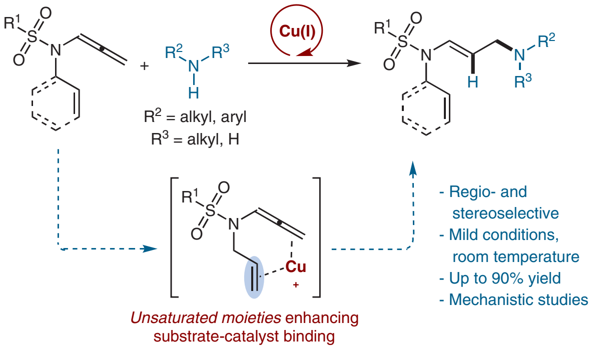
Copper-Catalysed Hydroamination of *N*-Allenylsulfonamides: The Key Role of Ancillary Coordinating Groups

Rémi Blieck[a]
Luca Alessandro Perego*[b,c]
Ilaria Ciofini[b]
Laurence Grimaud*[c]
Marc Taillefer*[a]
Florian Monnier*[a,d]

[a] Ecole Nationale Supérieure de Chimie de Montpellier, Institut Charles Gerhardt Montpellier UMR 5253 CNRS, AM2N, 8 rue de l'Ecole Normale, Montpellier 34296 Cedex 5, France
florian.monnier@enscm.fr
marc.taillefer@enscm.fr
[b] Chimie ParisTech, PSL University, CNRS, Institut de Recherche de Chimie Paris (IRCP), 75005 Paris, France
luca.perego@ens.fr
[c] PASTEUR, Département de Chimie, École Normale Supérieure, PSL University, Sorbonne Université, CNRS, 75005 Paris, France
laurence.grimaud@ens.fr
[d] Institut Universitaire de France, IUF, 1 rue Descartes, 75231 Paris Cedex 5, France



Published as part of the *50 Years SYNTHESIS – Golden Anniversary Issue*

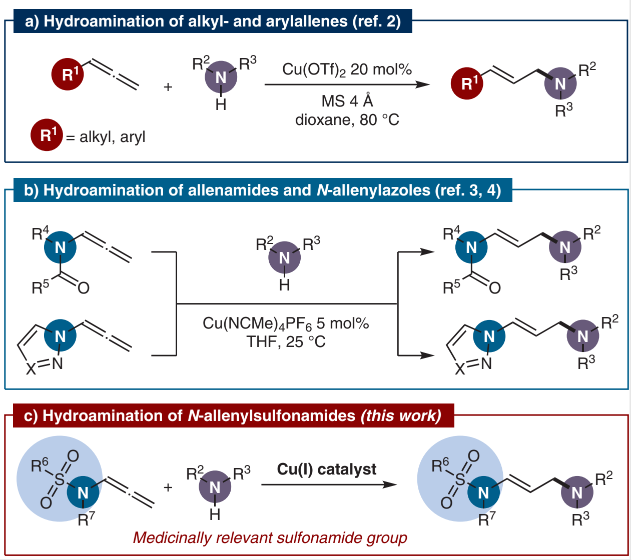
Received: 17.01.2019
Accepted: 18.01.2019

DOI: 10.1055/s-0037-1611673; Art ID: ss-2019-z0033-op

Abstract A copper-catalysed hydroamination reaction of *N*-allenylsulfonamides with amines has been developed through a rational approach based on mechanistic studies. The reaction is promoted by a simple copper(I) catalyst and proceeds at room temperature with complete regioselectivity and excellent stereoselectivity towards linear (*E*)-*N*-(3-aminoprop-1-enyl)sulfonamides. Density Functional Theory (DFT) studies allow interpreting the key role of unsaturated substituents on nitrogen as ancillary coordinating moieties for the copper catalyst.

Key words hydroamination, *N*-allenylsulfonamide, copper(I) catalyst, *N*-(3-aminoprop-1-enyl)sulfonamide, mechanistic study, ancillary coordinating moiety

Hydroamination, namely the addition of the N–H moiety across a C–C double or triple bond, is a straightforward and atom-economical method to access amine derivatives from simple precursors.[1] Moreover, the remarkable chemo- and stereoselectivity of some hydroamination protocols allows their application to highly functionalized substrates, ultimately leading to molecular architectures that would be challenging to obtain otherwise. In 2016 we reported the first copper-catalysed intermolecular hydroamination of allenes (Scheme 1, a)[2] and in-depth mechanistic studies[3] revealed the key role of cationic Cu(I) as the catalytically active species. Mechanistic insight stimulated the extension of our protocol to allenamides[3] and *N*-allenylazoles[4] (Scheme 1, b) under exceptionally mild conditions, i.e. at room temperature and with a comparatively low 5 mol% catalyst loading.

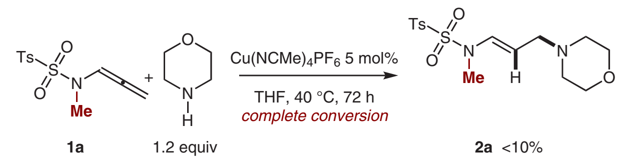


Scheme 1 Copper-catalysed hydroamination of allenes

Only a handful of naturally occurring compounds contain the sulfonamide functional group.[5] However, this moiety has played a central role in the development of biologically active molecules since the dawn of modern pharmacology with the discovery of the first synthetic antibacterials.[6] Nowadays, more than 110 active pharmaceutical ingredients are on the market[6b] and 489 compounds that reached clinical trials contain a sulfonamide group.[7] This moiety has been central in the development of several classes of drugs, including antimicrobials, anti-inflammatory agents, carbonic anhydrase inhibitors, hypoglycaemic agents, anticancers, and antivirals.[8]

Considering the importance of the sulfonamide functional group, we wondered if our protocol for the copper-catalysed hydroamination of allenes[3,4] could be extended to readily available *N*-allenylsulfonamides (Scheme 1, c) to access the corresponding amino-substituted *N*-alkenylsulfonamides. We present here the results of our studies, which highlighted the fundamental role of strategically placed metal-coordinating unsaturated functions for the success of this reaction.

At the beginning of our study, we expected that *N*-allenylsulfonamides would have a reactivity analogous to that of *N*-allenylcarboxamides (allenamides), but this turned out not to be the case. As a first attempt, *N*-allenyl-*N*-methyl-*p*-toluenesulfonamide (**1a**) was treated with morpholine under the standard conditions we optimized for other nitrogen-substituted allenes[3,4] (Scheme 2). Unfortunately, no reaction took place at 25 °C. Heating at 40 °C for 72 hours accomplished complete conversion of the starting material, but the expected hydroamination product was detected by ^1H NMR analysis in less than 10% yield, together with decomposition products of the allene (Scheme 2).



Scheme 2 Attempted hydroamination of *N*-allenyl-*N*-methyl-*p*-toluenesulfonamide

In our previous studies we observed that 1-allenyl-1,2-azoles are especially reactive in copper catalysis (Scheme 1, b) because their affinity for the catalyst is enhanced by chelation through the pyridine-like nitrogen (Figure 1, b).[4] Similarly, one of the factors contributing to the excellent reactivity of allenamides (Scheme 1, b) is the coordination of the C=O moiety to the copper catalyst (Figure 1, a).[3] Therefore, we turned our attention to *N*-allenylsulfonamides having a structural element possibly acting as an *innate* metal-directing group. Taking into account the good affinity of cationic copper(I) for C–C unsaturations,[3] we reasoned that introducing a strategically placed double bond could be enough to achieve the desired reactivity (Figure 1, c).

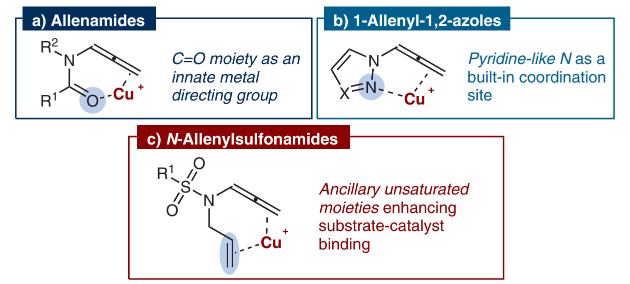
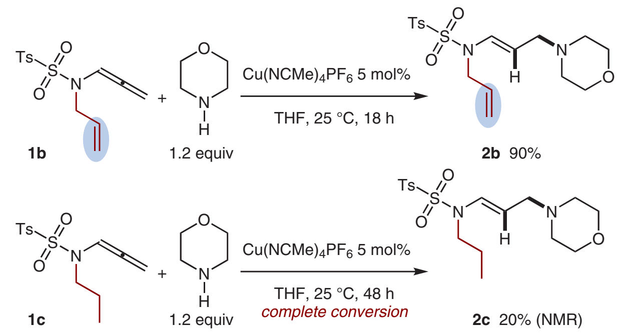


Figure 1 Strategies to enhance substrate-catalyst binding in several classes of allenes

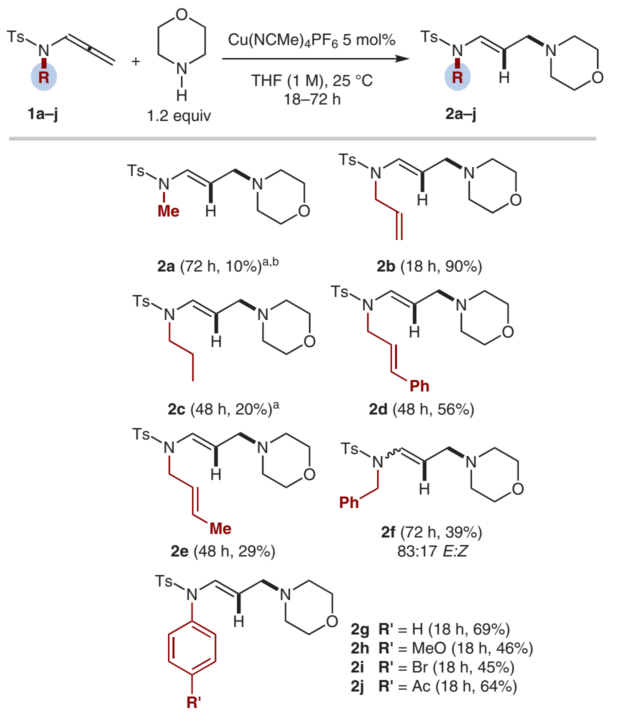
Indeed, *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**) reacted with morpholine to give an excellent yield of the hydroamination product **2b** at 25 °C with Cu(NCMe)$_4$PF$_6$ as the catalyst (Scheme 3). To reinforce the idea that this substantial enhancement of reactivity was not due to factors other than the terminal double bond, the behaviour of the analogous *N*-propyl derivative **1c** was also assessed in the same experimental conditions. The corresponding hydroamination product **2c** actually formed, but in only 20% NMR yield with complete conversion of the starting material **1c** that appeared to be fully decomposed (Scheme 3). This observation, thus, confirmed our initial hypothesis.[9]



Scheme 3 Comparison of the reactivity of *N*-allyl- and *N*-propylsulfonamide derivatives

The influence of the *N*-substituent of the sulfonamide on this reaction was then examined systematically by varying the nature of R in derivatives of general structure TsNR(CH=C=CH$_2$). Results are summarized in Scheme 4. The reaction of the substrate with R = *trans*-cinnamyl **1d** was less efficient than that of **1b**, but the expected hydroamination product **2d** was still obtained in a satisfactory 56% yield. The yield was further reduced for R = *trans*-crotyl (**2e**). Interestingly, for R = Bn **1f**, the hydroamination product **2f** was obtained in fair yield as an 83:17 *E*/*Z* mixture. For all the other substrates, complete selectivity for the *E* alkene was observed, as the *Z* product could not be detected by ^1H NMR analysis of the crude reaction mixture. Good reactivity was observed for R = Ph (**2g**). Both electron-donating (**2h**) and electron-withdrawing substituents (**2i**,**j**) are tolerated on the aromatic ring.

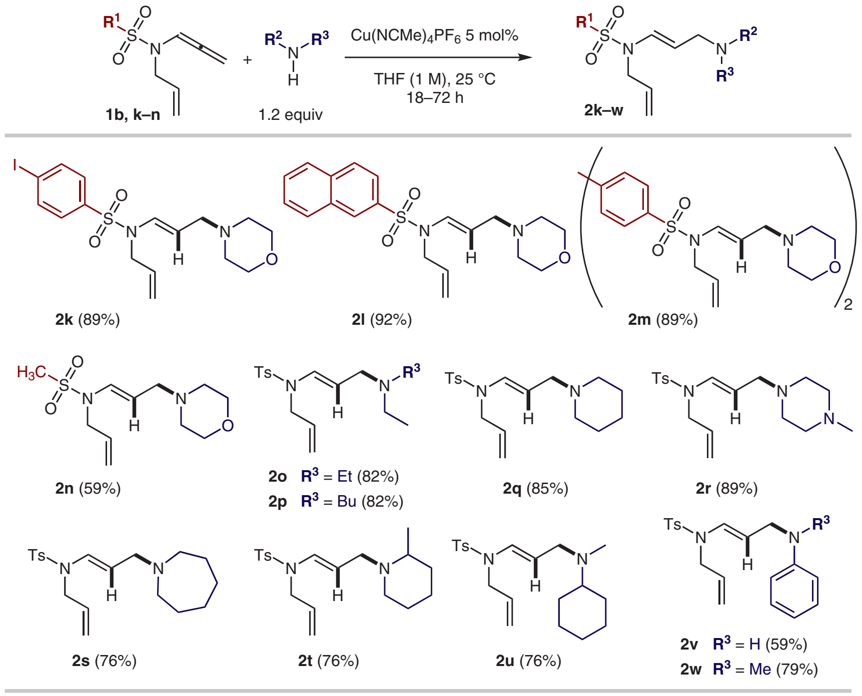
The scope of the reaction was then explored by varying the sulfonyl group and the amine coupling partner while keeping the *N*-allyl group constant (Scheme 5).



Scheme 4 Influence of *N*-substituents on the Cu-catalysed hydroamination of *N*-allenylsulfonamides. Isolated yields, if not specified otherwise. [a] Yield determined by ^{1}H NMR. [b] Reaction performed at 40 °C.

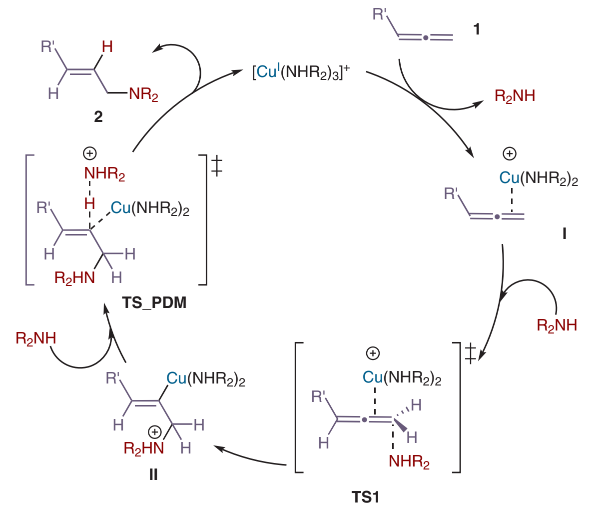
Different aromatic substituents can be accommodated in the sulfonyl moiety (**2k–m**). Notably, an iodo substituent, which in principle could be activated by the copper catalyst, survived the reaction. The dimeric product **2m** could be obtained in a very good yield. A methanesulfonamide also reacted efficiently to give **2n**. A variety of open chain (**2o**,**p**) and cyclic (**2q–s**) secondary aliphatic amines are suitable reaction partners, including sterically hindered ones (**2t**,**u**). No reaction was observed with primary aliphatic amines, as reported before.[3,4] However, both aniline and *N*-methylaniline gave good yields of the hydroamination products **2v**,**w**, in contradistinction to what we observed for the reactions of allenamides and *N*-allenylazoles.[3,4]

To shed more light on the reactivity trends we observed, DFT calculations have been performed. Computational details are reported in the Supporting Information. Consistently with our previous proposals regarding related transformations,[3,4] the reaction takes place by a turnover-limiting nucleophilic attack of the amine to a cationic Cu(I)/allene complex **I** via transition state **TS1** (Scheme 6). A *Z*-alkenylcopper **II** is obtained exclusively in this process, because the addition must take place *anti* with respect to copper. Stereospecific proto-demetallation with retention of the double bond configuration takes place through **TS_PDM** and delivers the *E*-alkene **2** (Scheme 6).



Isolated yields.

Scheme 5 Scope of the Cu-catalysed hydroamination of *N*-allenyl-*N*-allylsulfonamides



Scheme 6 General catalytic cycle for the Cu(I)-catalysed hydroamination of allenes

Conformational analysis of **TS1** is key to understanding the influence of the structure of the allene on reactivity. With *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**) and morpholine (mp) as model substrates, six conformers of **TS1** could be located (**TS1a–f**). Their 3D structures and schematic drawings are reported in Figure 2, together with computed free energies of formation (ΔG) with respect to non-interacting $[Cu(mp)_2]^+$, mp, and **1b**. In **TS1a** and **TS1b** the double bond of the allyl chain coordinates the copper centre in an η^2 fashion. In **TS1c** and **TS1d** one of the O atoms of the sulfonamide moiety interacts with the metal, similarly to what happens for allenamides (Figure 1, a).[3] **TS1e** and **TS1f** feature no secondary interaction of the substrate with the metal centre, but either the O (**TS1e**) or the N (**TS1f**) atom or the sulfonamide is hydrogen-bonded to one of the mp ligands, as it happens for allenyl ethers.[3]

In agreement with the crucial role played by the allyl chain to achieve good reactivity, the lowest-lying transition state features an η^2-coordination of copper by the C=C bond (**TS1a**, ΔG = +14.2 kcal mol^{-1}), while the *O*-chelate **TS1c** is

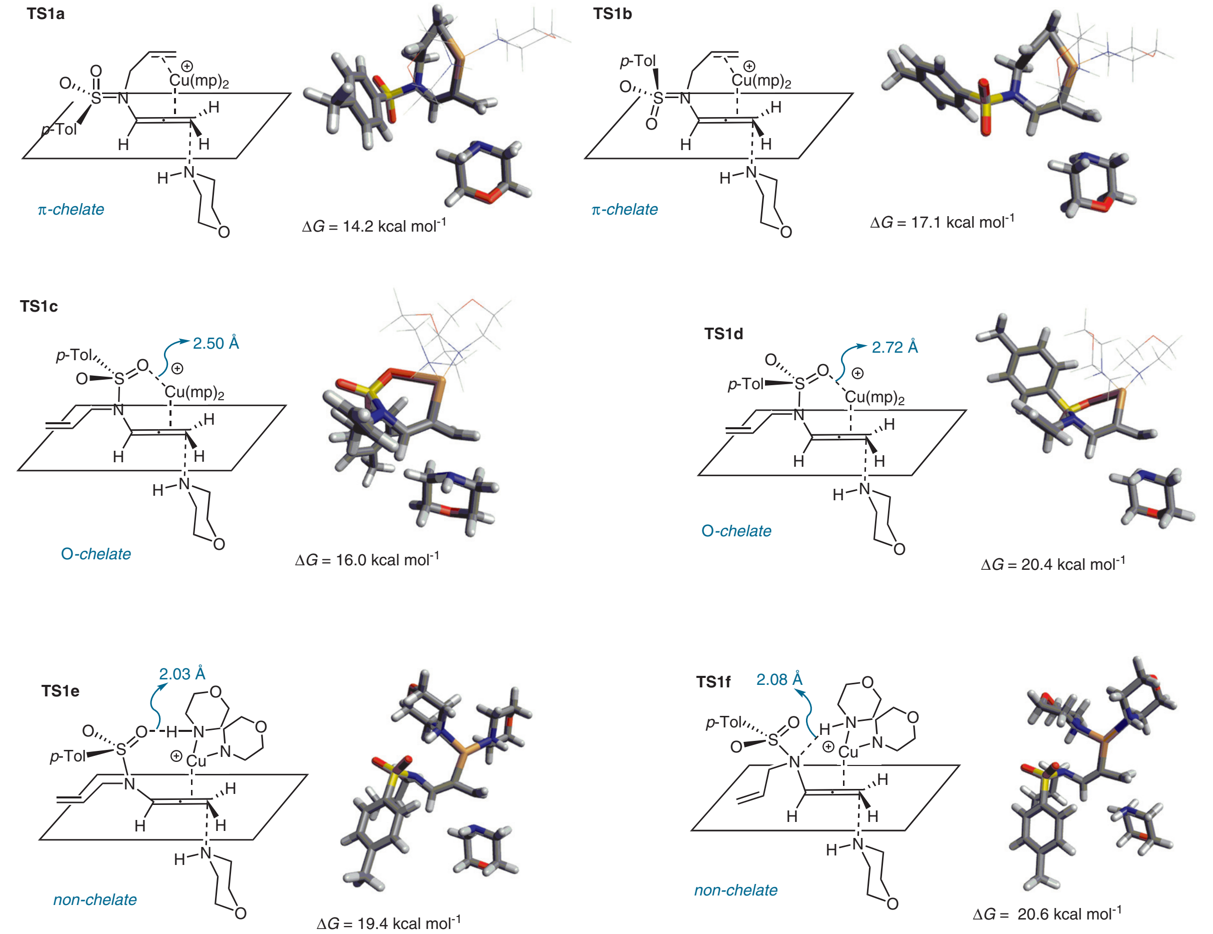


Figure 2 Transition states for the Cu-catalysed hydroamination of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**). Computed Gibbs free energies at 298 K (ΔG) relative to noninteracting $[Cu(mp)2]^+$, morpholine (mp), and **1b** are reported. For clarity, the mp ligands are shown as thin wireframe in the structures of **TS1a–d**.

just above in energy (ΔG = +16.0 kcal mol^{-1}). All the other transition states, having no significant interaction of the allyl chain with the metal (**TS1d–f**), are more than 5 kcal mol^{-1} higher in free energy than **TS1a**. The two transition states featuring π coordination by the double bond (**TS1a**,**b**) have a pseudo-tetrahedral arrangement of the four ligands (i.e., the allyl double bond, the allenyl moiety and the two molecules of mp) around the metal centre. In **TS1a** (refer to Figure 3 for structure and selected geometric parameters) the C(4)–Cu and C(5)–Cu distances are equal (2.20 Å) and indicative of a strong interaction. The complete computed energy profile for the formation of the alkenylcopper intermediate **II** is reported in the Supporting Information. Concerning the transition states featuring chelation through the sulfonamide oxygen atom **TS1c**,**d**, for compound **1b** the Cu–O distances (2.50 Å and 2.72 Å, respectively), are longer than that observed for allenamides (2.22 Å),[3] reflecting the weaker coordination ability of the S=O function than C=O.

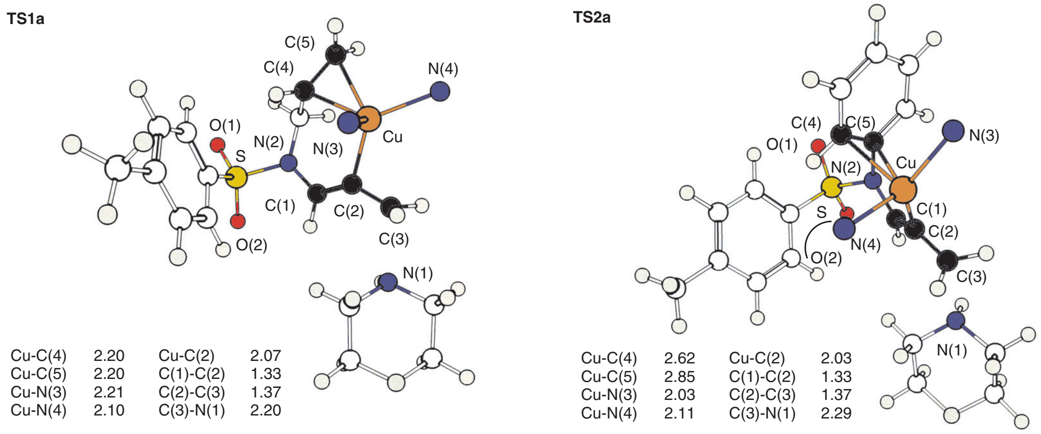
A similar theoretical analysis was also performed for sulfonamide **1g**, having an *N*-phenyl substituent, and for **1a**, which features an *N*-methyl group (see the Supporting Information for a detailed discussion). In the case of **1g**, the most stable conformation of the transition state for the addition of mp (**TS2a**, ΔG = +14.1 kcal mol^{-1}, Figure 3) is the one in which an η^2-type interaction with copper is established by the *ipso* and *ortho* carbons of the phenyl ring, analogously to what we previously observed for the allyl chain in **TS1a**. In **TS2a**, the C(4)–Cu and C(5)–Cu distances are not equal (2.62 Å and 2.85 Å, respectively) and longer than the C–Cu distances in **TS1a**, suggesting a weaker chelation ability of **1g** compared to **1b**. The most energetically accessible transition state for **1a**, which has no unsaturated moiety that can interact with copper, was found to be of the *O*-chelate type (**TS3c**, see the Supporting Information). Its formation is about 3 kcal mol^{-1} more endergonic (ΔG = +17.2 kcal mol^{-1}) than that of the most stable transition states involving **1b** and **1g**, in agreement with the poor reactivity of **1a**.

In summary, we disclosed efficient conditions for the copper-catalysed hydroamination of *N*-allenylsulfonamides at room temperature with complete regio- and stereoselectivity for the linear (*E*)-*N*-(3-aminoprop-1-enyl)sulfonamide. We established that satisfactory reactivity could be achieved for substrates having *N*-allyl or *N*-aryl substituents. DFT calculations allowed understanding the role of these unsaturated moieties as metal-directing groups that chelate the cationic copper(I) catalyst by acting as π-type coordination sites.

Unless otherwise stated, commercially available materials were used as received from suppliers. THF and dioxane were distilled from Na and benzophenone under argon before use. All the air-free manipulations have been performed by standard Schlenk techniques. Pre-coated F_{254} silica gel plates on aluminum foil (Fluka Analytical or Macherey-Nagel) were used for TLC analyses and visualized under UV light, with Dragendorff's reagent for tertiary amines or with alkaline $KMnO_4$ solution, as appropriate. NMR chemical shifts were referenced to the residual solvent peak. Syntheses and characterisation of substrates **1** are given in the Supporting Information.

Hydroamination of *N*-Allenylsulfonamides; General Procedure

An NMR tube (5-mm diameter) or a Schlenk flask of appropriate size was charged with $Cu(NCMe)_4PF_6$ (0.05 equiv) and closed with a rubber septum. After evacuation and back-filling with argon repeatedly (3 ×), dry THF (1 mL per mmol of substrate), the required secondary amine (1.2 equiv), and the *N*-allenylsulfonamide (1.0 equiv) were sequentially added. The vessel was shaken until a completely homogeneous solution resulted and the mixture was left overnight at 25 °C (or for a longer time if specified otherwise). Complete conversion was checked by no-D ^1H NMR, taking into consideration the disappearance of the characteristic allene resonances. The vessel was opened to the air and the content poured into EtOAc (10 volumes) and parti-



TS1a

Cu-C(4)	2.20	Cu-C(2)	2.07
Cu-C(5)	2.20	C(1)-C(2)	1.33
Cu-N(3)	2.21	C(2)-C(3)	1.37
Cu-N(4)	2.10	C(3)-N(1)	2.20

C(1)-C(2)-C(3)	138
C(2)-C(3)-N(1)	114
Cu-C(2)-C(3)	95

TS2a

Cu-C(4)	2.62	Cu-C(2)	2.03
Cu-C(5)	2.85	C(1)-C(2)	1.33
Cu-N(3)	2.03	C(2)-C(3)	1.37
Cu-N(4)	2.11	C(3)-N(1)	2.29

C(1)-C(2)-C(3)	140
C(2)-C(3)-N(1)	112
Cu-C(2)-C(3)	95

Figure 3 Structures and selected geometric parameters of **TS1a** and **TS2a**. Bond lengths are reported in Å and angles in degrees. For clarity, only the N atoms of the morpholine (mp) ligands are shown.

tioned with sat. aq NaCl solution (3 volumes). The aqueous phase was back-extracted with EtOAc (3 × 3 volumes) and the combined organic phases were dried (Na_2SO_4). Volatiles were evaporated under reduced pressure and the residue was purified by flash chromatography ($NaHCO_3$-treated silica gel as detailed in the Supporting Information) to afford the required hydroamination product.

(*E*)-*N*-Allyl-*N*-(3-morpholinoprop-1-enyl)-*p*-toluenesulfonamide (2b)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 125 mg, 0.50 mmol) with morpholine (52.5 µL, 0.60 mmol) according to the general procedure (flash chromatography: EtOAc) gave **2b** (151 mg, 90%) as a pale brown oil.

IR (ATR): 3084, 3048, 2965, 2946, 2916, 2858, 2812, 1658, 1348, 1158, 1113, 662 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.65 (d, J = 8.2 Hz, 2 H), 7.28 (d, J = 8.2 Hz, 2 H), 6.78 (d, J = 14.2 Hz, 1 H), 5.61 (ddt, J = 17.3, 10.4, 5.3 Hz, 1 H), 5.20–5.10 (m, 2 H), 4.79 (dt, J = 14.2, 7.2 Hz, 1 H), 3.99 (d, J = 5.3 Hz, 2 H), 3.70–3.65 (m, 4 H), 2.95 (d, J = 7.2 Hz, 2 H), 2.41 (s, 3 H), 2.40–2.34 (m, 4 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 144.0, 136.3, 131.6, 129.9, 129.2, 127.1, 118.0, 106.7, 67.0, 59.3, 53.3, 48.2, 21.7.

HRMS (EI): m/z [M]$^+$ calcd for $C_{17}H_{24}N_2O_3S$: 336.1508; found: 336.1521.

(*E*,*E*)-*N*-Cinnamyl-*N*-(3-morpholinoprop-1-enyl)-*p*-toluenesulfonamide (2d)

The reaction of (*E*)-*N*-allenyl-*N*-cinnamyl-*p*-toluenesulfonamide (**1d**; 71.0 mg, 0.218 mmol) with morpholine (23.0 µL, 0.262 mmol, 1.2 equiv) according to the general procedure (reaction time: 48 h, flash chromatography: toluene/EtOAc 80:20) gave **2d** (50.0 mg, 56%) as a yellow solid.

IR (ATR): 2964, 2919, 2851, 1656, 1598, 1451, 1162, 1113, 732 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.67 (d, J = 8.3 Hz, 2 H), 7.32–7.17 (m, 7 H), 6.80 (d, J = 14.3 Hz, 1 H), 6.42 (d, J = 16.0 Hz, 1 H), 5.90 (dt, J = 16.0, 6.8 Hz, 1 H), 4.86 (dt, J = 14.3, 7.1 Hz, 1 H), 4.17 (dd, J = 6.8, 1.7 Hz, 2 H), 3.60 (t, J = 4.7 Hz, 4 H), 2.95 (d, J = 7.1 Hz, 2 H), 2.38 (s, 3 H), 2.38–2.30 (m, 4 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 144.0, 136.4, 136.3, 133.3, 129.9, 128.6, 128.0, 127.2, 126.4, 122.8, 107.3, 66.9, 59.3, 53.4, 47.8, 21.6.

HRMS (ESI): m/z [M + H]$^+$ calcd for $C_{23}H_{29}N_2O_3S$: 413.1899; found: 413.1899.

(*E*,*E*)-*N*-(But-2-enyl)-*N*-(3-morpholinoprop-1-enyl)-*p*-toluenesulfonamide (2e)

The reaction of (*E*)-*N*-allenyl-*N*-(but-2-enyl)-*p*-toluenesulfonamide (**1e**; 163 mg, 0.62 mmol) with morpholine (65 µL, 0.74 mmol, 1.2 equiv) according to the general procedure (reaction time: 72 h, flash chromatography: toluene/EtOAc 80:20) gave **2e** (63.8 mg, 29%) as a pale yellow oil. NMR spectra of compound **2e** (and of its precursor **1e**) are complicated by the presence of at least two conformations in slow equilibrium on the timescale of NMR. Spectral data of the major conformer are given in the following data.

IR (ATR): 2971, 2920, 1597, 1445, 1354, 1161, 1093, 812, 662 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.63 (d, J = 8.2 Hz, 2 H), 7.27 (d, J = 8.2 Hz, 2 H), 6.74 (d, J = 14.2 Hz, 1 H), 5.70–5.45 (m, 1 H), 5.34–5.15 (m, 1 H), 4.80 (dt, J = 14.2, 7.1 Hz, 1 H), 3.92 (dt, J = 5.8, 1.6 Hz, 2 H), 3.68 (t, J = 4.7 Hz, 4 H), 2.95 (d, J = 7.1 Hz, 2 H), 2.46–2.32 (m, 4 H), 2.40 (s, 3 H), 1.58 (dd, J = 6.4, 1.6 Hz, 3 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 143.8, 136.4, 129.8, 129.6, 129.4, 127.0, 124.2, 106.5, 67.0, 59.3, 53.3, 47.6, 21.6, 17.6.

HRMS (EI): m/z [M]$^+$ calcd for $C_{18}H_{26}N_2O_3S$: 350.1664; found: 350.1651.

(*E*,*Z*)-*N*-Benzyl-*N*-(3-morpholinoprop-1-enyl)-*p*-toluenesulfonamide (2f)

The reaction of (*E*)-*N*-allenyl-*N*-benzyl-*p*-toluenesulfonamide (**1f**; 150 mg, 0.50 mmol) with morpholine (52.5 µL, 0.60 mmol, 1.2 equiv) according to the general procedure (reaction time: 72 h, flash chromatography: EtOAc) gave **2f** (75.0 mg, 39%) as a pale brown solid; ratio *E*/*Z* 83:17.

HRMS (EI): m/z [M]$^+$ calcd for $C_{21}H_{26}N_2O_3S$: 386.1664; found: 386.1663.

E Isomer

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.71–7.64 (m, 2 H), 7.38–7.15 (m, 7 H), 6.77 (dd, J = 14.2, 1.2 Hz, 1 H), 4.64 (dt, J = 14.3, 7.1 Hz, 1 H), 4.51 (s, 2 H), 3.60–3.51 (m, 4 H), 2.84 (dd, J = 7.1, 1.2 Hz, 2 H), 2.42 (s, 3 H), 2.21–2.13 (m, 4 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 144.1, 136.0, 135.3, 130.0, 129.0, 127.6, 127.1, 127.0, 108.5, 66.9, 59.1, 53.1, 49.5, 21.7.

Z Isomer

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.71–7.64 (m, 2 H), 7.38–7.15 (m, 7 H), 5.58 (dt, J = 7.6, 6.4 Hz, 1 H), 5.28 (dt, J = 7.6, 1.8 Hz, 1 H), 4.14 (s, 2 H), 3.09 (dd, J = 6.4, 1.8 Hz, 2 H), 3.54–3.49 (m, 4 H), 2.44 (s, 3 H), 2.04–1.96 (m, 4 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 143.9, 135.7, 135.0, 134.0, 129.9, 129.4, 128.6, 128.0, 127.7, 127.4, 67.0, 55.6, 54.9, 53.4, 21.7.

(*E*)-*N*-(3-Morpholinoprop-1-enyl)-*N*-phenyl-*p*-toluenesulfonamide (2g)

The reaction of *N*-allenyl-*N*-phenyl-*p*-toluenesulfonamide (**1g**; 100 mg, 0.35 mmol) with morpholine (36.8 µL, 0.42 mmol, 1.2 equiv) according to the general procedure (flash chromatography: EtOAc) gave **2g** (90.0 mg, 69%) as a pale brown solid.

IR (ATR): 3066, 3039, 2957, 2894, 2855, 2808, 1654, 1595, 1354, 1166, 1113, 696, 662 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.45 (d, J = 8.3 Hz, 2 H), 7.28–7.21 (m, 3 H), 7.18 (d, J = 8.3 Hz, 2 H), 7.03 (dt, J = 13.9, 1.2 Hz, 1 H), 6.90–6.83 (m, 2 H), 4.30 (dt, J = 13.9, 7.3 Hz, 1 H), 3.59–3.52 (m, 4 H), 2.83 (dd, J = 7.3, 1.2 Hz, 2 H), 2.34 (s, 3 H), 2.29–2.22 (m, 4 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 144.1, 136.5, 135.9, 132.3, 130.2, 129.7, 129.6, 129.1, 127.6, 106.9, 66.9, 58.8, 53.3, 21.7.

HRMS (EI): m/z [M]$^+$ calcd for $C_{20}H_{24}N_2O_3S$: 372.1508; found: 372.1520.

(*E*)-*N*-(4-Methoxyphenyl)-*N*-(3-morpholinoprop-1-enyl)-*p*-toluenesulfonamide (2h)

The reaction of *N*-allenyl-*N*-(4-methoxyphenyl)-*p*-toluenesulfonamide (**1h**; 157 mg, 0.50 mmol) with morpholine (52.5 µL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: pentane/EtOAc 20:80) gave **2h** (92 mg, 46%) as a white powder.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57–7.49 (m, 2 H), 7.26 (d, *J* = 8.0 Hz, 2 H), 7.12 (d, *J* = 13.9 Hz, 1 H), 6.84 (d, *J* = 2.0 Hz, 4 H), 4.39 (dt, *J* = 13.9, 7.3 Hz, 1 H), 3.79 (s, 3 H), 3.71–3.59 (m, 4 H), 2.92 (dd, *J* = 7.3, 0.8 Hz, 2 H), 2.43 (s, 3 H), 2.35 (s, 4 H).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 160.0, 144.1, 135.9, 132.5, 131.4, 129.7, 128.7, 127.7, 114.9, 106.6, 67.1, 58.8, 55.6, 53.4, 21.8.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{21}H_{27}N_2O_4S$: 403.1692; found: 403.1694.

(*E*)-*N*-(4-Bromophenyl)-*N*-(3-morpholinoprop-1-enyl)-*p*-toluenesulfonamide (2i)

The reaction of *N*-allenyl-*N*-(4-bromophenyl)-*p*-toluenesulfonamide (**1i**; 181 mg, 0.5 mmol) with morpholine (52.5 µL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: pentane/EtOAc 20:80) gave **2i** (101 mg, 45%) as an orange powder.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.53 (d, *J* = 8.3 Hz, 2 H), 7.47 (d, *J* = 8.7 Hz, 2 H), 7.28 (d, *J* = 8.1 Hz, 2 H), 7.08 (d, *J* = 14.1 Hz, 1 H), 6.87–6.79 (m, 2 H), 4.39 (dt, *J* = 14.1, 7.2 Hz, 1 H), 3.72–3.61 (m, 4 H), 2.92 (dd, *J* = 7.2, 0.9 Hz, 2 H), 2.44 (s, 3 H), 2.35 (br s, 4 H).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 144.4, 135.6, 135.6, 133.0, 131.98, 131.95, 129.9, 127.6, 123.4, 107.4, 67.0, 58.8, 53.4, 21.8.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{20}H_{24}N_2O_3SBr$: 451.0691; found: 451.0691.

(*E*)-*N*-(4-Acetylphenyl)-*N*-(3-morpholinoprop-1-enyl)-*p*-toluenesulfonamide (2j)

The reaction of *N*-(4-acetylphenyl)-*N*-allenyl-*p*-toluenesulfonamide (**1j**; 163 mg, 0.5 mmol) with morpholine (52 µL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: pentane/EtOAc 20:80) gave **2j** (132 mg, 64%) as a pale yellow powder.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.90 (d, *J* = 8.4 Hz, 2 H), 7.50 (d, *J* = 8.2 Hz, 2 H), 7.26 (d, *J* = 8.1 Hz, 2 H), 7.11–7.02 (m, 3 H), 4.39 (dt, *J* = 14.2, 7.2 Hz, 1 H), 3.68–3.56 (m, 4 H), 2.91 (d, *J* = 7.2 Hz, 2 H), 2.57 (s, 3 H), 2.41 (s, 3 H), 2.33 (s, 4 H).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 197.1, 144.5, 140.9, 137.3, 135.5, 131.8, 130.4, 129.9, 129.6, 127.5, 107.8, 66.9, 58.6, 53.2, 26.8, 21.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for $C_{22}H_{27}N_2O_4S$: 415.1692; found: 415.1691.

(*E*)-*N*-Allyl-*p*-iodo-*N*-(3-morpholinoprop-1-enyl)benzenesulfonamide (2k)

The reaction of *N*-allenyl-*N*-allyl-*p*-iodobenzenesulfonamide (**1k**; 175 mg, 0.48 mmol) with morpholine (51 µL, 0.58 mmol, 1.2 equiv) according to the general procedure (reaction time: 72 h, no chromatographic purification needed) gave **2k** (194 mg, 89%) as a brown solid.

IR (ATR): 2964, 2992, 2762, 1732, 1658, 1567, 1349, 1004, 729 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.86 (d, *J* = 8.5 Hz, 2 H), 7.48 (d, *J* = 8.5 Hz, 2 H), 6.73 (d, *J* = 14.1 Hz, 1 H), 5.61 (ddt, *J* = 17.2, 10.4, 5.3 Hz, 1 H), 5.23–5.11 (m, 2 H), 4.85 (dt, *J* = 14.1, 7.1 Hz, 1 H), 4.01 (d, *J* = 5.3 Hz, 2 H), 3.69 (t, *J* = 4.7 Hz, 4 H), 2.96 (d, *J* = 7.1 Hz, 2 H), 2.42–2.32 (m, 4 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 138.9, 138.6, 131.3, 128.7, 128.4, 118.4, 107.8, 100.6, 67.0, 59.2, 53.4, 48.3.

HRMS (EI): *m*/*z* [M]$^+$ calcd for $C_{16}H_{21}IN_2O_3S$: 448.0318; found: 448.0297.

(*E*)-*N*-Allyl-*N*-(3-morpholinoprop-1-enyl)naphthalene-2-sulfonamide (2l)

The reaction of *N*-allenyl-*N*-allylnaphthalene-2-sulfonamide (**1l**; 166 mg, 0.58 mmol) with morpholine (61 µL, 0.70 mmol, 1.2 equiv) according to the general procedure (reaction time: 72 h, no chromatographic purification needed) gave **2l** (200 mg, 92%) as a pale brown oil.

IR (ATR): 2956, 2893, 2854, 1656, 1591, 1454, 1348, 1163, 1196, 660 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.36 (d, *J* = 1.8 Hz, 1 H), 7.99–7.88 (m, 3 H), 7.72 (dd, *J* = 8.7, 1.9 Hz, 1 H), 7.69–7.57 (m, 2 H), 6.86 (d, *J* = 14.2 Hz, 1 H), 5.63 (ddt, *J* = 17.2, 10.4, 5.4 Hz, 1 H), 5.23–5.09 (m, 2 H), 4.82 (dt, *J* = 14.2, 7.2 Hz, 1 H), 4.06 (dt, *J* = 5.4, 1.7 Hz, 2 H), 3.66–3.61 (m, 4 H), 2.97 (d, *J* = 7.2 Hz, 2 H), 2.39–2.30 (m, 4 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.9, 134.9, 132.2, 131.5, 129.7, 129.3, 129.3, 129.2, 128.5, 128.0, 127.8, 122.0, 118.1, 107.0, 66.9, 59.2, 53.3, 48.3.

No meaningful HRMS data (either EI or ESI) could be obtained for this compound. However, comparison of spectral data with analogous compounds that could be fully characterized allowed establishing the structure beyond reasonable doubt.

N,*N*′-Diallyl-*N*,*N*′-bis[(*E*)-3-morpholinoprop-1-enyl]biphenyl-4,4′-disulfonamide (2m)

The reaction of *N*,*N*′-diallenyl-*N*,*N*′-diallylbiphenyl-4,4′-disulfonamide (**1m**; 79.3 mg, 0.17 mmol) with morpholine (35.5 µL, 0.41 mmol, 1.2 equiv) according to the general procedure (reaction time: 72 h, no chromatographic purification needed) gave **2m** (96.7 mg, 89%) as a pale brown solid.

IR (ATR): 2956, 2854, 1657, 1352, 1165, 714 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.87 (d, *J* = 8.4 Hz, 4 H), 7.70 (d, *J* = 8.4 Hz, 4 H), 6.82 (d, *J* = 14.2 Hz, 2 H), 5.72–5.58 (m, 2 H), 5.25–5.12 (m, 4 H), 4.87 (dt, *J* = 14.2, 7.1 Hz, 2 H), 4.07 (d, *J* = 5.5 Hz, 4 H), 3.68 (t, *J* = 4.7 Hz, 8 H), 2.98 (d, *J* = 7.1 Hz, 4 H), 2.39 (br s, 8 H).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 143.8, 139.2, 131.4, 128.9, 128.2, 127.9, 118.3, 107.4, 67.0, 59.2, 53.4, 48.3.

No meaningful HRMS data (either EI or ESI) could be obtained for this compound. However, comparison of spectral data with analogous compounds that could be fully characterized allowed establishing the structure beyond reasonable doubt.

(*E*)-*N*-Allyl-*N*-(3-morpholinoprop-1-enyl)methanesulfonamide (2n)

The reaction of *N*-allenyl-*N*-allylmethanesulfonamide (**1n**; 60.5 mg, 0.35 mmol) with morpholine (36.6 µL, 0.42 mmol, 1.2 equiv) according to the general procedure (reaction time: 72 h, gradient elution: toluene/EtOAc 80:20 to 50:50) gave **2n** (53.5 mg, 59%) as a pale yellow oil.

IR (ATR): 2962, 2928, 1658, 1455, 1347, 1155, 1114, 938, 748 cm^{-1}.

^{1}H NMR (300 MHz, CDCl$_3$): δ = 6.66 (dt, *J* = 14.2, 1.2 Hz, 1 H), 5.94–5.74 (m, 1 H), 5.36–5.22 (m, 2 H), 4.92 (dt, *J* = 14.3, 7.2 Hz, 1 H), 4.16 (dt, *J* = 5.4, 1.6 Hz, 2 H), 3.74–3.66 (m, 4 H), 2.98 (dd, *J* = 7.2, 1.2 Hz, 2 H), 2.91 (s, 3 H), 2.46–2.39 (m, 4 H).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 131.4, 128.9, 118.7, 106.3, 67.1, 59.2, 53.4, 48.2, 40.2.

HRMS (EI): *m*/*z* [M]$^+$ calcd for C$_{11}$H$_{20}$N$_2$O$_3$S: 260.1195; found: 260.1189.

(*E*)-*N*-Allyl-*N*-[3-(diethylamino)prop-1-enyl]-*p*-toluenesulfonamide (2o)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 74.8 mg, 0.30 mmol) with diethylamine (37.2 μL, 0.36 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: EtOAc) gave **2o** (79.3 mg, 82%) as a pale brown oil.

IR (ATR): 2969, 2929, 2809, 1656, 1613, 1354, 1164, 844, 813, 664 cm^{-1}.

^{1}H NMR (300 MHz, CDCl$_3$): δ = 7.64 (d, *J* = 8.3 Hz, 2 H), 7.28 (d, *J* = 8.3 Hz, 2 H), 6.75 (dt, *J* = 14.2, 1.2 Hz, 1 H), 5.62 (ddt, *J* = 17.3, 10.4, 5.4 Hz, 1 H), 5.21–5.08 (m, 2 H), 4.82 (dt, *J* = 14.2, 7.1 Hz, 1 H), 3.98 (dt, *J* = 5.4, 1.7 Hz, 2 H), 3.06 (dd, *J* = 7.1, 1.2 Hz, 2 H), 2.45 (q, *J* = 7.2 Hz, 4 H), 2.40 (s, 3 H), 0.99 (t, *J* = 7.2 Hz, 6 H).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 143.9, 136.4, 131.7, 129.8, 128.4, 127.1, 117.9, 108.2, 53.2, 48.2, 46.3, 21.6, 11.7.

HRMS (EI): *m*/*z* [M]$^+$ calcd for C$_{17}$H$_{26}$N$_2$O$_2$S: 322.1715; found: 322.1708.

(*E*)-*N*-Allyl-*N*-{3-[butyl(methyl)amino]prop-1-enyl}-*p*-toluenesulfonamide (2p)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 125 mg, 0.50 mmol) with *N*-methylbutylamine (71 μL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: petroleum ether/EtOAc gradient 90:10 to 100:0) gave **2p** (138 mg, 82%) as a red oil.

^{1}H NMR (400 MHz, CDCl$_3$): δ = 7.69–7.62 (m, 2 H), 7.28 (d, *J* = 8.0 Hz, 2 H), 6.76 (d, *J* = 14.2 Hz, 1 H), 5.63 (ddt, *J* = 17.2, 10.5, 5.3 Hz, 1 H), 5.20–5.12 (m, 2 H), 4.83 (dt, *J* = 14.2, 7.1 Hz, 1 H), 3.99 (d, *J* = 5.2 Hz, 2 H), 2.96 (d, *J* = 7.0 Hz, 2 H), 2.41 (s, 3 H), 2.32–2.22 (m, 2 H), 2.15 (s, 3 H), 1.48–1.36 (m, 2 H), 1.35–1.20 (m, 2 H), 0.89 (t, *J* = 7.3 Hz, 3 H).

^{13}C NMR (101 MHz, CDCl$_3$): δ = 143.9, 136.4, 131.7, 129.9, 128.6, 127.1, 118.0, 108.3, 58.1, 56.8, 48.2, 41.9, 29.6, 21.7, 20.9, 14.2.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for C$_{18}$H$_{29}$N$_2$O$_2$S: 337.1950; found: 337.1948.

(*E*)-*N*-Allyl-*N*-[3-(piperidin-1-yl)prop-1-enyl]-*p*-toluenesulfonamide (2q)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 74.8 mg, 0.30 mmol) with piperidine (35.6 μL, 0.36 mmol, 1.2 equiv) according to the general procedure (flash chromatography: EtOAc/petroleum ether 85:15) gave **2q** (85.3 mg, 85%) as a pale brown oil.

IR (ATR): 2932, 2853, 2800, 2759, 1656, 1357, 1306, 1164, 1090, 665 cm^{-1}.

^{1}H NMR (300 MHz, CDCl$_3$): δ = 7.65 (d, *J* = 8.2 Hz, 2 H), 7.29 (d, *J* = 8.2 Hz, 2 H), 6.75 (dt, *J* = 14.2, 1.2 Hz, 1 H), 5.63 (ddt, *J* = 17.2, 10.5, 5.3 Hz, 1 H), 5.23–5.09 (m, 2 H), 4.85 (dt, *J* = 14.2, 7.2 Hz, 1 H), 3.99 (dt, *J* = 5.4, 1.7 Hz, 2 H), 2.93 (dd, *J* = 7.2, 1.2 Hz, 2 H), 2.42 (s, 3 H), 2.32 (br t, *J* = 5.5 Hz, 4 H), 1.62–1.35 (m, 6 H).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 143.9, 136.4, 131.7, 129.9, 128.8, 127.1, 118.0, 107.9, 59.7, 54.3, 48.3, 26.0, 24.5, 21.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for C$_{18}$H$_{27}$N$_2$O$_2$S: 335.1793; found: 335.1793.

(*E*)-*N*-Allyl-*N*-[3-(4-methylpiperazin-1-yl)prop-1-enyl]-*p*-toluenesulfonamide (2r)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 125 mg, 0.50 mmol) with *N*-methylpiperazine (66 μL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: CH$_2$Cl$_2$/MeOH 99:1) gave **2r** (155 mg, 89%) as an orange oil.

^{1}H NMR (400 MHz, CDCl$_3$): δ = 7.68–7.59 (m, 2 H), 7.28 (d, *J* = 8.0 Hz, 2 H), 6.78 (d, *J* = 14.2 Hz, 1 H), 5.61 (ddt, *J* = 17.2, 10.5, 5.3 Hz, 1 H), 5.22–5.07 (m, 2 H), 4.81 (dt, *J* = 14.3, 7.2 Hz, 1 H), 3.99 (dt, *J* = 5.2, 1.5 Hz, 2 H), 2.99 (dd, *J* = 7.2, 0.9 Hz, 2 H), 2.47 (s, 8 H), 2.41 (s, 3 H), 2.31 (s, 3 H).

^{13}C NMR (101 MHz, CDCl$_3$): δ = 144.0, 136.3, 131.6, 129.9, 129.4, 127.1, 118.1, 106.7, 58.7, 54.9, 52.4, 48.2, 45.9, 21.7.

Due to the limited stability of this compound in the analysis conditions, no meaningful HRMS data (either EI or ESI) could be obtained. However, comparison of spectral data with analogous compounds that could be fully characterized allowed establishing the structure beyond reasonable doubt.

(*E*)-*N*-Allyl-*N*-[3-(azepan-1-yl)prop-1-enyl]-*p*-toluenesulfonamide (2s)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 125 mg, 0.50 mmol) with azepane (68 μL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: CH$_2$Cl$_2$/MeOH 98:2) gave **2s** (132 mg, 76%) as an orange oil.

^{1}H NMR (400 MHz, CDCl$_3$): δ = 7.69–7.62 (m, 2 H), 7.29 (d, *J* = 8.0 Hz, 2 H), 6.76 (d, *J* = 14.2 Hz, 1 H), 5.62 (ddt, *J* = 17.2, 10.5, 5.3 Hz, 1 H), 5.25–5.08 (m, 2 H), 4.88 (dt, *J* = 14.2, 7.1 Hz, 1 H), 3.99 (dt, *J* = 5.3, 1.5 Hz, 2 H), 3.12 (d, *J* = 7.0 Hz, 2 H), 2.60 (br s, 4 H), 2.42 (s, 3 H), 1.70–1.54 (m, 8 H).

^{13}C NMR (101 MHz, CDCl$_3$): δ = 144.0, 136.3, 131.6, 129.9, 127.1, 118.1, 95.1, 58.7, 55.1, 48.2, 27.6, 27.0, 21.7.

HRMS (ESI): *m*/*z* [M + H]$^+$ calcd for C$_{19}$H$_{29}$N$_2$O$_2$S: 349.1950; found: 349.1946.

(*E*)-*N*-Allyl-*N*-[3-(2-methylpiperidin-1-yl)prop-1-enyl]-*p*-toluenesulfonamide (2t)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 74.8 mg, 0.30 mmol) with 2-methylpiperidine (42.3 μL, 0.36 mmol, 1.2 equiv) according to the general procedure (flash chromatography: EtOAc/petroleum ether 85:15) gave **2t** (79.5 mg, 76%) as a pale brown oil.

IR (ATR): 2928, 2856, 2791, 1654, 1598, 1355, 1306, 1163, 1090, 664 cm^{-1}.

^{1}H NMR (300 MHz, CDCl$_3$): δ = 7.65 (d, *J* = 8.3 Hz, 2 H), 7.29 (d, *J* = 8.3 Hz, 2 H), 6.74 (dt, *J* = 14.0, 1.0 Hz, 1 H), 5.63 (ddt, *J* = 17.3, 10.4, 5.3 Hz, 1 H), 5.23–5.10 (m, 2 H), 4.85 (ddd, *J* = 14.2, 8.2, 6.2 Hz, 1 H), 4.10–3.89 (m, 2 H), 3.36 (ddd, *J* = 14.0, 6.2, 1.0 Hz, 1 H), 2.96 (ddd, *J* = 14.0, 8.2, 1.0 Hz, 1 H), 2.78 (ddd, *J* = 11.3, 4.6, 3.3 Hz, 1 H), 2.42 (s, 3 H), 2.26–2.11 (m, 1 H), 2.03 (td, *J* = 11.3, 3.3 Hz, 1 H), 1.73–1.44 (m, 4 H), 1.36–1.16 (m, 2 H), 1.07 (d, *J* = 6.2 Hz, 3 H).

^{13}C NMR (75 MHz, CDCl$_3$): δ = 143.9, 136.4, 131.8, 129.9, 128.8, 127.1, 118.0, 107.0, 55.9, 54.4, 52.0, 48.3, 34.7, 26.1, 24.1, 21.7, 19.2.

HRMS (EI): *m*/*z* [M]$^+$ calcd for C$_{19}$H$_{28}$N$_2$O$_2$S: 348.1871; found: 348.1879.

(*E*)-*N*-Allyl-*N*-{3-[cyclohexyl(methyl)amino]prop-1-enyl}-*p*-toluenesulfonamide (2u)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 125 mg, 0.50 mmol) with *N*-methylcyclohexylamine (72 μL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: petroleum ether/EtOAc gradient 10:90 to 0:100) gave **2u** (138 mg, 76%) as a red oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.66–7.61 (m, 2 H), 7.28–7.25 (m, 2 H), 6.75 (d, *J* = 14.2 Hz, 1 H), 5.60 (ddt, *J* = 17.2, 10.5, 5.3 Hz, 1 H), 5.19–5.09 (m, 2 H), 4.79 (dt, *J* = 14.2, 7.1 Hz, 1 H), 3.97 (d, *J* = 5.3 Hz, 2 H), 3.08 (dd, *J* = 7.1, 0.7 Hz, 2 H), 2.40–2.32 (m, 4 H), 2.16 (s, 3 H), 1.75 (br d, *J* = 8.0 Hz, 4 H), 1.60 (br d, *J* = 12.0 Hz, 1 H), 1.27–0.97 (m, 5 H).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 143.9, 136.2, 131.6, 129.9, 128.4, 127.0, 117.9, 108.6, 61.8, 54.2, 48.1, 37.0, 28.5, 26.3, 26.0, 21.6.

HRMS (ESI): *m*/*z* $[M + H]^+$ calcd for $C_{20}H_{31}N_2O_2S$: 361.2106; found: 361.2106.

(*E*)-*N*-Allyl-*N*-[3-(phenylamino)prop-1-enyl]-*p*-toluenesulfonamide (2v)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 125 mg, 0.50 mmol) with aniline (55 μL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: petroleum ether/EtOAc 90:10) gave **2v** (101 mg, 59%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.63–7.58 (m, 2 H), 7.27 (dd, *J* = 8.5, 0.5 Hz, 2 H), 7.20–7.15 (m, 2 H), 6.90 (d, *J* = 14.2 Hz, 1 H), 6.73 (t, *J* = 7.3 Hz, 1 H), 6.60 (dd, *J* = 8.5, 0.9 Hz, 2 H), 5.63 (ddt, *J* = 17.2, 10.5, 5.3 Hz, 1 H), 5.19–5.12 (m, 2 H), 4.92 (dt, *J* = 14.2, 6.3 Hz, 1 H), 3.99 (dt, *J* = 5.3, 1.6 Hz, 2 H), 3.74 (d, *J* = 6.3 Hz, 2 H), 2.42 (s, 3 H).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 147.9, 143.9, 136.3, 131.7, 130.0, 129.4, 128.7, 127.1, 118.0, 117.8, 113.3, 107.8, 48.3, 44.3, 21.7.

Due to the limited stability of this compound in the analysis conditions, no meaningful HRMS data (either EI or ESI) could be obtained. However, comparison of spectral data with analogous compounds that could be fully characterized allowed establishing the structure beyond reasonable doubt.

(*E*)-*N*-Allyl-4-methyl-*N*-{3-[methyl(phenyl)amino]prop-1-enyl}benzenesulfonamide (2w)

The reaction of *N*-allenyl-*N*-allyl-*p*-toluenesulfonamide (**1b**; 125 mg, 0.50 mmol) with *N*-methylaniline (65 μL, 0.6 mmol, 1.2 equiv) according to the general procedure (reaction time: 18 h, flash chromatography: petroleum ether/EtOAc 90:10) gave **2w** (141 mg, 79%) as an orange oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.60–7.54 (m, 2 H), 7.26–7.19 (m, 4 H), 6.78 (d, *J* = 14.2 Hz, 1 H), 6.76–6.68 (m, 3 H), 5.59 (ddt, *J* = 17.2, 10.5, 5.3 Hz, 1 H), 5.15–5.08 (m, 2 H), 4.81 (dt, *J* = 14.2, 6.1 Hz, 1 H), 3.94 (dt, *J* = 5.3, 1.5 Hz, 2 H), 3.89 (dd, *J* = 6.1, 1.0 Hz, 2 H), 2.86 (s, 3 H), 2.41 (s, 3 H).

^{13}C NMR (101 MHz, $CDCl_3$): δ = 143.9, 136.2, 131.6, 129.9, 129.3, 128.4, 127.1, 118.0, 116.9, 113.2, 106.5, 53.0, 48.2, 37.7, 21.7.

Due to the limited stability of this compound in the analysis conditions, no meaningful HRMS data (either EI or ESI) could be obtained. However, comparison of spectral data with analogous compounds that could be fully characterized allowed establishing the structure beyond reasonable doubt.

Acknowledgement

We thank Centre National de la Recherche Scientifique (CNRS), Ecole Normale Supérieure (ENS), Ecole Nationale Supérieure de Chimie de Paris (ENSCP - Chimie ParisTech), Ecole Nationale Supérieure de Chimie de Montpellier (ENSCM), Région Languedoc-Roussillon and the Agence Nationale de la Recherche (ANR) program CD2I (project CuFeCCBond) for financial support. F.M. also acknowledges the support of Institut Universitaire de France (IUF).

Supporting Information

Supporting information for this article is available online at https://doi.org/10.1055/s-0037-1611673.

References

(1) (a) Mueller, T. E.; Beller, M. *Chem. Rev.* **1998**, *98*, 675. (b) Brunet, J.-J.; Neibecker, D. In *Catalytic Hydrofunctionalization*; Togni, A.; Grützmacher, H., Ed.; Wiley-VCH: Weinheim, **2001**, 91. (c) Pohlki, F.; Doye, S. *Chem. Soc. Rev.* **2003**, *32*, 104. (d) Widenhoefer, R. A.; Han, X. *Eur. J. Org. Chem.* **2006**, 4555. (e) Severin, R.; Doye, S. *Chem. Soc. Rev.* **2007**, *36*, 1407. (f) Müller, T. E.; Hultzsch, K. C.; Yus, M.; Foubelo, F.; Tada, M. *Chem. Rev.* **2008**, *108*, 3795. (g) Patil, N. T.; Kavthe, R. D.; Shinde, V. S. *Tetrahedron* **2012**, *68*, 8079. (h) Reznichenko, A. L.; Hultzsch, K. C. *Top. Organomet. Chem.* **2013**, *43*, 51. (i) Nishina, N.; Yamamoto, Y. *Top. Organomet. Chem.* **2013**, *43*, 115. (j) Huang, L.; Arndt, M.; Gooßen, K.; Heydt, H.; Gooßen, L. J. *Chem. Rev.* **2015**, *115*, 2596. (k) Bernoud, E.; Lepori, C.; Mellah, M.; Schulz, E.; Hannedouche, J. *Catal. Sci. Technol.* **2015**, *5*, 2017. (l) Coman, S. M.; Parvulescu, V. I. *Org. Process Res. Dev.* **2015**, *19*, 1327. (m) Lepori, C.; Hannedouche, J. *Synthesis* **2016**, *49*, 1158. (n) Hannedouche, J. *Chimia* **2018**, *72*, 635.

(2) Blieck, R.; Bahri, J.; Taillefer, M.; Monnier, F. *Org. Lett.* **2016**, *18*, 1482.

(3) Perego, L. A.; Blieck, R.; Groué, A.; Monnier, F.; Taillefer, M.; Ciofini, I.; Grimaud, L. *ACS Catal.* **2017**, *7*, 4253.

(4) Perego, L. A.; Blieck, R.; Michel, J.; Ciofini, I.; Grimaud, L.; Taillefer, M.; Monnier, F. *Adv. Synth. Catal.* **2017**, *359*, 4388.

(5) (a) Mujumdar, P.; Poulsen, S.-A. *J. Nat. Prod.* **2015**, *78*, 1470. (b) Mujumdar, P.; Teruya, K.; Tonissen, K. F.; Vullo, D.; Supuran, C. T.; Peat, T. S.; Poulsen, S.-A. *J. Med. Chem.* **2016**, *59*, 5462. (c) Petkowski, J. J.; Bains, W.; Seager, S. *J. Nat. Prod.* **2018**, *81*, 423.

(6) (a) Reitz, A. B.; Smith, G. R.; Parker, M. H. *Expert Opin. Ther. Pat.* **2009**, *19*, 1449. (b) Kalgutkar, A. S.; Jones, R.; Sawant, A. In *Metabolism, Pharmacokinetics, Toxicity of Functional Groups: Impact of Chemical Building Blocks on ADMET*; Smith, D. A., Ed.; RSC Publishing: Cambridge, **2010**, 210.

(7) Chinthakindi, P. K.; Naicker, T.; Thota, N.; Govender, T.; Kruger, H. G.; Arvidsson, P. I. *Angew. Chem. Int. Ed.* **2017**, *56*, 4100.

(8) (a) Supuran, C. T.; Casini, A.; Scozzafava, A. *Med. Res. Rev.* **2003**, *23*, 535. (b) Supuran, C.; Innocenti, A.; Mastrolorenzo, A.; Scozzafava, A. *Mini-Rev. Med. Chem.* **2004**, *4*, 189. (c) Winum, J.-Y.; Scozzafava, A.; Montero, J.-L.; Supuran, C. T. *Med. Res. Rev.* **2006**, *26*, 767. (d) Smith, D. A.; Jones, R. M. *Curr. Opin. Drug Discovery Dev.* **2008**, *11*, 72. (e) Shoaib Ahmad Shah, S.; Rivera, G.;

Ashfaq, M. *Mini-Rev. Med. Chem.* **2013**, *13*, 70. (f) Ammazzalorso, A.; De Filippis, B.; Giampietro, L.; Amoroso, R. *Chem. Biol. Drug Des.* **2017**, *90*, 1094.

(9) Bäckvall and co-workers have already observed a similar influence of pendant allyl groups in a copper-catalysed reaction. N-Allyl and N-aryl secondary sulfonamides could be coupled with bromoallenes by the use of a copper catalyst giving N-allenyl-N-allylsulfonamides, but the reaction failed when saturated N-substituents were employed. Persson, A. K. Å.; Johnston, E. V.; Bäckvall, J.-E. *Org. Lett.* **2009**, *11*, 3814.