Supporting Information for
Nickel-Catalyzed β-Carboxylation of Ynamides with Carbon Dioxide

Ryohei Doi, Taichi Okano, Iman Abdulllah and Yoshihiro Sato

1Faculty of Pharmaceutical Sciences, Hokkaido University, Sapporo 060-0812, Japan
2Current position: Department of Chemistry, Faculty of Mathematic and Natural Sciences, Universitas
Indonesia, Depok 16424, Indonesia

Email: biyo@pharm.hokudai.ac.jp

General Information p. S2
Experimental Details pp. S3 – S11
References p. S11
Spectrum Data pp. S12 – S24
General Information

All reactions were performed under an atmosphere of nitrogen (1 atm) unless otherwise stated. Toluene was purified under nitrogen using The Ultimate Solvent System (Glass Counter Inc.). DMF, DMA, NMP, DMPU and acetonitrile used as solvents were distilled over CaH₂ and stored under nitrogen atmosphere. All other reagents were purchased and used as received. Column chromatography was performed on silica gel (Wakogel® FC-40, neutral, 20-40 μm, FUJIFILM Wako Chemical Corporation) with the indicated solvent as an eluent. Analytical thin-layer chromatography was performed on Silica gel 60 PF254a (Merck).

¹H NMR spectroscopy was recorded on JEOL ECA500 (500 MHz) ECP400, ECS400 or ECX400P (400 MHz) NMR spectrometer. Chemical shifts are reported in ppm from the residual solvent resonance as an internal standard (CDCl₃: δ= 7.26 ppm). NMR data are reported as follows: chemical shifts, multiplicity (s: singlet, d: doublet, t: triplet, q: quartet, m: multiplet, br: broad signal), coupling constant (Hz), and integration. ¹³C NMR spectroscopy was recorded on JEOL ECA500 (125 MHz), ECP400, ECS400 or ECX400P (100 MHz) with complete proton decoupling. Chemical shifts are reported in ppm from the internal reference (CDCl₃: δ= 77.00 ppm). Mass spectra were obtained on JEOL JMS-T100GCv mass spectrometer.

Compounds 1a-1f, 1k were synthesized in our previous paper.¹ Sulfonamides TsNH₄Bu², TsNH(CHPh₂)³ are known compounds.
**Experimental Details**

*Synthesis of Starting Materials*

**General Procedure A:**

![Reaction Scheme](image)

To a mixture of 1,10-phenanthroline (216 mg, 1.2 mmol), CuSO₄·5H₂O (150 mg, 0.6 mmol), K₃PO₄ (1.26 g, 6 mmol) and sulfonamide (3 mmol) in toluene (15 mL) was added bromoalkyne (3 mmol) at room temperature. The mixture was heated at 110 °C with stirring. After 23-56 h (TLC analysis was performed to check the consumption of starting material), the mixture was cooled to room temperature, filtered through a pad of Celite, and concentrated. The crude product was purified by flash column chromatography on silica gel.

**1g**

![Structure](image)

By following the general procedure A, the corresponding bromoalkyne² (2.38 g, 11 mmol) was transformed into ynamide 1g (880 mg, 2.5 mmol) in 23% yield. ¹H NMR (400 MHz, CDCl₃, rt, δ/ppm): 7.60 (2H, d, J = 8.1 Hz), 7.24-7.20 (13H, m), 6.31 (1H, s), 2.41 (3H, s), 2.13 (2H, t, J = 6.7 Hz), 1.27-1.24 (2H, m), 1.17-1.09 (2H, m), 0.78 (3H, t, J = 7.4 Hz). ¹³C NMR (100 MHz, CDCl₃, rt, δ/ppm): 143.9, 138.1, 135.3, 129.2, 128.6, 73.7, 71.7, 11.2, 30.6, 21.6, 21.6, 21.5, 18.1, 13.5. HRMS (ESI) calcd. for C₂₆H₂₇NO₂S Na [M+Na] 440.1655, found 440.1659.

**1h**

![Structure](image)

By following the general procedure A, the corresponding bromoalkyne² (483.1 mg, 3 mmol) was transformed into ynamide 1h (184.6 mg, 0.6 mmol) in 20% yield. ¹H NMR (400 MHz, CDCl₃, rt, δ/ppm): 7.82 (2H, d, J = 8.4 Hz), 7.29 (2H, d, J = 8.4 Hz), 2.43 (3H, s), 2.29 (2H, t, J = 7.0 Hz), 1.48-1.35 (13H, m), 0.89 (3H, t, J = 7.3 Hz). ¹³C NMR (100 MHz, CDCl₃, rt, δ/ppm): 143.7, 137.6, 129.2, 127.5, 73.0, 71.7, 63.1, 31.0, 29.1, 21.8, 18.2, 13.5. HRMS (APCI) calcd. for C₁₇H₂₆NO₂S [M+H], 308.1677, found 308.1677.
By following the general procedure A, the corresponding bromoalkyne\(^5\) (2.38 g, 11 mmol) was transformed into ynamide \(\text{I}_i\) (880 mg, 2.5 mmol) in 23% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\), rt, \(\delta/\text{ppm}\)): 7.75 (2H, d, \(J = 8.5\) Hz), 7.30-7.19 (7H, m), 2.81 (2H, t, \(J = 7.2\) Hz), 2.62 (2H, t, \(J = 7.2\) Hz), 2.43 (3H, s), 1.34 (9H, s). \(^{13}\)C NMR (100 MHz, CDCl\(_3\), rt, \(\delta/\text{ppm}\)): 143.8, 140.8, 137.9, 129.4, 128.6, 128.4, 127.7, 126.3, 73.9, 71.1, 63.4, 35.4, 29.2, 21.7, 20.9. HRMS (ESI) calcd. for C\(_{21}\)H\(_{25}\)NO\(_2\)S\(_\text{Na}\) [M+Na], 378.1498, found 378.1502.

By following the general procedure A, the corresponding bromoalkyne\(^6\) (1.32 g, 5 mmol) was transformed into ynamide \(\text{I}_j\) (375 mg, 0.87 mmol) in 17% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\), rt, \(\delta/\text{ppm}\)): 7.81 (d, \(J = 8.4\) Hz, 2H), 7.28 (d, \(J = 7.9\) Hz, 2H), 3.67 (t, \(J = 7.3\) Hz, 2H), 3.67 (t, \(J = 7.3\) Hz, 2H), 2.50 (t, \(J = 7.1\) Hz, 2H), 2.43 (s, 3H), 1.41 (s, 9H), 0.88 (t, \(J = 2.9\) Hz, 9H), 0.05 (t, \(J = 3.1\) Hz, 6H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\), rt, \(\delta/\text{ppm}\)): 143.6, 137.7, 129.3, 127.7, 74.0, 68.8, 63.3, 62.1, 29.2, 25.9, 23.1, 21.6, 18.3. HRMS (EI) calcd. for C\(_{21}\)H\(_{36}\)NO\(_3\)SSi [M+H], 410.2180, found 410.2179.

By following the general procedure A, the corresponding bromoalkyne\(^7\) (1.8 g, 10 mmol) was transformed into ynamide \(\text{I}_l\) (887 mg, 2.7 mmol) in 27% yield. \(^1\)H NMR (400 MHz, CDCl\(_3\), rt, \(\delta/\text{ppm}\)): 7.88 (2H, d, \(J = 8.1\) Hz), 7.33-7.27 (7H, m), 2.44 (3H, s), 1.51 (9H, s). \(^{13}\)C NMR (100 MHz, CDCl\(_3\), rt, \(\delta/\text{ppm}\)): 144.1, 137.4, 130.8, 129.5, 128.2, 127.8, 127.3, 123.6, 82.8, 72.6, 64.3, 29.4, 21.6. HRMS (ESI) calcd. for C\(_{19}\)H\(_{21}\)NO\(_2\)S\(_\text{Na}\) [M+Na], 350.1185, found 350.1188.
1m

By following the general procedure A, the corresponding bromoalkyne\textsuperscript{7} (1.03 g, 15 mmol) was transformed into ynamide 1\textsuperscript{0} (1.12 g, 3.2 mmol) in 21% yield. \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}, rt, \(\delta/\text{ppm}\)): 7.85 (2H, d, \(J = 8.4\) Hz), 7.31 (2H, d, \(J = 8.1\) Hz), 7.19-6.96 (4H, m), 2.43 (3H, s), 1.50 (9H, d, \(J = 4.8\) Hz). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}, rt, \(\delta/\text{ppm}\)): 162.39 (d, \(J = 246.4\) Hz), 144.31, 137.34, 129.75 (d, \(J = 8.5\) Hz), 129.53, 127.76, 126.44 (d, \(J = 3.1\) Hz), 125.50 (d, \(J = 10\) Hz), 117.36 (d, \(J = 23.1\) Hz), 114.42 (d, \(J = 21.7\) Hz), 83.97, 71.96, 64.44, 29.34, 21.62. HRMS (EI) calcd for C19H20FNO2S, 345.1199, found 345.1194.

1n

By following the general procedure A, the corresponding bromoalkyne\textsuperscript{7} (846 g, 4 mmol) was transformed into ynamide 1\textsuperscript{n} (260 mg, 0.73 mmol) in 18% yield. \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}, rt, \(\delta/\text{ppm}\)): 7.86 (d, \(J = 8.5\) Hz, 2H), 7.25-7.31 (m, 4H), 6.80-6.83 (m, 2H), 3.80 (s, 3H), 2.43 (s, 3H), 1.48 (s, 9H). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}, rt, \(\delta/\text{ppm}\)): 159.12, 143.97, 137.44, 132.94, 129.39, 127.78, 115.49, 113.83, 72.13, 64.19, 55.28, 29.33, 21.63 (one carbon was missing probably due to low intensity or overlapping with CDCl\textsubscript{3}). HRMS (ESI) calcd for C20H23NO3SNa [M+Na], 380.1290, found 380.1294.

Table 2-3: Substrate Scope

**General Procedure B:**

A Schlenk flask equipped with a rubber septum and a stirring bar was charged with Ni(acac)\textsubscript{2} (5.1 mg, 0.02 mmol), MgBr\textsubscript{2} (110 mg, 0.6 mmol) under nitrogen atmosphere. Into the flask cooled down to 0 °C were added a solution of ynamide 1 (0.2 mmol) in NMP (2 mL) and COD (24 \(\mu\)L, 0.2 mmol) by use of syringes. To the reaction vessel degassed by freeze-pump-thaw cycle was introduced CO\textsubscript{2} which was supplied from a balloon. To the mixture was added ZnEt\textsubscript{2} (1M toluene solution, 0.6 mL, 0.6 mmol) at the same temperature. Then, the reaction mixture was heated at 50 °C for 1 h. After the disappearance of the starting material was confirmed by TLC analysis, the solution was cooled with ice bath and was quenched with 3M HCl aq. Separated aqueous layer was extracted with ether and the combined organic layer was washed with water and brine. The solution desiccated by Na\textsubscript{2}SO\textsubscript{4} was concentrated and then, dissolved in methanol/ether (1:4). To the solution was added TMSCHN\textsubscript{2} along with careful monitoring.
Supporting Information for
Nickel-Catalyzed β-Carboxylation of Ynamides with Carbon Dioxide

by TLC. The solution was concentrated and purified by column chromatography to afford a desired product 2.

2a

By following the general procedure B, the hydrocarboxylation of ynamide 1a (53 mg, 0.2 mmol) delivered 47.8 mg of compound 2a (73%). The spectrum data matched to that of our previous report.8

2b

By following the general procedure B, the hydrocarboxylation of ynamide 1b (37.9 mg, 0.2 mmol) delivered 24.4 mg of compound 2b (49%). The spectrum data matched to that of our previous report.1

2c

By following the general procedure B, the hydrocarboxylation of ynamide 1c (33.4 mg, 0.2 mmol) delivered compound 2c (1H NMR yield 28%). The spectrum data matched to that of our previous report.8

2d

By following the general procedure B, the hydrocarboxylation of ynamide 1d (36.7 mg, 0.2 mmol) delivered compound 2d (1H NMR yield 42%). The spectrum data matched to that of our previous report.8

2e

By following the general procedure B, the hydrocarboxylation of ynamide 1e (56.9 mg, 0.2 mmol) delivered 51.8 mg of compound 2e (65%). The spectrum data matched to that of our previous report.1
2f

By following the general procedure B, the hydrocarboxylation of ynamide 1f (66.7 mg, 0.2 mmol) delivered 61.9 mg of compound 2f (79%). The spectrum data matched to that of our previous report.1

2g

By following the general procedure B, the hydrocarboxylation of ynamide 1g (83.5 mg, 0.2 mmol) delivered 29.2 mg of compound 2g (30%). 1H NMR (400 MHz, CDCl3, rt, δ/ppm): 7.59 (2H, d, J = 8.1 Hz), 7.27-7.25 (8H, m), 7.10-7.09 (4H, m), 6.59 (1H, s), 6.32 (1H, s), 3.71 (3H, s), 2.45 (3H, s), 2.26 (2H, t, J = 8.1 Hz), 1.29-1.20 (2H, m), 1.10-1.08 (2H, m), 0.84 (3H, t, J = 7.4 Hz). 13C NMR (100 MHz, CDCl3, rt, δ/ppm): 167.6, 143.7, 138.9, 137.8, 136.6, 129.6, 129.1, 128.2, 127.7, 127.5, 115.2, 67.6, 51.9, 29.9, 27.9, 23.2, 21.5, 13. HRMS (EI) calcd. for C26H28NO2S [M–CO2Me], 418.1841, found 418.1838.

2h

By following the general procedure B, the hydrocarboxylation of ynamide 1h (61.5 mg, 0.2 mmol) delivered 57.4 mg of compound 2h (78%). 1H NMR (400 MHz, CDCl3, rt, δ/ppm): 7.65 (2H, d, J = 8.5 Hz), 7.25 (2H, d, J = 4.0 Hz), 6.74 (1H, s), 3.76 (3H, s), 2.39 (3H, s), 2.22 (2H, t, J = 7.9 Hz), 1.30 (9H, s), 1.24-1.19 (4H, m), 0.83 (3H, t, J = 7.2 Hz). 13C NMR (100 MHz, CDCl3, rt, δ/ppm): 167.6, 143.3, 140.2, 138.3, 134.1, 129.5, 129.4, 127.7, 115.2, 61.6, 51.9, 29.6, 29.4, 27.2, 23.2, 21.5, 13. HRMS (EI) calcd. for C19H29NNaO4S [M+Na], 390.1714, found 390.1715.

2i

By following the general procedure B, the hydrocarboxylation of ynamide 1i (71.1 mg, 0.2 mmol) delivered 61.6 mg of compound 2i (75%). 1H NMR (400 MHz, CDCl3, rt, δ/ppm): 7.66 (2H, d, J = 8.1 Hz), 7.24-7.19 (7H, m), 6.81 (1H, s), 3.79 (3H, s), 2.67-2.63 (4H, m), 2.38 (3H, s), 1.22 (9H, s). 13C NMR (100 MHz, CDCl3, rt, δ/ppm): 167.3, 143.4, 141.9, 139.0, 138.4, 135.2, 129.5, 128.4, 127.7, 125.6, 61.5, 52.0, 33.5, 29.7, 29.2, 21.5. HRMS (EI) calcd. for C23H29NO4SNa [M+Na], 438.1710, found 438.1711.
By following the general procedure B, the hydrocarboxylation of ynamide 1j (65.5 mg, 0.2 mmol) delivered 66.2 mg of compound 2j (71%). $^1$H NMR (400 MHz, CDCl₃, rt, δ/ppm): 7.64 (2H, d, J = 8.5 Hz), 7.25 (2H, d, J = 3.8 Hz), 6.82 (1H, s), 3.76 (3H, s), 3.67 (2H, t, J = 7.2 Hz), 2.53 (2H, t, J = 7.0 Hz), 2.39 (3H, s), 1.29 (9H, s), 0.86 (9H, s), 0.02 (6H, s). 13C NMR (100 MHz, CDCl₃, rt, δ/ppm): 167.339, 143.4, 138.4, 136.7, 136.2, 130.0, 127.7, 120.3, 115.3, 61.5, 61.0, 51.9, 30.7, 29.3, 25.9, 21.5, 18.3. HRMS (EI) calcd for C₂₃H₃₉NO₅SSi Na [M+Na], 492.2210, found 492.2214.

By following the general procedure B, the hydrocarboxylation of ynamide 1k delivered compound 2k ($^1$H NMR yield 28%). The spectrum data matched to that of our previous report.8

By following the general procedure B, the hydrocarboxylation of ynamide 1l (65.5 mg, 0.2 mmol) delivered 42 mg of compound 2l (54%). $^1$H NMR (400 MHz, CDCl₃, rt, δ/ppm): 7.35 (5H, s), 7.27 (2H, d, J = 6.7 Hz), 7.10 (2H, d, J = 8.1 Hz), 3.80 (3H, s), 2.37 (3H, s), 1.28 (9H, s). 13C NMR (100 MHz, CDCl₃, rt, δ/ppm): 167.3, 143.2, 138.8, 136.7, 136.4, 133.5, 129.2, 127.9, 127.8, 127.6, 61.8, 52.5, 30.1, 29.1, 21.4. HRMS (EI) calcd for C₂₁H₂₅NO₄S Na [M+Na], 410.1397, found 410.1401.

By following the general procedure B, the hydrocarboxylation of ynamide 1m (65.5 mg, 0.2 mmol) delivered 51.1 mg of compound 2m (63%). $^1$H NMR (400 MHz, CDCl₃, rt, δ/ppm): 7.28-7.03 (8H, m), 3.81 (3H, s), 2.39 (3H, s), 1.30 (9H, s). 13C NMR (100 MHz, CDCl₃, rt, δ/ppm): 166.61, 163.46 (d, J = 247.4 Hz), 143.28, 138.17, 137.05, 135.19-135.09 (probably one doublet and one singlet signals are overlapping), 129.07, 128.90 (d, J = 8.5 Hz), 127.38, 125.55 (d, J = 2.8 Hz), 116.90 (d, J = 22.7 Hz), 114.65 (d, J = 20.8 Hz), 61.88, 52.37, 28.93, 21.21. HRMS (ESI) calcd for C₂₁H₂₅FNO₄SNa [M+Na], 428.1302, found 428.1304.
By following the general procedure B, the hydrocarboxylation of ynamide 1n (65.5 mg, 0.2 mmol) delivered 56 mg of compound 2n (67%). X-ray quality crystals were obtained from hot hexane solution.

\[
\text{H NMR (400 MHz, CDCl}_3, \text{rt, } \delta/\text{ppm}): 7.37 (2H, d, J = 8.5 Hz), 7.27 (2H, d, J = 5.6 Hz), 7.15 (1H, s), 7.12 (2H, d, J = 8.1 Hz), 6.85 (2H, d, J = 9.4 Hz), 3.83 (3H, s), 3.79 (3H, s), 2.37 (3H, s), 1.25 (9H, s).
\]

\[
\text{13C NMR (100 MHz, CDCl}_3, \text{rt, } \delta/\text{ppm}): 167.7, 159.3, 143.1, 138.6, 136.4, 135.8, 131.2, 129.2, 127.7, 125.6, 113.2, 62.0, 55.2, 52.4, 29.2, 21.4. \text{HRMS (EI)} \text{ calcld for } C_{22}H_{27}NO_5SNa [M+Na], 440.1502, \text{ found } 440.1503.
\]

Crystallographic data: \( M = 835.04 \), colorless, block, triclinic, \( P-1 \) (#2), \( a = 12.4921(7) \ \text{Å}, b = 13.3080(8) \ \text{Å}, c = 13.8130(9) \ \text{Å}, \alpha = 107.827(8) ^\circ, \beta = 90.241(6)^\circ, \gamma = 104.057(7)^\circ, V = 2112.9(3) \ \text{Å}^3, Z = 2, D_{\text{calc}} = 1.312 \ \text{g/cm}^3, T = -140 ^\circ \text{C}, R_1(wR_2) = 0.0690 (0.1490). \)

Scheme 2: Transformation of the product

A flask equipped with a stirring bar was added 2i (1 mmol, 41.6 mg) and HCl solution in ether (1 M, 1 mL). The reaction mixture was stirred for 24 h and then volatiles were removed by evaporation. To the residue was added methanol (4 mL) and 10% Pd/C (11 mg). The atmosphere was replaced with hydrogen by use of a balloon and the mixture was stirred for 15 h. Evaporation and column chromatography of the crude product gave compound 4 (25.6 mg, 70%). Our trial to isolate intermediate enamide was unfruitful because of poor stability of the product.

\[
\text{H NMR (400 MHz, CDCl}_3, \text{rt, } \delta/\text{ppm}): 7.72 (2H, d, J = 8.1 Hz), 7.25-7.18 (7H, m), 5.00 (1H, s), 3.65 (3H, s), 3.14-3.11 (2H, m), 2.62-2.58 (3H, m), 2.42 (3H, s), 1.95-1.82 (2H, m). \text{13C NMR (100 MHz, CDCl}_3, \text{rt, } \delta/\text{ppm): 174.8, 143.5, 140.7, 136.8, 129.7, 128.4, 128.3, 127.0, 126.1, 52.0, 44.2, 43.5, 32.9, 30.9, 21.5. \text{HRMS (EI)} \text{ calcld for } C_{19}H_{23}NO_4S, 361.1348, \text{ found } 361.1351.
\]
Figure 2: Mechanistic Study

Deuterium quench (a)
The reaction was performed by following general procedure B. The reaction mixture was quenched with DCI/Et₂O instead of 3M HCl aq. NMR yield of 2a was estimated in CDCl₃ solution with the aid of 1,1,2,2-tetrachloroethane as an internal standard. No deuterium incorporation was observed.

5' (not described in Figure 2)

A Schlenk flask equipped with a rubber septum and a stirring bar was charged with Ni(acac)₂ (5.1 mg, 0.02 mmol), MgBr₂ (110 mg, 0.6 mmol) under nitrogen atmosphere. Into the flask cooled down to 0 °C were added a solution of ynamide 1a (53 mg, 0.2 mmol) in NMP (2 mL), COD (24 μL, 0.2 mmol) and ZnEt₂ (1M toluene solution, 0.6 mL, 0.6 mmol) by use of syringes. Then, the reaction mixture was heated at 50 °C for 1 h. The solution was cooled with ice bath and was quenched with 3M HCl aq. Separated aqueous layer was extracted with ether and the combined organic layer was washed with water and brine. The solution was dried over Na₂SO₄ and was concentrated in vacuo. The yield of 5’ was estimated by means of ¹H NMR analysis. However, isolation of 5’ was hampered by contamination of unidentified by-products. Synthesis of 5’: In a glove box, a flask was charged with ynamide 1a (53 mg, 0.2 mmol), NMP (1 mL) and Ni(cod)₂ (55 mg, 0.2 mmol). The reaction mixture was stirred at 50 °C for 1 h. The reaction was quenched with 1M HCl and the water layer was extracted with ether three times. The crude product was purified by column chromatography and preparative thin-layer chromatography to afford 5’ in 27% yield (14.3 mg). ¹H NMR (400 MHz, CDCl₃, rt, δ/ppm): 7.67 (2H, d, J = 8.1 Hz), 7.31 (2H, d, J = 7.7 Hz), 5.48 (1H, d, J = 7.7 Hz), 5.36 (1H, q, J = 7.4 Hz), 2.82 (3H, s), 2.43 (3H, s), 2.21-2.19 (2H, m), 1.31-1.30 (4H, m), 0.88 (3H, t, J = 7.1 Hz). ¹³C NMR (99 MHz, CDCl₃, rt, δ/ppm): 143.34, 134.12, 132.30, 129.45, 127.81, 126.75, 37.83, 31.18, 26.66, 22.46, 21.53, 13.86. HRMS (EI) calcd for C₁₄H₂₁NO₂S, 267.1293, found 267.1293.

5 (b)
The same procedure for 5’ was conducted. The reaction mixture was quenched with DCI/Et₂O solution. The mixture was diluted with Et₂O and then washed with water and brine. The combined organic layer was dried over Na₂SO₄ and was evaporated in vacuo. The ¹H NMR yield was estimated with the aid of 1,1,2,2,-tetrachloroethane as an internal standard. Then, the mixture was purified by column chromatography (Hexane/EA = 10:1) to afford 27.4 mg of 5 which was not pure but allowed us to calculate deuterium incorporation rate by means of ¹H NMR analysis.
The same procedure for 5’ was applied. The reaction mixture was quenched by addition of solid I₂ (310 mg, 1.2 mmol). The mixture was diluted with Et₂O and then washed with water and brine. The combined organic layer was dried over Na₂SO₄ and was evaporated in vacuo. The ¹H NMR yield was estimated with the aid of 1,1,2,2,-tetrachloroethane as an internal standard. Then, the mixture was purified by column chromatography (Hexane/Et = 20:1) followed by preparative thin-layer chromatography (Hexane/CHCl₃ = 1:1) to afford 17.8 mg of 6 (0.045 mmol, 23%). ¹H NMR (400 MHz, CDCl₃, rt, δ/ppm): 7.65 (2H, d, J = 8.5 Hz), 7.35 (2H, d, J = 8.1 Hz), 5.92 (1H, s), 2.75 (3H, s), 2.60 (2H, t, J = 7.4 Hz), 2.60 (2H, t, J = 7.4 Hz), 2.45 (3H, s), 1.50-1.46 (2H, m), 1.36-1.29 (2H, m), 0.92 (3H, t, J = 7.4 Hz). ¹³C NMR (100 MHz, CDCl₃, rt, δ/ppm): 144.0, 133.4, 133.1, 129.8, 127.7, 114.7, 37.7, 36.7, 31.3, 21.7, 21.6, 13.9. HRMS (EI) calcd for C14H20INO2S, 393.0259, found 393.0261.

**Reaction with LiBr (d)**

The reaction was conducted by following general procedure B with LiBr instead of MgBr₂. The yield of 2a was determined by ¹H NMR with the aid of 1,1,2,2-tetrachloroethane as an internal standard.

**References**


Supporting Information for
Nickel-Catalyzed β-Carboxylation of Ynamides with Carbon Dioxide

Spectrum Data

1g
1H NMR

13C NMR

1h
1H NMR
Supporting Information for
Nickel-Catalyzed β-Carboxylation of Ynamides with Carbon Dioxide

\[ \text{13C NMR} \]

\[ \text{1H NMR} \]

\[ \text{13C NMR} \]
Supporting Information for
Nickel-Catalyzed β-Carboxylation of Ynamides with Carbon Dioxide

1j

\(^1\)H NMR

\[^{13}\text{C}\] NMR

1m

\(^1\)H NMR
$^{13}$C NMR

$^1$H NMR

$^{13}$C NMR
16

1\textsuperscript{H} NMR

1\textsuperscript{3}C NMR

2g

1\textsuperscript{H} NMR
Supporting Information for
Nickel-Catalyzed \( \beta \)-Carboxylation of Ynamides with Carbon Dioxide

\(^{13}\)C NMR

\(^{1}H\) NMR

\(^{13}\)C NMR
**Supporting Information for**

*Nickel-Catalyzed β-Carboxylation of Ynamides with Carbon Dioxide*

---

**2m**

**1H NMR**

---

**13C NMR**

---

**2n**

**1H NMR**
$^{13}$C NMR

$^1$H NMR

$^{13}$C NMR
**Supporting Information**

**Nickel-Catalyzed β-Carboxylation of Ynamides with Carbon Dioxide**

---

**5′**

**$^{1}H$ NMR**

![$^{1}H$ NMR Spectrum](image1)

**$^{13}C$ NMR**

![$^{13}C$ NMR Spectrum](image2)

---

**6**

**$^{1}H$ NMR**

![$^{1}H$ NMR Spectrum](image3)
$^{13}$C NMR