupling can happen for coupling the alkyne (scheme 2).

The *E*-selectivity may be explained by steric arguments: the diisopropylamine (and to a lesser extent the diethylamine) group hinders the presence of the cyano group, which is bigger than a proton. Therefore, the *E*-isomer should be more stable than the *Z*-isomer. This statement was corroborated by G4MP2 high-level ab initio[18] and B3LYP/6-31+G(d,p)[19] DFT calculations using simple acetylene or phenylacetylene and diisopropylamine as substituents in the gas phase or in THF. In each case, the difference of free energy between the two isomers was significant (above 10 $kJ.mol^{-1}$) in the gas phase and was even reinforced in THF, reaching 24 $kJ.mol^{-1}$ for the simplest model (for more details, see electronic supplementary information).

We cannot rule out the fact that an ynamine has intermediately been formed as we demonstrated with BrC_5N.[7] Nevertheless, all attempts to synthesize the ynamine from BrC_3N and diisopropylamine were unsuccessful so far. An alternative mechanism that would consist in first a Cadiot-Chodkiewicz coupling between the two acetylenic compounds (to yield a

conjugated diyne) followed by the 1,4-addition of the amine is less likely. Indeed, we showed that the 1,6-addition of an amine to conjugated cyanobutadiyne derivatives is generally more favorable than the 1,4-addition.[20] However, we never detected any traces of a product coming from a 1,6-addition in these experiments, which tends to rule out this kind of mechanism.



Scheme 2 Postulated sequence of reactions leading to the formation of enynenitriles.

To conclude, this article describes an original method to synthesize 1,3-enynenitriles in one-step from acetylenic compounds in a stereoselective manner, which opens a new way towards 1,3-enynes. Moreover, to the best of our knowledge, the reactivity of BrC_3N, which synthesis has been reported for more than 50 years ago, had never been investigated, except recently for generating C_3N radical, C_3N^- anion and metal acetylides in the gas phase.[21] Therefore, BrC_3N appears as a promising precursor of novel molecules that could interest the field of optoelectronics.

Experimental section

General

Reactions were monitored by thin layer chromatography (Merck TLC silica gel 60 F_{254} on aluminum sheets) and visualized under UV irradiation at 254 nm or $KMnO_4$ staining solution. Compounds were purified by column chromatography using Geduran® silica gel 60 (0.040-0.063 nm). NMR spectra were recorded on Bruker Avance 400 MHz spectrometer. Spectra were recorded in deuterochloroform referenced to $CHCl_3$ (^{1}H, 7.26 ppm) or $CDCl_3$ (^{13}C, 77.2 ppm). Chemical shifts (δ) are reported in ppm and coupling contants (J) are reported in Hertz. The following abbreviations are used to describe multiplicity: s-singlet, d-doublet, t-triplet, q-quartet, quin-quintuplet, sept-septet and m-multiplet. HRMS experiments were carried out on a Waters Q-Tof 2 spectrometer.

Single crystal diffraction data were collected at low temperature on a D8 Venture Bruker AXS CMOS diffractometer with multilayers monochromatized Mo K α radiation. Structure was solved by dual-space algorithm using SHELXT program.[22] All non-hydrogen atoms were refined anisotropically by the full-matrix least-squares techniques using the program SHELXL-2014.[23] Hydrogen atoms were located geometrically and treated using a riding model with isotropic atomic displacement parameter constrained to the equivalent adp of the bonded carbon atom.

Bromocyanoacetylene (2). Bromocyanoacetylene **2** was synthesized according to a published procedure.[10] Crystal data (CCDC #1516110): C_3BrN, M = 129.95 g.mol^{-1}, T = 150 K, monoclinic, space group = *P 2$_1$/m*, a = 5.0950(10) Å, b = 6.1734(13) Å, c = 6.2035(14) Å, α = 90°, β = 95.735(9)°, γ = 90°, V = 194.14(7) Å^3, Z = 2, Dc = 2.223 g cm^{-3}, absorption coefficient = 10.357 mm^{-1}, F(000) = 120, reflections collected = 1670, independent reflections = 486 (Rint = 0.0407), data/restraints/ parameters = 486/0/31. Final R indices (I > 2σ): R1 = 0.0289. R indices (all data): wR2 = 0.0719, goodness-of-fit on F^2 of 1.217.

General procedure for preparation of enynes 5 to 23. A solution of 1-bromo-1-propynenitrile in 10 mL of THF (0.2 M) was placed into a two-neck flask under nitrogen atmosphere. The acetylene (2 equiv), $PdCl_2(PPh_3)_2$ (0.1 equiv) and the amine (5 equiv) were added quickly one after the other. The solution was degassed during 10 min of stirring and then CuI (0.1 equiv) was added. After 17h at r.t., the solvent was evaporated under vacuum. The residue was purified by column chromatography.

(*E*)-3-(diethylamino)-5-phenylpent-2-en-4-ynenitrile (5). The general procedure was followed with phenylacetylene and diethylamine. The residue was purified by chromatography (SiO_2, *n*-pentane/CH_2Cl_2 from 1/0 to 0/1). Compound **5** was obtained as orange oil in 34% yield (126.7 mg / 0.57 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 7.56 (m, 2H), 7.26-7.36 (m, 3H), 4.09 (s, 1H), 3.37 (q, $^3J_{HH}$ = 7.1 Hz, 4H), 1.18 (t, $^3J_{HH}$ = 7.1 Hz, 6H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 144.8, 132.1, 129.7, 128.5, 121.8, 121.2, 97.5, 81.6, 67.0, 45.5, 12.8. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 247.1211, found 247.1210.

(*E*)-3-(diisopropylamino)-5-phenylpent-2-en-4-ynenitrile (6). The general procedure was followed with phenylacetylene and diisopropylamine. Compound **6** was obtained as orange oil in 82% yield (307.5 mg / 1.48 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 7.59 (m, 2H), 7.35 (m, 3H), 4.24 (s, 1H), 3.97 (sept, $^3J_{HH}$ = 6.8 Hz, 2H), 1.27 (d, $^3J_{HH}$ = 6.9 Hz, 12H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 142.9, 131.3, 129.2, 128.0, 121.4, 120.9, 97.1, 82.9, 68.9, 48.9, 19.8. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 275.1524, found 275.1526.

(*E*)-3-(bis((*R*)-1-phenylethyl)amino)-5-phenylpent-2-en-4-ynenitrile (7). The general procedure was followed with phenylacetylene and (*R*)-bis((*R*)-1-phenylethyl)amine. Compound **7** was obtained as a brown oil in 42 % yield (139.3 mg / 0.36 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 7.60 – 7.56 (m, 2H), 7.45 – 7.33 (m, 3H), 7.32 – 7.16 (m, 10H), 5.37 (q, $^3J_{HH}$ = 7.2 Hz, 2H), 3.95 (s, 1H), 1.80 (d, $^3J_{HH}$ = 7.1 Hz, 6H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 143.0, 139.4, 132.6, 132.2, 129.8, 128.6, 128.6, 127.7, 127.1, 121.2, 98.8, 83.1, 73.1, 56.6, 17.1. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 399.1832, found 399.1833.

(*E*)-3-(diisopropylamino)-5-(trimethylsilyl)pent-2-en-4-ynenitrile (8). The general procedure was followed with trimethylsilylacetylene and diisopropylamine. Compound **8** was obtained as yellow oil in 60% yield (244.3 mg / 0.99 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 4.19 (s, 1H), 3.97 (sept, $^3J_{HH}$ = 7.0 Hz, 2H), 1.25 (d, $^3J_{HH}$ = 7.0 Hz, 12H), 0.25 (s, 9H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 143.7, 122.2, 105.4, 98.3, 70.9, 50.0, 20.9, 0.0. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 271.1607, found 271.1608.

(*E*)-3-(diisopropylamino)-5-(triethylsilyl)pent-2-en-4-ynenitrile (9). The general procedure was followed with triethylsilylacetylene and diisopropylamine. The residue was purified by chromatography (SiO_2, CH_2Cl_2). Compound **9** was obtained as a dark oil in 25% yield (40.7 mg / 0.14 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 4.20 (s, 1H), 3.98 (sept, $^3J_{HH}$ = 6.9 Hz, 2H), 1.26 (d, $^3J_{HH}$ = 6.9 Hz, 12H), 1.03 (t, $^3J_{HH}$ = 7.9 Hz, 9H), 0.69 (q, $^3J_{HH}$ = 7.9 Hz, 6H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 143.2, 121.6, 103.0, 98.7, 70.4, 49.4, 20.4, 7.5, 4.2. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 313.2071, found 313.2074.

(*E*)-3-(diisopropylamino)-5-(triisopropylsilyl)pent-2-en-4-ynenitrile (10). The general procedure was followed with triisopropylsilylacetylene and diisopropylamine. Compound **10** was obtained as a beige solid in 23% yield (128.2 mg / 0.44 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 4.18 (s, 1H), 4.03 (sept, $^3J_{HH}$ = 6.8 Hz, 2H), 1.24 (d, $^3J_{HH}$ = 6.9 Hz, 12H), 1.11 (m, 21H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 143.1, 121.5, 101.8, 99.2, 70.3, 49.5, 20.3, 18.6, 11.3. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 355.2546, found 355.2546. Crystal data (CCDC #1485944): $C_{20}H_{36}N_2Si$, M = 332.60 g.mol^{-1}, T = 150 K, orthorhombic, space group = *Pbca*, a = 15.4294(14) Å, b = 15.5710(14) Å, c = 17.8506(15) Å, α = 90°, β = 90°, γ = 90°, V = 4288.6(7)

Å^3, Z = 8, Dc = 1.030 g cm^{-3}, absorption coefficient = 0.112 mm^{-1}, F(000) = 1472, reflections collected = 32096, independent reflections = 4912 (Rint = 0.0887), data/restraints/ parameters = 4912/0/218. Final R indices (I > 2σ): R1 = 0.0658. R indices (all data): wR2 = 0.1633, goodness-of-fit on F^2 of 1.023.

(*E*)-3-(diisopropylamino)-7-(triisopropylsilyl)hepta-2-en-4,6-diynenitrile (11). The general procedure was followed with triisopropylsilyl-1,3-butadiyne[7] and diisopropylamine. Compound **11** was obtained as orange oil in 75% yield (545.5 mg / 1.52 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 4.27 (s, 1H), 3.90 (sept, $^3J_{HH}$ = 6.7 Hz, 2H), 1.20 (d, $^3J_{HH}$ = 6.7 Hz, 12H), 1.03 (m, 21H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 141.7, 120.7, 92.4, 88.0, 82.0, 72.0, 67.8, 49.6, 20.1, 18.4, 11.1. **HRMS** (ESI) m/z calculated [M+Na]$^+$ 379.2545, found 379.2542.

(*E*)-3-(diisopropylamino)undec-2-en-4-ynenitrile (12). The general procedure was followed with 1-octyne and diisopropylamine. Compound **12** was obtained as colorless oil in 55% yield (213.3 mg / 0.82 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 4.05 (s, 1H), 3.91 (sept, $^3J_{HH}$ = 6.8 Hz, 2H), 2.35 (t, $^3J_{HH}$ = 7.1 Hz, 2H), 1.52 (quin, $^3J_{HH}$ = 7.8 Hz, 2H), 1.36 (quin, $^3J_{HH}$ = 13.7 Hz, 2H), 1.22 (m, 4H), 1.17 (d, $^3J_{HH}$ = 6.9 Hz, 12H), 0.80 (t, $^3J_{HH}$ = 7.0 Hz, 3H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 143.9, 122.0, 100.0, 74.6, 68.3, 49.1, 31.1, 28.5, 27.8, 22.4, 20.1, 19.3, 13.9. **HRMS** (ESI) m/z calculated [M+Na]$^+$ 283.2150, found 283.2152.

(*E*)-3-(diisopropylamino)-5-(*p*-tolyl)pent-2-en-4-ynenitrile (14). The general procedure was followed with 4-ethynyltoluene and diispropylamine. Compound **14** was obtained as an orange oil in 57 % yield (95.4 mg / 0.36 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 7.49 – 7.45 (m, 2H), 7.19 – 7.13 (m, 2H), 4.24 (s, 1H), 4.00 (sept, $^3J_{HH}$ = 6.9 Hz, 2H), 2.36 (s, 3H), 1.31 (d, $^3J_{HH}$ = 6.9 Hz, 12H) -**^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 143.8, 140.1, 131.9, 129.3, 122.1, 118.5, 98.2, 82.9, 69.4, 49.5, 21.7, 20.5. **HRMS** (ESI) m/z calculated [M+Na]$^+$ 289.1675, found 289.1676.

Methyl-(*E*)-4-(4-cyano-3-(diisopropylamino)but-3-en-1-yn-1-yl)benzoate (17). The general procedure was followed with methyl 4-ethynylbenzoate and diispropylamine. The residue was purified by chromatography (SiO_2, CH_2Cl_2/MeOH = 1:0 to 99:1). Compound **17** was obtained as an orange oil in 55 % yield (118 mg / 0.38 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 8.05 – 7.94 (m, 2H), 7.65 – 7.58 (m, 2H), 4.28 (s, 1H), 3.97 (sept, $^3J_{HH}$ = 6.9 Hz, 2H), 3.89 (s, 3H), 1.29 (d, $^3J_{HH}$ = 6.9 Hz, 12H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm) : 166.3, 143.0, 131.8, 130.7, 129.6, 126.0, 121.7, 96.5, 85.7, 70.5, 52.4, 49.6, 20.4. **HRMS** (ESI) m/z calculated [M+Na]$^+$ 333.1574, found 333.1574.

(*E*)-3-(diisopropylamino)-5-(4-(trifluoromethyl)phenyl)pent-2-en-4-ynenitrile (18). The general procedure was followed with 4-trifluoromethylphenylacetylene and diisopropylamine. Compound **18** was obtained as a brown oil in 82 % yield (239.4 mg / 0.74 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 7.77 – 7.56 (m, 4H), 4.32 (s, 1H), 4.01 (sept, $^3J_{HH}$ = 6.9 Hz, 2H), 1.33 (d, $^3J_{HH}$ = 6.9 Hz, 12H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm) : 143.1, 135.3, 132.9, 132.3, 131.5, 131.2, 125.6, 125.6, 125.5, 125.5, 125.3, 121.8, 96.1, 85.4, 70.7, 49.7, 20.6. **HRMS** (ESI) m/z calculated [M+Na]$^+$ 343.1392, found 343.1391.

(*E*)-3-(diisopropylamino)-1-N-benzyl-4-methylbenzenesulfonamidepent-2-en-4-ynenitrile (20). The general procedure was followed with N-benzyl-N-ethynyl-4-methylbenzenesulfonamide[13] and diisopropylamine. Compound **20** was obtained as a colorless oil in 23% yield (64 mg / 0.15 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 7.71 (m, 2H), 7.36 (m, 2H), 7.24 (m, 5H, Hm), 4.54 (s, 2H), 3.97 (s, 1H), 3.76 (sept, $^3J_{HH}$ = 6.9 Hz, 2H), 2.36 (s, 3H), 1.08 (d, $^3J_{HH}$ = 6.9 Hz, 12H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 145.2, 143.5, 134.8, 134.3, 130.1, 129.2, 128.7, 128.5, 127.8, 122.5, 90.9, 66.5, 55.8, 49.6, 21.8, 20.2. **HRMS** (ESI) m/z calculated [M+Na]$^+$ 458.1873, found 458.1874.

(*E*)-3-(diisopropylamino)-5-(4-methoxyphenyl)pent-2-en-4-ynenitrile (21). The general procedure was followed with 4-ethynylanisole and diisopropylamine. Compound **21** was obtained as an orange oil in 66 % yield (96.2 mg / 0.34 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 7.55 – 7.50 (m, 2H), 6.90 – 6.84 (m, 2H), 4.22 (s, 1H), 4.01 (sept, $^{3}J_{HH}$ = 6.9 Hz, 2H), 3.82 (s, 3H), 1.31 (d, $^{3}J_{HH}$ = 6.9 Hz, 12H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm) : 160.8, 144.1, 133.7, 122.3, 114.3, 113.6, 98.4, 82.5, 69.0, 55.5, 49.5, 20.6. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 305.1624, found 305.1620.

(*E*)-3-(diisopropylamino)-5-ferrocen-2-en-4-ynenitrile (22). The general procedure was followed with ethynylferrocene and diisopropylamine. Compound **22** was obtained as red solid in 80% yield (431.5 mg / 1.20 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 4.52 (t, $^{3}J_{HH}$ = 2.0 Hz, 2H), 4.28 (s, 5H), 4.26 (t, $^{3}J_{HH}$ = 2.0 Hz, 2H), 4.16 (s, 1H), 3.97 (sept, $^{3}J_{HH}$ = 7.0 Hz, 2H), 1.25 (d, $^{3}J_{HH}$ = 7.0 Hz, 12H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 143.8, 122.1, 98.1, 79.5, 71.6, 70.1, 69.5, 68.4, 62.6, 49.2, 20.4. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 383.1187, found 383.1181.

(*E*)-3-(diisopropylamino)-5-(4'-ethynyl-[1,1'-biphenyl]-4-yl)pent-2-en-4-ynenitrile (23). The general procedure was followed with 4,4'-diethynylbiphenyl[14] and diisopropylamine. Compound **23** was obtained as beige solid in 44% yield (123.1 mg / 0.35 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 7.60 (m, 2H), 7.52 (m, 2H), 7.49, (m, 4H), 4.22 (s, 1H), 3.95 (sept, $^{3}J_{HH}$ = 6.9 Hz, 2H), 3.08 (s, 1H), 1.26 (d, $^{3}J_{HH}$ = 7.0 Hz, 12H) - **^{13}C NMR** 100 MHz $CDCl_3$ δ (ppm): 143.6, 141.4, 140.5, 132.8, 132.5, 127.2, 127.0, 122.1, 121.8, 120.9, 97.7, 84.3, 83.5, 78.3, 69.9, 53.6, 20.6, 13.1. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 375.1837, found 375.1839.

(2*E*,8*E*)-3,8-bis(diisopropylamino)deca-2,8-dien-4,6-diynedinitrile (**24**). A solution of tetra-*n*-butylammonium fluoride (1.0 M in THF, 0.32 mmol) in dry THF (5 mL) was added over 2 h *via* syringe to a stirred solution of anhydrous $Cu(OAc)_2$ (175,4 mg, 0,96 mmol) and compound **10** (107,3 mg, 0.32mmol) in a mixture of dry pyridine / diethyl ether (3:1, 97 mL). The blue solution became progressively emerald green as the tetra-*n*-butylammonium fluoride solution was added. Once addition was complete, the solution was poured into diethyl ether and aqueous HCl (1 M). The organic phase was washed with aqueous HCl (1 M) until all the pyridine was removed. Then the organic phase was dried and concentrated to yield a crude solid, which was further purified by chromatography (SiO_2, CH_2Cl_2) to yield compound **24** as an orange oil in 10% yield (11.1 mg / 0.031 mmol). **^{1}H NMR** 400 MHz $CDCl_3$ δ (ppm): 4.37 (s, 2H), 3.97 (sept, $^{3}J_{HH}$ = 6.7 Hz, 4H), 1.27 (d, $^{3}J_{HH}$ = 6.9 Hz, 24H) - **^{13}C NMR** 100 MHz, $CDCl_3$ δ (ppm) : 141.4, 120.8, 80.3, 77.3, 72.9, 50.1, 20.4. **HRMS** (ESI) m/z calculated $[M+Na]^+$ 373.2363 found 373.2363.

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