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A Convenient Synthesis of γ -Amino-Ynamides via Additions of Lithiated Ynamides to Aryl Imines. Observation of an Aza-Meyer-Schuster Rearrangement.[†]

Rui Qi^a, Xiao-Na Wang^b, Kyle A. DeKorver^c, Yu Tang^a, Chao-Chao Wang^a, Qian Li^a, Hui Li^a, Ming-Can Lv^a, Qing Yu^a, and Richard P. Hsung^b

^aSchool of Pharmaceutical Science and Technology, and Tianjin Key Laboratory for Modern Drug Delivery & High-Efficiency, Tianjin University, Tianjin 300072 P. R. China

^bDepartment of Chemistry and Division of Pharmaceutical Sciences, School of Pharmacy, University of Wisconsin–Madison, Madison, WI 53705 USA

^cDow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, IN 46268 USA

Abstract

Efforts in developing an expeditious and convenient method for synthesizing γ -amino-ynamides via nucleophilic addition of lithiated ynamides to aryl imines are described. This work also features an *aza*-variant of a Meyer-Schuster rearrangement of γ -amino-ynamides and the synthetic utility of γ -amino-ynamides in an intramolecular ketenimine-[2 + 2] cycloaddition.

Keywords

Lithiated ynamides; γ -amino-ynamides; aryl imine addition; azetene; *aza*-Meyer-Schuster rearrangement

Introduction

We have been involved with the chemistry of ynamides for the last 17 years, and this burgeoning field has attracted an immense amount of attention from the synthetic community in recent years.^{1–4} Consequently, new and improved protocols for synthesizing ynamides³ and structural relatives of ynamides^{5,6} have continued to appear in the literature.^{3e} Recently, when we employed γ -amino-ynamides **1** [see Scheme 1] to develop *N*-tethered intramolecular transformations for constructing *N*-heterocycles,⁷ we recognized that this class of ynamides is not trivial to make.

The existing copper-catalyzed protocols,^{1,2,5} albeit attractive, may not be suitable to directly couple amides with *N*-unprotected propargyl amines **3** [see retrosynthetic cleavage a].⁸ On the other hand, with *N*-protected propargyl amines **5**, it would constitute an encumbered process in addition to the fact that the penultimate deprotection step could still pose problems to the stability of ynamides. The most direct access would be retrosynthetic

[†]With the deepest respect and admiration, authors wish to dedicate this paper to Professor Scott E. Denmark on a very special occasion in celebrating his 60th Birthday.

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Correspondence to: Kyle A. DeKorver; Yu Tang; Richard P. Hsung.

Fax: 608-262-5345. kadekorver@dow.com, tangyu114@gmail.com, rhsung@wisc.edu.

pathway b in which the metallated ynamide **7** could be added to a nitrogen source in the form of an imine. While metallated ynamides have been added to a number of electrophiles,⁹ to the best of our knowledge, it is not known in adding to imines.¹ Inspired by Poisson's recent account¹⁰ on additions of lithiated ynol-ethers to imines,¹¹ we explored this potentially expeditious method. We wish to report here a general and convenient protocol for synthesizing γ -amino-ynamides.

Results and Discussions

Deprotonation of ynamides **8** with 1.5 equiv LHMDs in THF at $-50\text{ }^{\circ}\text{C}$ followed by the addition of various imines turned out to be a highly efficient protocol. A diverse array of *N*-sulfonyl or *N*-carbamoyl- γ -amino-ynamides **9-15** could be accessed in good yields through this simple method [Table 1]. Ynamide precursors could be those of oxazolidinone-substituted [entries 1-6], sulfonyl-substituted [entries 7-14], or even phosphoryl-substituted¹² [entry 15]. Ketimines were also suitable substrates [entries 5 and 13], while aldimines could include electron withdrawing [entry 11] or donating [entries 4 and 12] sulfonyl systems.

What intrigued us was that some of these γ -amino-ynamides did not overtly stable to silica gel column chromatography and appeared to rearrange cleanly to another compound especially in the presence of acid. Upon further examination, we found that ynamide **12a** could rearrange to α,β -unsaturated amidine **16** when treated with 5 mol% of HNTf₂ at rt [Scheme 2]. The assignment of amidine **16** was confirmed through its single-crystal X-ray structure [Figure 1]. Two possible mechanistic pathways could be proposed to account for this rearrangement. Pathway-a features an acid promoted γ -elimination followed by re-association of the departed amide with the allenylidene iminium ion **17**. Pathway-b favors an intramolecular non-dissociative possibility through pericyclic ring-opening of an azetene intermediate **19**.¹³

To further delineate these two possibilities, we carried out the following crossover experiments [Scheme 3]. After treating a mixture of γ -amino-ynamides **12a** and **12z** with a ratio of either 4:1 [Reaction-A] or 1:4 [Reaction-B] with 5 mol% HNTf₂, we examined closely the crude reaction mixture and all fractions resulting from purifications of both reactions. We did not find possible crossover products **16az** and **16za** in either reaction using ¹H-NMR, and ynamides **12a** and **12z** in both reactions appeared to yield only their respective rearranged products **16a** and **16z**. The presence of products **16az** and **16za** would have implied pathway-a being operative.

To be more precise, we scanned the crude mixture from incomplete reactions using LCMS, and impressively, we did not find fractions with the mass that would correlate to either **16az** or **16za** [see red arrows in Figure 2, which indicate where **16az** and **16za** would be respectively when co-injected with the crude mixtures from Reaction A and B]. It is noteworthy that rearrangement of **12a** appears to be much faster than that **12z**. These results suggest pathway-b that would involve the formation of azetene **19** and pericyclic ring-opening. Related ring-opening through oxetenes^{14,15} is quite well-known, and the current rearrangement essentially constitutes an aza-variant of Meyer-Schuster rearrangements.¹⁶

While this rearrangement is of interest both synthetically and mechanistically, and that this has become an ongoing project of another focus, we demonstrate here how these γ -amino-ynamides can be utilized in further transformations. As shown in Scheme 4, the γ -amino group in **9a** could be readily *N*-allylated using Mitsunobu conditions, leading to ynamide **20** in 60% yield. This *N*-allylation proved to quite general for a number of γ -amino-ynamides such as **12a**, **14**, and **15** to give *N*-allylated products **21-23**, respectively. An immediate

application is a Pd(0)-catalyzed *aza*-Claisen rearrangement¹⁷⁻¹⁹ in tandem with ketenimine-[2 + 2] cycloaddition,²⁰⁻²³ leading to either a rare crossed cycloadduct **24** from ynamide **22**, or fused cycloadduct **25** from ynamide **23** in a highly stereoselective manner [Scheme 5].⁷

Conclusion

We have described here our efforts in developing an expeditious and convenient method for synthesizing γ -amino-ynamides via nucleophilic addition of lithiated ynamides to aryl imines. In this study, we also uncovered an *aza*-variant of a Meyer-Schuster rearrangement of γ -amino-ynamides and demonstrated the usefulness of these γ -amino-ynamides in designing intramolecular transformation.

Experimental Section

General Procedure for Additions to Aryl Imines

To a solution of ynamide in freshly distilled THF (*concn* = 0.1 M) at $-50\text{ }^{\circ}\text{C}$ was added LHMDs (1.5 equiv, 1.0 M solution in THF) dropwise via syringe. The reaction was allowed to stir at $-50\text{ }^{\circ}\text{C}$ for 1 h to ensure complete deprotonation. Then a solution of imine (1.5 equiv, 1.5 M in freshly distilled THF) was added via 10 min. After 1 h, H_2O (5 mL) was added and the reaction was allowed to warm to room temperature and diluted with EtOAc. The organic phase was separated and the aqueous phase extracted twice with EtOAc. The combined organic phases were washed with sat aq NaCl, dried over Na_2SO_4 , and concentrated *in vacuo*. The resulting crude product was purified through silica gel flash column chromatography (gradient eluent: EtOAc in petroleum ether) to give corresponding γ -amino-ynamides.

γ -Amino-Ynamide (9a)—(68%, 0.16 g); R_f = 0.46 [2:3 hexanes/EtOAc]; white solid; mp = $147\text{--}149\text{ }^{\circ}\text{C}$.

IR (KBr): 1415 (m), 1475 (m), 1492 (w), 1597 (w), 1761 (s), 1928 (w), 2268 (m), 2912 (w), 2972 (w), 3062 (w), 3086 (w), 3263 (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.43 (s, 3H), 3.64–3.73 (ddd, 2H, J = 8.0 Hz), 4.39 (dd, 2H, J = 8.0 Hz), 4.92 (d, 1H, J = 8.4 Hz), 5.48 (d, 1H, J = 8.4 Hz), 7.29–7.34 (m, 5H), 7.47 (d, 2H, J = 6.8 Hz), 7.80 (d, 2H, J = 8.4 Hz).

^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ = 21.4, 46.7, 48.9, 64.0, 68.2, 77.0, 127.3, 127.6, 128.4, 128.9, 129.8, 138.80, 138.82, 143.06, 156.14.

MS (ESI): m/z (% relative intensity) 763 (100) ($2\text{M}+\text{Na}$)⁺.

HRMS (ESI): m/z calcd for $\text{C}_{19}\text{H}_{18}\text{N}_2\text{O}_4\text{SK}^+$: 409.0987; found 409.0668.

γ -Amino-Ynamide (9b)—(80%, 0.18 g); R_f = 0.41 [2:3 hexanes/EtOAc]; light yellow solid; mp = $155\text{--}157\text{ }^{\circ}\text{C}$. IR (KBr): 1386 (w), 1423 (s), 1445 (w), 1477 (m), 1497 (w), 1597 (w), 1747 (s), 2274 (m), 2860 (w), 2910 (w), 1373 (w), 1984 (w), 3205 (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.42 (s, 3H), 3.73 (dd, 2H, J = 8.0 Hz), 4.39 (t, 2H, J = 8.0 Hz), 5.16 (d, 1H, J = 8.0 Hz), 5.52 (d, 1H, J = 8.0 Hz), 6.26 (d, 1H, J = 3.2 Hz), 6.36 (d, 1H, J = 3.2 Hz), 7.28 (s, 1H), 7.30 (d, 2H, J = 6.8 Hz), 7.77 (d, 2H, J = 8.4 Hz).

^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ = 21.5, 43.7, 46.4, 63.1, 66.5, 75.3, 108.6, 110.5, 127.4, 129.5, 137.4, 143.1, 143.5, 149.2, 155.6.

MS (ESI): m/z (% relative intensity) 743 (100) (2M+Na)⁺.

HRMS (ESI): m/z calcd for C₁₇H₁₆N₂O₅SNa⁺: 383.0780; found 383.0833.

γ-Amino-Ynamide (9c)—(81%, 0.26 g); R_f = 0.33 [2:3 hexanes/EtOAc]; white solid; mp = 199–201 °C.

IR (KBr): 1367 (s), 1408 (m), 1435 (w), 1454 (m), 1478 (m), 1566 (w), 1598 (w), 1731 (s), 1782 (s), 2270 (w), 2355 (w) 2914 (w), 2986 (w), 3246 (brs).

¹H NMR (400 MHz, CDCl₃): δ = 2.66 (s, 9 H), 2.24 (s, 3 H), 3.59–3.71 (ddd, 2 H, J = 8.0 Hz), 4.38 (dd, 2 H, J = 8.0 Hz), 4.93 (d, 1H, J = 8.8 Hz), 5.59 (d, 1H, J = 8.8 Hz), 7.21–7.24 (m, 3 H), 7.30–7.33 (t, 1 H, J = 8.0 Hz), 7.68 (d, 1 H, J = 8.0), 7.71 (s, 1H), 7.80 (d, 2H, J = 8.0 Hz) 8.10 (d, 1 H, J = 8.0 Hz).

¹³C NMR (100 MHz, DMSO-*d*₆): δ = 21.4, 28.1, 42.0, 46.5, 64.1, 67.5, 76.0, 84.5, 115.2, 118.4, 120.5, 123.2, 125.0, 125.2, 127.35, 128.0, 129.7, 135.7, 138.6, 143.1, 149.3, 156.3.

MS (ESI): m/z (% relative intensity) 1041 (100) (2M+Na)⁺.

HRMS (ESI): m/z calcd for C₂₆H₂₇N₃O₆SNa⁺: 532.1621; found 532.1829.

γ-Amino-Ynamide (9d)—(72%, 0.18 g); R_f = 0.26 [2:3 hexanes/EtOAc]; white solid; mp = 148–150 °C.

IR (KBr): 1421 (m), 1477 (m), 1499 (m), 1579 (m), 1596 (m), 1757 (s), 2260 (m), 2848 (w), 2916 (w), 2974 (w), 3032 (w), 3080 (w), 3010 (w), 3292 (brs).

¹H NMR (400 MHz, CDCl₃): δ = 3.66–3.70 (ddd, 2H, J = 8.0 Hz), 3.88 (s, 3 H), 4.38 (dd, 2 H, J = 8.0 Hz), 4.98 (d, 1 H, J = 8.8 Hz), 5.46 (d, 1 H, J = 6.8 Hz), 6.99 (d, 2 H, J = 8.8 Hz) 7.29–7.34 (m, 3 H), 7.48 (d, 2H, J = 8 Hz), 7.85 (d, 2H, J = 8.8 Hz).

¹³C NMR (100 MHz, DMSO-*d*₆): δ = 46.5, 48.9, 56.1, 64.0, 68.4, 77.0, 114.5, 127.6, 128.3, 128.8, 129.4, 133.4, 138.9, 156.0, 162.6.

MS (ESI): m/z (% relative intensity) 795 (100) (2M+Na)⁺.

HRMS (ESI): m/z calcd for C₁₉H₁₈N₂O₅SNa⁺: 409.0936; found 409.1123.

γ-Amino-Ynamide (10)—(73%, 0.15 g); R_f = 0.30 [7:3 hexanes/EtOAc]; white solid; mp = 183–185 °C.

IR (KBr): 1421 (m), 1449 (w), 1479 (w), 1599 (w), 1632 (w), 1767 (s), 2266 (m), 2320 (w), 2378 (w), 2878 (w), 2920 (w), 2938 (w), 3059 (w), 3165 (s), 3440 (brs).

¹H NMR (400 MHz, CDCl₃): δ = 2.41 (s, 3H), 3.78 (t, 2H, J = 8.0 Hz), 4.40 (t, 2H, J = 8.0 Hz), 5.38 (s, 1H), 7.19 (d, 2H, J = 4.0 Hz), 7.24–7.33 (m, 6 H), 7.50 (d, 4H, J = 8.0 Hz), 7.61 (d, 2H, J = 8.0 Hz).

¹³C NMR (100 MHz, DMSO-*d*₆): δ = 21.4, 46.4, 62.7, 64.1, 70.5, 79.9, 127.2, 127.4, 127.8, 128.4, 129.3, 140.4, 142.6, 143.8, 156.1.

MS (ESI): m/z (% relative intensity) 915 (100) (2M+Na)⁺.

HRMS (ESI): m/z calcd for C₂₅H₂₂N₂O₄SK⁺: 485.1300; found 485.1325.

γ -Amino-Ynamide (11)—(61%, 0.26 g); R_f = 0.56 [2:3 hexanes/EtOAc]; white solid; mp = 102–104 °C.

IR (KBr): 1377 (w), 1421 (m), 1454 (w), 1475 (w), 1493 (w), 1526 (s), 1687 (s), 1773 (s), 2262 (m), 2330 (w), 2360 (w), 2920 (w), 3033 (w), 3057 (w), 3309 (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.91 (t, 2H, J = 8.0 Hz), 4.44 (t, 2H, J = 8.0 Hz), 5.14 (dd, 2H, J = 12.0, 16.0 Hz), 5.30 (d, 1H, J = 8.8 Hz), 5.85 (d, 1H, J = 8.8 Hz), 7.29–7.38 (m, 6H), 7.52 (d, 2H, J = 7.2 Hz).

^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ = 46.5, 46.9, 64.1, 66.2, 69.6, 75.6, 127.3, 128.2, 128.3, 128.3, 128.8, 128.9, 137.3, 140.0, 155.9, 156.5.

MS (ESI): m/z (% relative intensity) 723 (38) ($2\text{M}+\text{Na}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{20}\text{H}_{18}\text{N}_2\text{O}_4\text{K}^+$: 389.1267; found 389.1141.

γ -Amino-Ynamide (12a)—(84%, 0.61 g); R_f = 0.28 [2:3 hexanes/EtOAc]; white solid; mp = 158–160 °C.

IR (KBr): 1362 (s), 1400 (w), 1427 (m), 1450 (m), 1492 (m), 1597 (m), 1917 (w), 1964 (w), 2249 (m), 2367 (w), 2837 (w), 2871 (w), 2922 (w), 3070 (w), 3275 (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.37 (s, 3H), 2.43 (s, 3H), 4.29 (dd, 2H, J = 13.6, 20.8 Hz), 4.72 (d, 1H, J = 8.4 Hz), 5.34 (d, 1H, J = 8.4 Hz), 7.12 (d, 2H, J = 6.8 Hz), 7.18–7.20 (m, 5H), 7.22–7.26 (m, 4H), 7.29–7.33 (m, 3H), 7.60 (d, 2H, J = 8.4 Hz), 7.68 (d, 2H, J = 8.4 Hz).

^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ = 21.4, 21.6, 48.8, 55.2, 68.7, 79.4, 127.1, 127.6, 127.9, 128.3, 128.6, 128.7, 128.7, 128.9, 129.7, 130.5, 134.4, 135.2, 138.9, 139.2, 142.8, 145.4.

MS (ESI): m/z (% relative intensity) 1111 (100) ($2\text{M}+\text{Na}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{30}\text{H}_{28}\text{N}_2\text{O}_4\text{S}_2\text{K}^+$: 583.1490; found 583.1080.

γ -Amino-Ynamide (12b)—(67%, 0.35 g); R_f = 0.20 [7:3 hexanes/EtOAc]; white solid; mp = 116–117 °C.

IR (KBr): 1367 (s), 1420 (w), 1440 (m), 1498 (m), 1529 (w), 1660 (w), 1732 (w), 1801 (w), 1917 (w), 2247 (m), 2368 (w), 2723 (w), 2877 (w), 3032 (w), 3120w (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.35 (s, 3H), 2.42 (s, 3H), 4.30 (dd, 2H, J = 21.6, 14.0 Hz), 5.06 (d, 1H, J = 8.5 Hz), 5.38 (d, 1H, J = 8.5 Hz), 6.09 (d, 1H, J = 3.2 Hz), 6.20 (t, 1H, J = 2.9 Hz), 7.16 (m, 4H), 7.26 (m, 6H), 7.63 (d, 2H, J = 8.2 Hz), 7.67 (d, 2H, J = 8.2 Hz).

^{13}C NMR (100 MHz, CDCl_3): δ = 21.5, 21.7, 43.7, 55.2, 66.7, 78.9, 108.3, 110.4, 127.2, 127.7, 128.4, 128.6, 128.7, 129.6, 129.8, 134.1, 134.5, 137.4, 142.9, 143.5, 144.9, 149.8.

MS (ESI): m/z (% relative intensity) 1091 (100) ($2\text{M}+\text{Na}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{28}\text{H}_{26}\text{N}_2\text{O}_5\text{S}_2\text{K}^+$: 573.1283; found 573.1393.

γ -Amino-Ynamide (12c)—(79%, 0.19 g); R_f = 0.27 [4:1 hexanes/EtOAc]; white solid; mp = 143–145 °C.

IR (KBr): 1082 (m), 1159 (s), 1370 (s), 1454 (m), 1597 (w), 1735 (s), 2254 (m), 2981 (w), 3252 (s).

^1H NMR (400 MHz, CDCl_3): δ = 1.66 (s, 9H), 2.30 (s, 3H), 2.41 (s, 3H), 4.17 (d, 1H, J = 14.4 Hz), 4.37 (d, 1H, J = 14.4 Hz), 5.03 (d, 1H, J = 8.8 Hz), 5.60 (d, 1H, J = 8.4 Hz), 7.06–7.11 (m, 4H), 7.15–7.21 (m, 3H), 7.23–7.27 (m, 3H), 7.29–7.34 (m, 2H), 7.55 (d, 1H, J = 4.4 Hz), 7.60 (d, 2H, J = 8 Hz), 7.64–7.66 (m, 3H).

^{13}C NMR (100 MHz, CDCl_3): δ = 21.4, 21.6, 28.1, 42.7, 55.1, 67.7, 79.0, 84.0, 115.1, 117.5, 119.7, 122.8, 124.7, 124.9, 127.2, 127.4, 127.5, 128.3, 128.4, 128.5, 129.3, 129.7, 134.2, 134.6, 135.9, 137.2, 143.3, 144.7, 149.3.

MS (ESI): m/z (% relative intensity) 1389 (100) ($2\text{M}+\text{Na}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{37}\text{H}_{37}\text{N}_3\text{O}_6\text{S}_2\text{K}^+$: 722.2124; found 722.2424.

γ -Amino-Ynamide (12d)—(78%, 0.16 g); R_f = 0.38 [7:3 hexanes/EtOAc]; white solid; mp = 141–143 °C.

IR (KBr): 1167 (s), 1348 (s), 1529 (s), 1597 (w), 2248 (m), 3275 (s).

^1H NMR (400 MHz, CDCl_3): δ = 2.45 (s, 3H), 4.32 (s, 2H), 5.33 (d, 1H, J = 8.0 Hz), 5.47 (d, 1H, J = 8.0 Hz), 7.15 (d, 2H), 7.20–7.27 (m, 6H), 7.29–7.33 (m, 4H), 7.64 (d, 2H, J = 8.4 Hz), 7.90 (d, 2H, J = 8.8 Hz), 8.15 (d, 2H, J = 8.8 Hz).

^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ = 21.6, 49.8, 55.0, 68.0, 80.4, 124.1, 127.2, 127.5, 128.2, 128.5, 128.6, 128.7, 129.9, 133.9, 134.3, 137.1, 145.0, 146.1, 149.8 (2 carbon peaks missing due to overlap).

MS (ESI): m/z (% relative intensity) 1173 (100) ($2\text{M}+\text{Na}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{29}\text{H}_{25}\text{N}_3\text{O}_6\text{S}_2\text{Na}^+$: 598.0987; found 598.1057.

γ -Amino-Ynamide (12e)—(70%, 0.12 g); R_f = 0.30 [7:3 hexanes/EtOAc]; white solid; mp = 150–152 °C.

IR (KBr): 1367 (s), 1404 (w), 1435 (m), 1495 (s), 1579 (s), 1597 (s), 1801 (w), 1895 (w), 1951 (w), 1969 (w), 2032 (w), 2250 (s), 2585 (w), 2844 (w), 2947 (w), 3014 (w), 3032 (w), 3105 (w), 3226 (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.45 (s, 3H), 3.83 (s, 3H), 4.34 (dd, 2H, J = 13.6, 24.4 Hz), 4.85 (d, 1H, J = 8.4 Hz), 5.35 (d, 1H, J = 8.4 Hz), 6.89 (d, 2H, J = 8.8 Hz), 7.15 (d, 2H, J = 6.4 Hz), 7.20–7.33 (m, 10H), 7.63 (d, 2H, J = 8.0 Hz), 7.75 (d, 2H, J = 8.8 Hz).

^{13}C NMR (100 MHz, CDCl_3): δ = 21.6, 49.4, 55.1, 55.5, 68.5, 79.9, 114.1, 127.1, 127.6, 128.2, 128.4, 128.5, 128.5, 128.7, 129.3, 129.7, 131.9, 134.1, 134.5, 137.7, 144.8, 162.8.

MS (ESI): m/z (% relative intensity) 583 (100) ($\text{M}+\text{Na}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{30}\text{H}_{28}\text{N}_2\text{O}_5\text{S}_2\text{Na}^+$: 583.1440; found 583.1829.

γ -Amino-Ynamide (12z)—(76%, 0.12 g); R_f = 0.24 [7:3 hexanes/EtOAc]; white solid; mp = 152–154 °C.

IR (KBr): 1360 (s), 1463 (w), 1496 (m), 1556 (s), 1576 (s), 1610 (s), 2830 (w), 3021 (w), 3445 (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.38 (s, 3H), 3.74 (s, 3H), 4.35 (dd, 2H, J = 13.8, 34.2 Hz), 4.91 (d, 1H, J = 8.4 Hz), 5.48 (d, 1H, J = 8.4 Hz), 6.79 (d, 2H, J = 9.0 Hz), 7.14 (d, 2H, J = 7.8 Hz), 7.17 (d, 2H, J = 7.8 Hz), 7.24–7.31 (m, 4H), 7.46–7.49 (m, 2H), 7.60 (d, 2H, J = 7.8 Hz).

^{13}C NMR (100 MHz, CDCl_3): δ = 21.6, 49.7, 55.2, 55.5, 68.6, 80.3, 114.1, 125.0, 126.2, 126.3, 126.4, 127.6, 127.6, 128.2, 128.4, 128.5, 128.6, 128.7, 129.4, 129.8, 131.9, 133.0, 133.0, 134.2, 134.5, 135.1, 144.8, 162.8.

MS (ESI): m/z (% relative intensity) 611.2 (100) ($\text{M} + \text{H}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{34}\text{H}_{30}\text{N}_2\text{O}_5\text{S}_2\text{Na}^+$: 633.1596; found 633.1487.

γ -Amino-Ynamide (13)—(65%, 0.13 g); R_f = 0.25 [10:3 hexanes/EtOAc]; white solid; mp = 147–149 °C.

IR (KBr): 1367 (s), 1400 (m), 1438 (m), 1452 (s), 1493 (m), 1594 (m), 1649 (w), 1762 (w), 1803 (w), 1818 (w), 1936 (w), 2256 (s), 2322 (w), 2956 (w), 3034 (w), 3089 (w), 3208 (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.41 (s, 3H), 2.44 (s, 3H), 4.35 (s, 2H), 5.14 (s, 1H), 7.09 (d, 2H, J = 8.0 Hz), 7.15–7.30 (m, 17H), 7.39 (d, 2H, J = 8.0 Hz), 7.71 (d, 2H, J = 8.0 Hz).

^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ = 21.4, 21.5, 54.8, 62.7, 71.3, 82.2, 127.0, 127.2, 127.7, 127.9, 128.2, 128.6, 128.8, 128.9, 129.2, 130.49, 134.5, 135.0, 140.4, 142.3, 143.6, 145.4.

MS (ESI): m/z (% relative intensity) 1263 (100) ($2\text{M} + \text{Na}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{36}\text{H}_{32}\text{N}_2\text{O}_4\text{S}_2\text{K}^+$: 659.1803; found 659.2013.

γ -Amino-Ynamide (14)—(74%, 0.31 g); R_f = 0.22 [3:1 hexanes/EtOAc]; white solid; mp = 123–124 °C.

IR (film): 2961 (m), 2922 (m), 2248 (m), 1738 (m), 1597 (m), 1365 cm^{-1} (s).

^1H NMR (400 MHz, CDCl_3): δ = 2.39 (s, 3H), 2.43 (s, 3H), 3.72 (ddt, 1H, J = 1.2, 6.4, 14.8 Hz), 3.78 (ddt, 1H, J = 1.2, 6.4, 14.8 Hz), 4.98 (d, 1H, J = 8.4 Hz, 1H), 5.10 (dq, 1H, J = 1.2, 16.8 Hz), 5.12 (dq, 1H, J = 1.2, 10.4 Hz), 5.41 (d, 1H, J = 8.4 Hz), 5.52 (ddt, 1H, J = 6.4, 10.4, 16.8 Hz), 7.22 (dd, 2H, J = 0.8, 8.4 Hz), 7.26 (dd, 2H, J = 0.8, 8.4 Hz), 7.28–7.34 (m, 3H), 7.39–7.41 (m, 2H), 7.63 (d, 2H, J = 8.4 Hz), 7.71 (d, 2H, J = 8.4 Hz).

^{13}C NMR (125 MHz, CDCl_3): δ = 21.6, 21.8, 49.6, 54.0, 68.1, 79.7, 120.1, 127.4, 127.4, 127.8, 128.4, 128.7, 129.7, 129.9, 130.7, 134.6, 137.7, 137.9, 143.5, 145.0.

MS (ESI): m/z (% relative intensity) 495 (100) ($\text{M} + \text{H}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{26}\text{H}_{27}\text{N}_2\text{O}_4\text{S}_2$ [$\text{M} + \text{H}$] $^+$: 495.1407; found 495.1427.

γ -Amino-Ynamide (15)—(48%, 0.65 g); R_f = 0.23 [1:1 hexanes/EtOAc]; white solid; mp = 137–138 °C.

IR (film): 3143 (brm), 2968 (m), 2934 (m), 2888 (m), 2251 (m), 1454 (m), 1325 (s), 1273 cm^{-1} (s).

^1H NMR (500 MHz, CDCl_3): δ = 0.84 (s, 3H), 1.01 (s, 3H), 2.38 (s, 3H), 3.60–3.69 (m, 2H), 3.94–4.02 (m, 4H), 5.15 (d, 1H, J = 9.5 Hz), 5.18 (d, 1H, J = 16.0 Hz), 5.35 (s, 1H), 5.67–5.75 (m, 1H), 6.22 (brs, 1H), 7.20–7.26 (m, 5H), 7.38–7.40 (m, 2H), 7.73 (d, 2H, J = 8.5 Hz).

^{13}C NMR (125 MHz, CDCl_3): δ = 20.4, 20.9, 21.2, 31.7 (d, J = 6.8 Hz), 49.1, 52.8 (d, J = 5.8 Hz), 62.6 (d, J = 5.8 Hz), 78.0 (d, J = 6.8 Hz), 81.5 (d, J = 4.8 Hz), 118.5, 126.0, 126.8 (d, J = 4.9 Hz), 127.7, 128.1, 129.1, 131.9, 137.6, 138.2, 142.8.

^{31}P NMR (202 MHz, CDCl_3) δ = -1.31.

MS (ESI): m/z (% relative intensity) 489 (100) ($\text{M}+\text{H}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{24}\text{H}_{30}\text{N}_2\text{O}_5\text{PS}$ [$\text{M}+\text{H}$] $^+$: 489.1608; found 489.1600.

General Procedure for the Rearrangement

To a 0.05 *M* solution of ynamide in anhyd CH_2Cl_2 was added HNTf_2 (0.05 equiv) at rt. The resulting solution was stirred at rt and the reaction progress was monitored using TLC analysis. When the starting material was completely consumed, the reaction mixture was quenched with Et_3N . Removal of the solvent *in vacuo* led to a crude material that was purified using silica gel flash column chromatography (gradient eluent: EtOAc in hexane).

Rearranged Product (16a)—(78%, 0.14 g); R_f = 0.59 [7:3 hexanes/EtOAc]; white solid; mp = 156–157 °C.

IR (KBr): 1346 (m), 1380 (w), 1399 (w), 1446 (w), 1495 (w), 1512 (w), 1558 (m), 1576 (m), 1612 (m), 1705 (m), 1747 (w), 2928 (w), 2964 (w), 3030 (w), 3064 (w), 3443 (brs).

^1H NMR (400 MHz, CDCl_3): δ = 2.39 (s, 6H), 4.93 (s, 2H), 7.03–7.16 (m, 5H), 7.18–7.24 (m, 6H), 7.38–7.43 (m, 5H), 7.46 (d, 2H, J = 8.4 Hz), 7.51 (d, 2H, J = 8.4 Hz).

^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): δ = 21.5, 21.6, 52.0, 119.4, 127.0, 127.8, 128.2, 128.3, 128.4, 128.6, 128.9, 129.2, 129.6, 130.6, 134.3, 135.4, 135.7, 138.5, 143.1, 144.7, 145.0, 164.1.

MS (APCI): m/z (% relative intensity) 545.32 (100) ($\text{M}+\text{H}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{30}\text{H}_{28}\text{N}_2\text{O}_4\text{S}_2\text{K}^+$: 583.1490; found 583.1641.

Rearranged Product (16z)—(65%, 0.060 g); R_f = 0.33 [7:3 hexanes/EtOAc]; yellow solid; mp = 139–140 °C.

IR (KBr): 1364 (s), 1429 (m), 1454 (m), 1496 (s), 1557 (m), 1596 (s), 2252 (m), 2843 (w), 2914 (w), 3062 (w), 3219 (s).

^1H NMR (600 MHz, CDCl_3): δ = 2.39 (s, 3H), 3.80 (s, 3H), 4.95 (s, 2H), 6.81 (d, 2H, J = 12.0 Hz), 7.14 (d, 2H, J = 12.0 Hz), 7.20–7.26 (m, 7H), 7.49–7.58 (m, 7H), 7.80 (s, 1H), 7.84 (t, 3H, J = 6.0 Hz).

^{13}C NMR (150 MHz, CDCl_3): δ = 21.6, 52.1, 55.6, 100.0, 113.7, 119.5, 123.6, 126.8, 127.5, 127.8, 128.2, 128.4, 128.6, 128.7, 128.8, 129.1, 129.6, 130.5, 131.8, 133.2, 133.3, 134.4, 135.3, 135.8, 145.01, 145.02, 162.7, 164.0.

MS (ESI): m/z (% relative intensity) 611.2 (100) ($\text{M}+\text{K}$) $^+$.

HRMS (ESI): m/z calcd for $C_{34}H_{30}N_2O_5S_2Na^+$: 633.1596; found 633.1490.

Rearranged Product (16az)—(72%, 0.24 g); R_f = 0.39 [7:3 hexanes/EtOAc]; yellow solid; mp = 149–151 °C.

IR (KBr): 1361 (s), 1322 (m), 1496 (m), 1556 (s), 1577 (s), 1595 (s), 1610 (s), 2841 (w), 2935 (w), 2960 (w), 3033 (w), 3062 (w).

1H NMR (600 MHz, $CDCl_3$): δ = 2.39 (s, 3H), 3.82 (s, 3H), 4.95 (s, 2H), 6.81 (d, 2H, J = 8.5 Hz), 7.02 (d, 1H, J = 16.2 Hz), 7.11–7.14 (m, 3H), 7.18–7.25 (m, 5H), 7.38 (m, 5H), 7.48 (d, 2H, J = 7.8 Hz), 7.56 (d, 2H, J = 8.4 Hz)

^{13}C NMR (150 MHz, $CDCl_3$): δ = 21.6, 52.0, 55.6, 113.7, 119.4, 127.8, 128.2, 128.3, 128.3, 128.6, 128.9, 129.1, 129.6, 130.6, 133.2, 134.3, 135.3, 135.7, 144.6, 145.0, 162.7, 164.0.

MS (ESI): m/z (% relative intensity) 561 (100) ($M + H$) $^+$.

HRMS (ESI): m/z calcd for $C_{30}H_{28}N_2O_5S_2Na^+$: 583.1440; found 583.1332.

Rearranged Product (16za)—(57%, 0.19 g); R_f = 0.54 [7:3 hexanes/EtOAc]; yellow solid; mp = 178–179 °C.

IR (KBr): 1361 (s), 1454 (w), 1496 (w), 1593 (m), 3028 (w), 3260 (w).

1H NMR (600 MHz, $CDCl_3$): δ = 2.38 (s, 6H), 4.95 (s, 2H), 7.14 (d, 2H, J = 7.8 Hz), 7.16 (d, 2H, J = 7.2 Hz), 7.21–7.26 (m, 7H), 7.48 (d, 2H, J = 8.4 Hz), 7.52 (d, 4H, J = 7.8 Hz), 7.57 (d, 1H, J = 8.4 Hz), 7.80 (s, 1H), 7.85 (m, 3H).

^{13}C NMR (150 MHz, $CDCl_3$): δ = 21.5, 21.6, 52.1, 119.5, 123.6, 125.6, 126.8, 127.0, 127.5, 127.8, 128.2, 128.4, 128.6, 128.7, 128.8, 129.2, 129.6, 130.5, 131.8, 133.2, 134.4, 135.3, 135.7, 138.5, 143.1, 145.0, 145.2, 164.2.

MS (ESI): m/z (% relative intensity) 595 (100) ($M + H$) $^+$.

HRMS (ESI): m/z calcd for $C_{34}H_{30}N_2O_4S_2Na^+$: 617.1647; found 617.1535.

N-Allylations of γ -Amino-Ynamide. A Representative Procedure using

Ynamide 14—To a flame-dried screw-cap vial were charged with γ -amino-ynamide **14** (125.0 mg, 0.25 mmol), cinnamyl alcohol (36.9 mg, 0.275 mmol), PPh_3 (72.1 mg, 0.275 mmol) and THF (0.8 mL). The solution was stirred for 5 min at rt before being cooled to 0 °C, and DIAD (51.0 μ L, 0.275 mmol) was added dropwise. After which, the cooling bath was removed and the reaction mixture was allowed to warm to rt. The reaction was monitored using TLC and when the starting material was consumed after 15 h, the solvent was removed *in vacuo*. The crude residue was purified through silica gel flash column chromatography (isocratic eluent: 4:1 hexanes/EtOAc + 2% NEt_3 [to buffer the column]) to afford ynamide **22** as a mixture with DIAD being the byproduct. Ynamide **22** (67.0 mg, 0.11 mmol, 44%) could be recrystallized cleanly from the mixture with benzene:hexane.

N-Allylated Ynamides (20)—(60%, 0.18 g); R_f = 0.22 [7:3 hexanes/EtOAc]; white solid; mp = 129–130 °C.

IR (film): 1368 (w), 1417 (m), 1424 (m), 1441 (w), 1473 (m), 1493 (m), 1599 (w), 1789 (s), 2250 (m), 2924 (w), 2986 (w), 3038 (w), 3432 (brs).

¹H NMR (600 MHz, CDCl₃): δ = 2.42 (s, 3H), 3.56 (dq, 2H, *J* = 8.4, 26.4 Hz), 3.81 (d, 2H, *J* = 6.6 Hz), 4.29–4.33 (m, 2H), 5.70 (dt, 1H, *J* = 6.6, 22.8 Hz), 6.14 (d, 1H, *J* = 15.6 Hz), 6.29 (s, 1H), 7.02 (d, 2H, *J* = 7.2 Hz), 7.15 (t, 1H, *J* = 7.2 Hz), 7.20 (t, 2H, *J* = 7.2 Hz), 7.24–7.26 (m, 1H), 7.30–7.32 (m, 4H), 7.59 (d, 2H, *J* = 7.8 Hz), 7.85 (d, 2H, *J* = 8.4 Hz).

¹³C NMR (125 MHz, CDCl₃): δ = 21.5, 46.4, 47.4, 53.4, 63.0, 66.5, 78.4, 125.7, 126.3, 127.4, 127.9, 128.2, 128.3, 128.5, 129.6, 132.7, 136.2, 136.6, 136.9, 143.4, 155.7 (1 carbon missing due to overlap).

MS (APCI): *m/z* (% relative intensity) 487 (100) (M+H)⁺.

HRMS (ESI): *m/z* calcd for C₂₈H₂₆N₂O₄SNa⁺: 509.1613; found 509.1950.

N-Allylated Ynamides (21)—(37%, 0.17 g); R_f = 0.54 [7:3 hexanes/EtOAc]; white solid; mp = 125–126 °C.

IR (film): 1363 (m), 1399 (w), 1427 (w), 1454 (m), 1490 (m), 1592 (m), 2245 (m), 2857 (w), 2921 (w), 3028 (w), 3064 (w), 3438 (brs).

¹H NMR (600 MHz, CDCl₃): δ = 2.33 (s, 3H), 2.38 (s, 3H), 3.56 (dd, 1H, *J* = 7.2, 15 Hz), 3.72 (dd, 1H, *J* = 5.4, 15 Hz), 4.36 (dd, 2H, *J* = 14.4, 39 Hz), 5.51–5.56 (m, 1H), 5.98 (d, 1H, *J* = 15.6 Hz), 6.22 (s, 1H), 6.90 (d, 2H, *J* = 6 Hz), 7.10 (d, 2H, *J* = 7.2 Hz), 7.16–7.23 (m, 12H), 7.26–7.29 (m, 3H), 7.64 (d, 2H, *J* = 8.4 Hz), 7.75 (d, 2H, *J* = 7.2 Hz).

¹³C NMR (125 MHz, CDCl₃): δ = 21.5, 21.6, 47.4, 53.6, 55.2, 66.3, 81.6, 125.6, 126.4, 127.4, 127.7, 127.8, 128.0, 128.1, 128.3, 128.4, 128.5, 128.7, 129.7, 129.9, 132.4, 134.3, 134.7, 136.6, 136.96, 136.97, 143.4, 144.9 (1 carbon peak missing due to overlap).

MS (APCI): *m/z* (% relative intensity) 661 (100) (M+H)⁺.

HRMS (ESI): *m/z* calcd for C₃₉H₃₆N₂O₄S₂Na⁺: 683.8441; found 683.1985.

N-Allylated Ynamides (22)—(44%, 0.070 g); R_f = 0.38 [2:1 hexanes/EtOAc]; white solid; mp = 80–81 °C.

IR (film): 2961 (m), 2922 (m), 2248 (m), 1738 (m), 1597 (m), 1365 cm⁻¹ (s).

¹H NMR (500 MHz, CDCl₃): δ = 2.38 (s, 6H), 3.77 (ddd, 1H, *J* = 1.0, 8.0, 15.5 Hz), 3.82 (ddt, 2H, *J* = 1.5, 3.0, 6.0 Hz), 3.88 (ddd, 1H, *J* = 1.0, 6.0, 15.5 Hz), 5.11 (dq, 1H, *J* = 1.0, 11.0 Hz), 5.11 (dq, 1H, *J* = 1.0, 17.5 Hz), 5.53 (ddt, 1H, *J* = 6.0, 11.0, 17.5 Hz), 5.60 (ddd, 1H, *J* = 6.0, 8.0, 16.0 Hz), 6.13 (d, 1H, *J* = 16.0 Hz), 6.26 (s, 1H), 6.94 (dd, 2H, *J* = 1.5, 7.5 Hz), 7.14–7.20 (m, 2H), 7.22–7.30 (m, 7H), 7.54 (dd, 2H, *J* = 1.0, 7.0 Hz), 7.68 (d, 2H, *J* = 8.5 Hz), 7.78 (d, 2H, *J* = 8.5 Hz).

¹³C NMR (125 MHz, CDCl₃): δ = 21.7, 21.8, 47.7, 53.7, 54.1, 65.9, 81.4, 120.0, 125.7, 126.5, 127.6, 127.8, 127.9, 128.28, 128.34, 128.4, 128.5, 129.8, 130.0, 130.9, 132.7, 134.9, 136.7, 137.1, 137.2, 143.5, 145.1.

MS (ESI): *m/z* (% relative intensity) 495 (60) (M–C₉H₁₀+H), 611 (30) (M+H)⁺.

HRMS (ESI): Attempted but not stable enough for an accurate mass.

N-Allylated Ynamides (23)—(57%, 0.31 g); R_f = 0.32 [Et₂O]; colorless oil.

IR (film): 2974 (m), 2891 (m), 2249 (m), 1453 (m), 1331 (s), 1281 cm⁻¹ (s).

^1H NMR (500 MHz, CDCl_3): δ = 1.04 (s, 3H), 1.08 (s, 3H), 1.31 (s, 3H), 2.44 (s, 3H), 3.57–3.79 (m, 4H), 4.01–4.09 (m, 2H), 4.12–4.19 (m, 2H), 4.57 (d, 2H, J = 47.0 Hz), 5.20 (d, 1H, J = 10.0 Hz), 5.21 (d, 1H, J = 17.0 Hz), 5.72–5.78 (m, 1H), 6.19 (d, 1H, J = 3.0 Hz), 7.26–7.34 (m, 5H), 7.52–7.54 (m, 2H), 7.77 (d, 2H, J = 8.0 Hz).

^{13}C NMR (126 MHz, CDCl_3): δ = 19.4, 21.1 (d, J = 2.4 Hz), 21.4, 32.1 (d, J = 6.8 Hz), 51.2, 53.0 (d, J = 5.8 Hz), 54.1 (d, J = 1.4 Hz), 59.5 (d, J = 5.8 Hz), 77.8 (d, J = 7.2 Hz), 77.9 (d, J = 6.7 Hz), 83.7 (d, J = 5.3 Hz), 113.8, 118.7, 127.7, 127.8, 127.9, 128.5, 129.4, 132.2 (d, J = 2.0 Hz), 136.1, 137.0 (d, J = 1.0 Hz), 140.9, 143.3.

^{31}P NMR (202 MHz, CDCl_3) δ = –0.75.

MS (APCI): m/z (% relative intensity) 543 (57) ($\text{M}+\text{H}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{28}\text{H}_{39}\text{N}_3\text{O}_5\text{PS}$ [$\text{M}+\text{NH}_4$] $^+$: 560.2343; found 560.2337.

General Procedure for [2 + 2] Cycloadditions—To a flame-dried screw-cap vial were added ynamide **23** (54.4 mg, 0.10 mmol), $\text{Pd}(\text{PPh}_3)_4$ (5.80 mg, 0.0050 mmol), and toluene (1 mL; *concn* = 0.1 M for ynamide). The vial was sealed under N_2 and heated to 70 °C. After 2 h, TLC analysis showed complete consumption of the starting ynamide and the solvent was removed *in vacuo*. The crude residue was purified through silica gel flash column chromatography (isocratic eluent: 1:1 hexanes/EtOAc) to afford cycloadduct **25** (46.3 mg, 0.085 mmol) in 85% yield.

[2 + 2] Cycloadduct (24)—(95%, 0.060 g); R_f = 0.40 [2:1 hexanes/EtOAc]; white solid; mp = 114–115 °C.

IR (film): 3032 (w), 2930 (m), 2852 (m), 1727 (m), 1660 (s), 1597 (m), 1453 (m), 1327 cm^{-1} (s).

^1H NMR (500 MHz, CDCl_3): δ = 1.76 (dd, 1H, J = 9.0, 15.5 Hz), 1.84 (ddt, 1H, J = 2.0, 5.0, 15.5 Hz), 2.03 (s, 1H), 2.37 (s, 3H), 2.45 (s, 3H), 3.62 (s, 1H), 4.21 (s, 1H), 4.21 (d, 1H, J = 15.5 Hz), 4.62 (dd, 1H, J = 5.5, 11.0 Hz), 4.76 (dd, 1H, J = 1.0, 17.0 Hz), 5.07 (d, 1H, J = 10.0 Hz), 5.48 (dddd, 1H, J = 5.0, 9.0, 10.0, 17.0 Hz), 5.72 (s, 1H), 6.88 (d, 2H, J = 7.0 Hz), 7.03 (t, 2H, J = 8.0 Hz), 7.07–7.09 (m, 4H), 7.16 (t, 1H, J = 7.5 Hz), 7.21–7.23 (m, 5H), 7.33 (d, 2H, J = 8.0 Hz), 7.83 (d, 2H, J = 8.0 Hz).

^{13}C NMR (100 MHz, CDCl_3): δ = 21.6, 21.8, 30.7, 45.9, 53.1, 54.0, 66.1, 72.2, 120.1, 127.0, 127.7, 127.8, 127.9, 128.1, 128.5, 128.6, 128.9, 129.5, 129.8, 130.8, 136.2, 136.4, 136.6, 137.0, 143.3, 144.7, 193.5.

MS (ESI): m/z (% relative intensity) 611 (100) ($\text{M}+\text{H}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{35}\text{H}_{35}\text{N}_2\text{O}_4\text{S}_2$ [$\text{M}+\text{H}$] $^+$: 611.2038; found 611.2047.

[2 + 2] Cycloadduct (25)—(85%, 0.050 g); R_f = 0.15 [1:1 hexanes/EtOAc]; colorless oil.

IR (film): 2966 (m), 2933 (m), 2879 (m), 1702 (s), 1340 (s), 1287 cm^{-1} (s).

^1H NMR (500 MHz, CDCl_3): δ = 0.95 (s, 3H), 1.37 (s, 3H), 1.45 (s, 3H), 2.02–2.06 (m, 1H), 2.13–2.18 (m, 1H), 2.29 (s, 3H), 3.28 (t, 2H, J = 2.5 Hz), 3.38 (d, 1H, J = 10.5 Hz), 3.83 (d, 1H, J = 10.5 Hz), 3.98 (dd, 2H, J = 10.5, 21.0 Hz), 4.39 (dd, 1H, J = 4.0, 10.0 Hz), 4.59 (dd, 1H, J = 1.5, 17.0 Hz), 4.90 (dd, 1H, J = 1.0, 10.0 Hz), 5.24 (s, 1H), 5.65–5.73 (m, 1H), 6.95 (t, 4H, J = 8.0 Hz), 7.10–7.15 (m, 4H), 7.21 (d, 1H, J = 7.5 Hz).

^{13}C NMR (125 MHz, CDCl_3): δ = 19.8, 20.3, 21.4, 22.2, 32.4 (d, J = 6.2 Hz), 32.5, 43.6, 53.2 (d, J = 16.2 Hz), 59.8, 70.4 (d, J = 27.4 Hz), 71.6 (d, J = 2.4 Hz), 77.8 (d, J = 7.2 Hz), 78.2 (d, J = 6.7 Hz), 118.7, 126.8, 128.0, 128.3, 128.8, 129.0, 131.7, 135.4, 135.7, 142.7, 200.4 (d, J = 9.6 Hz).

^{31}P NMR (202 MHz, CDCl_3) δ = -3.02.

MS (APCI): m/z (% relative intensity) 543 (100) ($\text{M}+\text{H}$) $^+$.

HRMS (ESI): m/z calcd for $\text{C}_{28}\text{H}_{36}\text{N}_2\text{O}_5\text{PS}$ [$\text{M}+\text{H}$] $^+$: 543.2078; found 543.2062.

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Scheme 1.
Possible Approaches to γ -Amino-Ynamides.

Scheme 2.
An Acid Promoted Rearrangement of **12a**.

Figure 1.
X-ray Structure of Vinyl Amidine **16**.

Scheme 3.
A Crossover Experiment.

Figure 2.
LC-Traces from LCMS of Crossover Experiments A and B.

Scheme 4.
N-Allylations of γ -Amino-Ynamides.

Scheme 5.
Application of γ -Amino-Ynamides in [2 + 2].

Table 1

Lithiated Ynamide Additions to Aryl Imines.