Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information of

Taming the Reactivity of Alkyl Azides by Intramolecular Hydrogen Bonding: Site-Selective Conjugation of Unhindered Diazides

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[1] General Information Including Important Notices

Caution!: Organic azides, especially multiple azido compounds, are potentially hazardous and explosive. Although we have never experienced those severe incidents in our study, all manipulation should be carefully conducted behind a safety shield in a hood to avoid an explosion. Sodium azide should be handled with a plastic spatula. At the azidation stages, complete removal of residual halogenated solvent used in the last steps or extractions should be in mind. Otherwise, the generation of explosive species such as diazidomethane from dichloromethane is possible.[1] Also, as well as considering Smith's ratio (special attention be paid for the compounds of $(C + O)/N < 3$), organic azides should be designed and prepared with due consideration of their structure, stability, and reactivity of azido groups.[2]

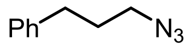
Analysis and Reagents: ^{1}H and ^{13}C NMR spectra were recorded using a JEOL JNM-ECP500 spectrometer (500 MHz for ^{1}H NMR, 126 MHz for ^{13}C NMR, and 202 MHz for ^{31}P NMR). Chemical shifts are reported as δ values in ppm and calibrated with respect to the residual solvent peak ($CDCl_3$: δ 7.26 for ^{1}H NMR and δ 77.00 for ^{13}C NMR; DMSO-d6: δ 2.50 for ^{1}H NMR and δ 39.52 for ^{13}C NMR), internal standard reagent (tetramethylsilane: δ 0.0 for ^{1}H NMR) or external standard reference (phosphoric acid in benzene-d_6: δ 0.0 for ^{31}P NMR). The abbreviations used are as follows: s (singlet), d (doublet), t (triplet), q (quartet), br (broad), and m (multiplet). Melting points were measured using a Yanaco Micro melting point apparatus. Infrared spectra were measured using a JASCO FT-IR-4200 spectrometer. Mass spectra were recorded using a JEOL JMS-700 MStaion [EI-magnetic sector (70 eV), CI-magnetic sector, and ESI-TOF], JEOL JMS-S3000 (MALDI-spiralTOF), and JMS-T100LP AccuTOF LC-plus 4G (DART-TOF). The progress of the reactions was monitored by silica gel thin layer chromatography (TLC) (Merck TLC Silica gel 60 F_{254}). Phosphomolybdic acid-cerium(IV) sulfate sulfuric acid solution, phosphomolybdic acid ethanol solution, or anisaldehyde ethanol solution was used for the TLC stains, and TLC was also monitored with UV lamp. Flash column chromatography was performed using neutral silica gel N60 from Kanto Chemical Co. Inc. If not specified as neutral silica gel column chromatography, Merck Silica gel 60 or packed column of Biotage® SNAP Ultra with HP-Sphere™ 25μm was used. If necessary, further purification of the crude materials was performed using a LC-908 recycling gel permeation chromatography (GPC) equipped with a JAIGEL 2H-40 column (chloroform elution) made by Japan Analytical Industry Co., Ltd. All reagents were purchased from Sigma-Aldrich, Wako Pure Chemical Industries, Ltd, TCI (Tokyo Chemical Industry, Co. Ltd), Kanto Chemical Co. Inc., and Nacalai Tescque. Anhydrous solvents such as tetrahydrofuran (THF), toluene, acetonitrile, and dichloromethane were purchased from Wako Pure Chemical. Deionized water was used for reaction solvent, quenching reactions, and separation sequences.

Computation: The DFT calculations were performed with the Gaussian09 suite of programs using the dispersion-corrected B3LYP-D3 density functional with the 6-311G** basis set.[3]

[2] Synthesis of Substrates

Preparation of Mono-Azide Substrates

3-Phenylpropyl azide (3a)

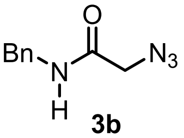


3a

To a stirred solution of 3-phenylpropyl bromide (0.75 mL, 5.0 mmol) in *N*,*N*-dimethylformamide (2 mL) was added sodium azide (490 mg, 7.5 mmol) at room temperature, and the mixture was kept stirred for 14 h. After quenching the reaction with water, the mixture was extracted with ethyl acetate, and was washed with water and brine. The organic layer was dried over sodium sulfate and then was concentrated *in vacuo*. The obtained residue was purified by silica gel chromatography (hexane elution) to give **3a** (660 mg, 82%) as a colorless oil.

Colorless oil; R_f 0.63 (hexane/ethyl acetate = 1/1); IR (NaCl, neat) 2942, 2096 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31 (dd, 2H, J = 7.5, 7.5 Hz), 7.23–7.19 (m, 3H), 3.30 (t, 2H, J = 6.5 Hz), 2.71 (t, 2H, J = 7.0 Hz), 1.92 (tt, 2H, J = 7.0, 6.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 140.8, 128.5, 128.4, 126.1, 50.6, 32.7, 30.4; HRMS (CI) calcd for $C_9H_{12}N_3$ $[M+H]^+$ 162.1031, found 162.1027.

N-Benzyl-2-azidoacetamide (3b)

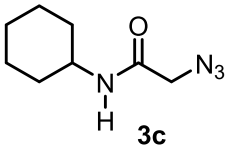


3b

To a stirred solution of benzylamine (2.2 mL, 20 mmol) in dichloromethane (20 mL) was added bromoacetyl bromide (0.85 mL, 10 mmol) at 0 °C under nitrogen atmosphere. Then, the mixture was warmed up to room temperature and was stirred for 2 h. After filtration to remove salt precipitates, the filtrate was washed with 2 M hydrochloric acid and was dried over sodium sulfate. The residue obtained by concentration *in vacuo* (see Caution section) was dissolved in THF (22 mL) and water (5.5 mL). To the stirred solution was added sodium azide (3.3 g, 50 mmol) at room temperature, and the resulting mixture was warmed up to reflux. After 17 h, the mixture was extracted with diethyl ether, and was washed with water and brine. The organic layer was dried over sodium sulfate followed by concentration *in vacuo*. The obtained residue was purified by silica gel column chromatography (hexane / ethyl acetate = 4 / 1) to give **3b** (1.5 g, 77%) as a white solid.

White solid; R_f 0.43 (hexane / ethyl acetate = 1 / 1); m.p. 39–40 °C; IR (NaCl, neat) 3297, 3087, 3065, 3032, 2925, 2106, 1661, 1540, 1270 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 (dd, 2H, J = 6.5, 6.5 Hz), 7.31–7.27 (m, 3H), 6.74 (br, 1H), 4.45 (d, 2H, J = 5.5 Hz), 4.00 (s, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.4, 137.3, 128.7, 127.9, 127.7, 52.5, 43.3; HRMS (CI) calcd 191.0933 for $C_9H_{11}N_4O$ $[M+H]^+$, found 191.0935.

N-Cyclohexyl-2-azidoacetamide (3c)

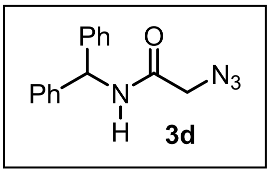


3c

To a stirred solution of cyclohexylamine (0.69 mL, 6 mmol) in dichloromethane (6.0 mL, 0.5 M), bromoacetyl bromide (0.26 mL, 3.0 mmol) was added dropwise at 0 °C. Then, the resulting mixture was stirred at room temperature for 4 h. The mixture was concentrated *in vacuo* (see Caution section). The crude material was dissolved in *N*,*N*-dimethylformamide (6.0 mL, 0.5M), and sodium azide (490 mg, 7.5 mmol) was added to the solution at room temperature. The resulting mixture was stirred for 4 d and was poured into iced water. The mixture was extracted with ethyl acetate and was washed with water and brine. The organic layer was dried over sodium sulfate followed by concentration *in vacuo*. The obtained residue was purified by silica gel column chromatography (10% to 50% ethyl acetate in hexane) to give **3c** (467 mg, 85%) as a white solid.

White solid; R_f value 0.57 (hexane / ethyl acetate = 1 / 1); m.p. 85.9–86.3 °C; IR (NaCl, neat) ν_{max} 3284, 3089, 2927, 2853, 2101, 1642, 1559, 1270, 1254 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.16 (s, 1H), 3.98 (s, 2H), 3.82–3.76 (m, 1H), 1.93–1.90 (m, 2H), 1.75–1.71 (m, 2H), 1.65–1.61 (m, 1H), 1.42–1.33 (m, 2H), 1.22–1.14 (m, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.4, 52.8, 48.2, 32.9, 25.4, 24.7; LRMS (EI, M = $C_8H_{14}N_4O$) *m/z* 182 (6%, M^+), 126 (18), 83 (100); HRMS (EI) calcd for $C_8H_{14}N_4O$ (M^+) 182.1168, found 182.1164.

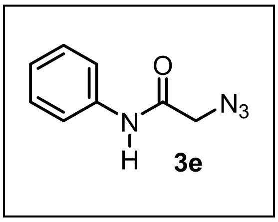
***N*-Benzhydryl-2-azidoacetamide (3d)**



To a stirred solution of benzhydrylamine hydrochloride (1.1 g, 5 mmol) in *N*,*N*-dimethylformamide (7.5 mL, 0.33 M) and triethylamine (0.7 mL, 5.0 mmol), bromoacetyl bromide (0.22 mL, 2.5 mmol) was added dropwise at 0 °C. Then, the resulting mixture was stirred at room temperature for 10 h. The mixture was filtered through filter paper and was concentrated *in vacuo.* The crude material obtained was dissolved in *N*,*N*-dimethylformamide (7.5 mL), and sodium azide (407 mg, 6.3 mmol) was added to the solution at room temperature. The resulting mixture was stirred for 24 h and was poured into iced water. The mixture was extracted with ethyl acetate and was washed with water and brine. The organic layer was dried over sodium sulfate followed by concentration *in vacuo*. The obtained residue was purified by silica gel column chromatography (9% to 17% to 20% ethyl acetate in hexane) to give **3d** (400 mg, 60%) as a white solid.

White solid; R_f value 0.45 (hexane / ethyl acetate = 2 / 1); m.p. 130 °C; IR (NaCl, neat) ν_{max} 3244, 3210, 3059, 2097, 1653, 1551, 1494, 1452, 1417, 1239 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37–7.34 (m, 4H), 7.31–7.28 (m, 2H), 7.24–7.22 (m, 4H), 6.95 (d, 1H, *J* = 8.0 Hz), 6.26 (d, 1H, *J* = 8.0 Hz), 4.08 (s, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.6, 140.8, 128.8, 127.7, 127.3, 56.7, 52.6; LRMS (EI, M = $C_{15}H_{14}N_4O$) *m/z* 266 (9%, M^+), 167 (100), 161 (40); HRMS (EI) calcd for $C_{15}H_{14}N_4O$ (M^+) 266.1168, found 266.1169.

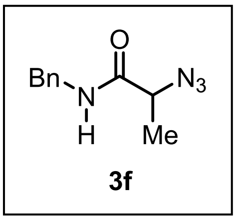
***N*-Phenyl-2-azidoacetamide (3e)**



To a stirred solution of aniline (0.46 mL, 5 mmol) in dichloromethane (5 mL) was added bromoacetyl bromide (0.22 mL, 2.5 mmol) dropwise at 0 °C. After warming up to room temperature, the mixture was stirred for 2 h. The mixture was filtered through filter paper and was concentrated *in vacuo* to give light pink solid (see Caution section). The obtained solid was dissolved in DMSO (12.5 mL), and sodium azide (406.8 mg, 6.25 mmol) was added to the mixture at room temperature. After stirred for 2 h, the mixture was poured into iced water. Then, the organic components were extracted with ethyl acetate, and was washed with water and brine, followed by drying over sodium sulfate. After concentration *in vacuo*, the obtained residue was purified by silica gel column chromatography (20% to 25% to 33% ethyl acetate in hexane) to give **3e** (406 mg, 92%) as a white solid.

white solid; R_f value 0.63 (hexane / ethyl acetate = 2 / 1); m.p. 84.7–85.7 °C; IR (NaCl, neat) ν_{max} 3296, 3202, 2111, 1669, 1604, 1538, 1499, 1444 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.00 (s, 1H), 7.55 (dd, 2H, *J* = 9.0, 1.0 Hz), 7.36 (dd, 2H, *J* = 7.0, 7.0 Hz), 7.16 (tt, 1H, *J* = 7.5, 1.0 Hz), 4.16 (s, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 164.4, 136.7, 129.1, 125.1, 120.0, 53.0; LRMS (EI, M = $C_8H_8N_4O$) *m/z* 176 (32%, M^+), 120 (87), 77 (100); HRMS (EI) calcd for $C_8H_8N_4O$ (M^+) 176.0698, found 176.0700.

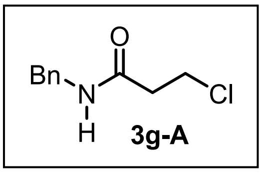
***N*-Benzyl-2-azidopropanamide (3f)**



To a stirred solution of benzylamine (0.55 mL, 5.0 mmol) in dichloromethane (5 mL) was added 2-bromopropionyl bromide (0.26 mL, 2.5 mmol) at 0 °C under nitrogen atmosphere, and the mixture was stirred at room temperature for 2 h. After filtration to remove salt precipitates, the filtrate was concentrated *in vacuo* (see Caution section). The obtained residue was dissolved in DMSO (12.5 mL). To the stirred solution was added sodium azide (410 mg, 6.3 mmol) at room temperature. After 9.5h, the mixture was extracted with diethyl ether, and was washed with water and brine. The organic layer was dried over sodium sulfate followed by concentration *in vacuo*. The obtained residue was purified by silica gel column chromatography (hexane / ethyl acetate = 10 / 1) to give **3f** (400 mg, 79%) as a colorless oil which was frozen in refrigerator.

Colorless oil (frozen in refrigerator); R_f 0.50 (hexane/ethyl acetate = 2/1); IR (NaCl, neat) 3299, 3087, 3066, 3032, 2982, 2933, 2109, 1657, 1535, 1236 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.37–7.26 (m, 5H), 6.65 (br-s, 1H), 4.45 (d, 2H, J = 5.5 Hz), 4.14 (q, 1H, J = 7.0 Hz), 1.59 (d, 3H, J = 7.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.7, 137.5, 128.7, 127.64, 127.61, 59.1, 43.4, 17.1; HRMS (CI) calcd 205.1084 for $C_{10}H_{13}N_4O$ $[M+H]^+$ 205.1084, found 205.1082.

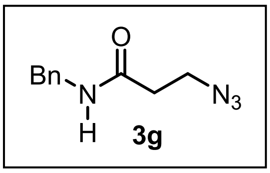
N-Benzyl-3-chloropropanamide (3g-A)



To a stirred solution of 3-chloropropionyl chloride (0.29 mL, 3 mmol) in dichloromethane (2.1 mL) was added benzylamine (0.59 mL, 5.4 mmol) dropwise at 0 °C under nitrogen atmosphere. After warming up to room temperature, the mixture was stirred for 3 h. The mixture was filtered through filter paper and was concentrated *in vacuo*. The obtained residue was recrystallized from ethanol to give **3g-A** (460 mg, 78%) as a white solid.

white solid; R_f value 0.23 (hexane / ethyl acetate = 2 / 1); m.p. 92.5–93.3 °C; IR (NaCl, neat) ν_{max} 3290, 3095, 1638, 1559, 1454, 1426 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.36–7.26 (m, 5H), 5.95 (br-s, 1H), 4.47 (d, 2H, J = 5.5 Hz), 3.84 (t, 2H, J = 6.5 Hz), 2.66 (t, 2H, J = 6.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.3, 137.8, 128.7, 127.8, 127.6, 43.8, 40.1, 39.6; LRMS (EI, M = $C_{10}H_{12}ClNO$) *m/z* 197 (60%, M^+), 162 (43), 106 (63), 91 (100); HRMS (EI) calcd for $C_{10}H_{12}ClNO$ (M^+) 197.0607, found 197.0608.

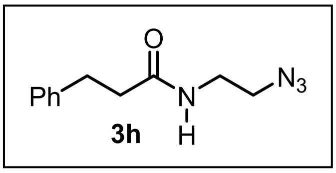
N-Benzyl-3-azidopropanamide (3g)



To a stirred solution of **3g-A** (240 mg 1.2 mmol) in dimethyl sulfoxide (6.3 mL) were added tetrabutylammonium iodide (464 mg, 1.3 mmol) and sodium azide (204 mg, 3.1 mmol) at room temperature. Then, the mixture was warmed up to 50 °C. After for 25 h, the mixture was poured into iced water. Then, the organic components were extracted with diethyl ether and was washed with water and brine. The organic layer was dried over sodium sulfate followed by concentration *in vacuo*. The obtained residue was purified by silica gel column chromatography (33% to 50% ethyl acetate in hexane) to give **3g** (223 mg, 93%) as a light-yellow oil.

Light yellow oil (frozen in refrigerator); R_f 0.23 (hexane/ethyl acetate = 2/1); IR (NaCl, neat) 3295, 3087, 3032, 2930, 2100, 1648, 1552 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.34–7.25 (m, 5H), 5.87 (br-s, 1H), 4.47 (d, 2H, J = 5.5 Hz), 3.66 (t, 2H, J = 6.0 Hz), 2.42 (t, 2H, J = 6.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.8, 137.8, 128.7, 127.7, 127.5, 47.3, 43.6, 35.7; HRMS (CI) calcd for $C_{10}H_{13}N_4O$ $[M+H]^+$ 205.1084, found 205.1086.

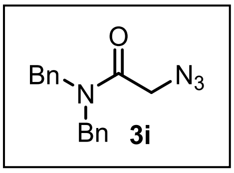
N-(2-Azidoethyl)-3-phenylpropanamide (3h)



To a stirred solution of 2-aminoethyl bromide hydrobromide (1.2 g, 6 mmol) in *N*,*N*-dimethylformamide (6 mL) and triethylamine (0.83 mL) was added 3-phenylpropionyl chloride (0.44 mL, 3.0 mmol) dropwise at 0 °C, and the mixture was stirred at room temperature for 6 h. Then, the mixture was filtered through filter paper, and was washed with water, 1N HCl, and brine. Concentration *in vacuo* gave the crude material. The obtained material and tetrabutylammonium iodide (1.11 g, 3.0 mmol) were dissolved in DMSO (15 mL), and sodium azide (489 mg, 7.5 mmol) was added to the stirred mixture. Then, the mixture was heated at 50 °C. After 24 h, the mixture was poured into iced water. Then, the organic components were extracted with ethyl acetate and was washed with water and brine. The organic layer was dried over sodium sulfate followed by concentration *in vacuo*. The obtained residue was purified by silica gel column chromatography (50% to 67% ethyl acetate in hexane) to give **3h** (327 mg, 50%) as an orange oil.

Orange oil; R_f value 0.35 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3297, 3085, 3064, 3028, 2931, 2866, 2102, 1950, 1874, 1808, 1731, 1651, 1556, 1494, 1454, 1263 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.30–7.26 (m, 2H), 7.22–7.18 (m, 3H), 6.09 (br-s, 1H), 3.35 (s, 4H), 2.95 (t, 2H, *J* = 8.0 Hz), 2.49 (t, 2H, *J* = 8.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.5, 140.5, 128.4, 128.2, 126.2, 50.6, 38.7, 38.1, 31.4; LRMS (EI, M = $C_{11}H_{14}N_4O$) *m/z* 218 (26%, M^+), 133 (30), 105 (89), 91 (100); HRMS (EI) calcd for $C_{11}H_{14}N_4O$ (M^+) 218.1168, found 218.1166.

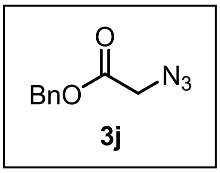
***N,N*-Dibenzyl-2-azidoacetamide (3i)**



3i

The compound was prepared by following our previous reports.[4]

Benzyl azidoacetate (3j)

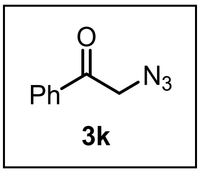


3j

To a stirred solution of benzyl alcohol (0.26 mL, 2.5 mmol) and sodium bicarbonate (630 mg, 7.5 mmol) in acetonitrile (13 mL) was added 2-bromoacetyl bromide (0.30 mL, 3.5 mmol) at 0 °C under nitrogen atmosphere. After 1 h, the mixture was extracted with dichloromethane and was washed with water. Concentration of the organic layer *in vacuo* gave crude material which was then dissolved in DMSO (13 mL) (see Caution section). To the stirred solution was added sodium azide (410 mg, 6.3 mmol) at room temperature. After 4.5 h, the reaction was quenched with water. Then, the mixture was extracted with ether and was washed with water and brine. The organic layer was dried over sodium sulfate followed by concentration *in vacuo*. The obtained residue was purified by silica gel column chromatography (hexane / ethyl acetate = 50 / 1) to give **3j** (390 mg, 82%) as a colorless oil.

Colorless oil ; R_f value 0.43 (hexane/ethyl acetate = 2/1); IR (NaCl, neat) 2104, 1742, 1176 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.41–7.36 (m, 5H), 5.23 (s, 2H), 3.92 (s, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.1, 134.8, 128.7 (overlapping two signals), 128.5, 67.5, 50.3; LRMS (EI, M = $C_9H_9N_3O_2$) *m/z* 191 (M^+, 0.2%), 119 (5), 91 (100), 65 (8); HRMS (EI) calcd for $C_9H_9N_3O_2$ (M^+) 191.0695, found 191.0695.

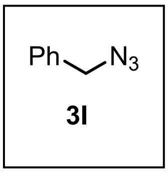
Phenacyl azide (3k)



3k

The compound was prepared by following our previous reports.[4]

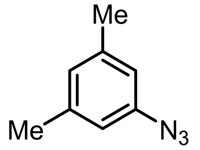
Benzyl azide (3l)



3l

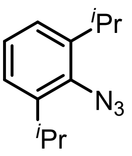
The compound was prepared by following our previous report.[5]

1-Azido-3,5-dimethylbenzene (3m)


3m

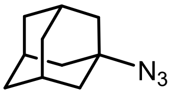
The compound was prepared by following the previous report.[6]

2-Azido-1,3-diisopropylbenzene (3n)


3n

The compound was prepared by following the previous reports.[7]

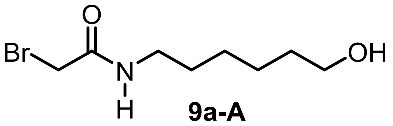
1-Azidoadamantane (3o)


3o

This compound was purchased from Sigma-Aldrich.

Preparation of Diazides

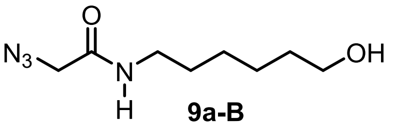
2-Bromo-*N*-(6-hydroxyhexyl)acetamide (9a-A)


9a-A

To a stirred solution of commercially available 6-aminohexanol (118 mg, 1.0 mmol) in dichloromethane (2 mL), bromoacetyl bromide (43 μL, 0.5 mmol) was added dropwise at 0 °C under nitrogen atmosphere. Then the resulting mixture was warmed up to room temperature and was stirred for 2 h. The mixture was extracted with ethyl acetate and was washed with water and brine, followed by drying over sodium sulfate. Concentration *in vacuo* followed by purification by silica gel column chromatography (33% to 100% ethyl acetate in hexane) gave **9a-A** (56.4 mg, 47%) as a white solid.

White solid; R_f value 0.14 (hexane / ethyl acetate = 1 / 1); m.p. 70.4–71.2 °C; IR (NaCl, neat) ν_{max} 3304, 3087, 2931, 2855, 1652, 1557 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.49 (br-s, 1H), 3.89 (s, 2H), 3.65 (t, 2H, J = 7.0 Hz), 3.30 (dt, 2H, J = 7.0, 6.0 Hz), 1.60–1.54 (m, 4H), 1.43–1.37 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.2, 62.7, 40.1, 32.5, 29.4, 29.3, 26.5, 25.3; HRMS (CI) calcd for $C_8H_{17}{}^{79}BrNO_2$ [M+H]$^+$ 238.0437, found 238.0441.

2-Azido-*N*-(6-hydroxyhexyl)acetamide (9a-B)

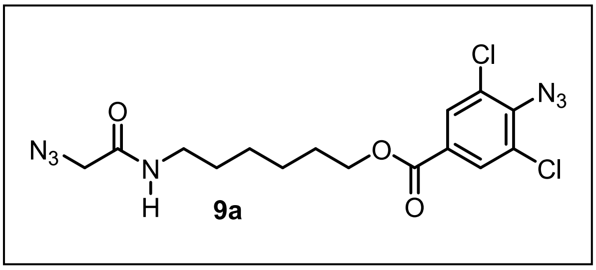

9a-B

To a stirred solution of 2-bromo-*N*-(6-hydroxyhexyl)acetamide **9a-A** (56.4 mg, 0.23 mmol) in dimethylformamide (0.77 mL, 0.3M), sodium azide (38.4 mg, 0.59 mmol) was added at room temperature and stirred for 2 h. The mixture was poured into ice water, extracted with ethyl acetate and washed with water and brine, following by drying over sodium sulfate. Concentration *in vacuo* followed by silica gel column chromatography (50% to 100% ethyl acetate in hexane) gave the product **9a-B** (22.6 mg, 49%) as colorless oil.

Colorless oil; R_f value 0.50 (ethyl acetate); IR (NaCl, neat) ν_{max} 3299, 2935, 2860, 2107, 1657, 1550, 1275 cm^{-1}; ^{1}H

NMR (500 MHz, $CDCl_3$) δ 6.43 (s, 1H), 3.98 (s, 2H), 3.64 (t, 2H, *J* = 6.5 Hz), 3.30 (dt, 2H, *J* = 6.0, 7.0 Hz), 1.92 (s 1H), 1.60–1.52 (m, 4H), 1.42–1.34 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.6, 62.5, 52.6, 39.2, 32.4, 29.3, 26.4, 25.2; HRMS (CI) calcd for $C_8H_{17}N_4O_2$ $[M+H]^+$ 201.1346, found 201.1347.

6-(2-Azidoacetamido)hexyl 4-azido-3,5-dichlorobenzoate (9a)



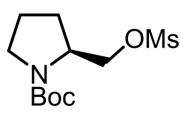
9a

4-Azido-3,5-dichlorobenzoic acid was prepared by following the report of Yoshida and Hosoya's group.[8] To a stirred solution of commercially available 4-amino-3,5-dichlorobenzoic acid (1.12 g, 5.4 mmol) in acetonitrile (13.6 mL, 0.4M), *tert*-butyl nitrite (0.96 mL, 8.0 mmol) and trimethylsilyl azide (1.1 mL, 8.0 mmol) were added at 0 °C and stirred for 19 h. The mixture was concentrated and used it in the next step without purification.

To a stirred solution of 2-azido-*N*-(6-hydroxyhexyl)acetamide **9a-B** (160.0mg, 0.8 mmol) and the prepared crude 4-azido-3,5-dichlorobenzoic acid (257.4 mg, 1.1 mmol) in 1,2-dichloromethane (4.0 mL, 0.2 M), *N*-(3-dimethylaminopropyl)-*N'*-ethylcarbodiimide hydrochloride (184.2 mg, 0.96 mmol) and 4-dimethylaminopyridine (4.7 mg, 0.04 mmol) were added at room temperature under N_2 gas and was stirred for 1 d. The mixture was extracted with ethyl acetate and washed with water, 1 M HCl, and brine, followed by drying over sodium sulfate. Concentration *in vacuo* followed by silica gel column chromatography (20% ethyl acetate in hexane) gave **9a** (161.7 mg, 49%) as white solid.

White solid; R_f value 0.52 (hexane / ethyl acetate = 1 / 1); m.p. 59.3–59.9 °C; IR (NaCl, neat) ν_{max} 3300, 3079, 2935, 2859, 2109, 1723, 1659, 1552, 1456, 1386, 1328, 1267 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.93 (s, 2H), 6.35 (s, 1H), 4.32 (t, 2H, *J* = 7.0 Hz), 4.00 (s, 2H), 3.31 (dt, 2H, *J* = 7.0, 7.0 Hz), 1.78 (tt, 2H, *J* = 7.0, 7.0 Hz), 1.58 (tt, 2H, *J* = 6.5, 7.5 Hz), 1.48–1.39 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.5, 163.8, 137.9, 130.1, 129.1, 128.3, 65.7, 52.7, 39.3, 29.3, 28.5, 26.4, 25.5; HRMS (CI) calcd for $C_{15}H_{18}{}^{35}Cl_2N_7O_3$ $[M+H]^+$ 414.0848, found 414.0841.

tert-Butyl (*S*)-2-(((methylsulfonyl)oxy)methyl)pyrrolidine-1-carboxylate (9b-A)

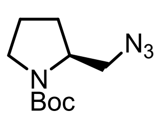


9b-A

To a stirred solution of commercially available *N*-(*tert*-butoxycarbonyl)-L-prolinol (598 mg, 3 mmol) in THF (10 mL), triethylamine (0.62 mL, 4.5 mmol) and methanesulfonyl chloride (0.28 mL, 3.6 mmol) were added at 0 °C under nitrogen atmosphere and the mixture was stirred for 1 h. Then, the mixture was filtered through filter paper to remove precipitate. Concentration of the filtrate *in vacuo* followed by silica gel column chromatography (17% to 33% ethyl acetate in hexane) gave **9b-A** (827 mg, 99%) as a light-yellow oil.

Light-yellow oil; R_f value 0.55 (hexane / ethyl acetate = 1 / 1) ; $[\alpha]_D^{25}$ −48.7 (c = 0.1, $CHCl_3$); IR (NaCl, neat) ν_{max} 2976, 2935, 2885, 1690, 1395, 1358, 1173 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 4.30 (d, 2H, *J* = 6.0 Hz), 4.12–4.04 (m, 1H), 3.36 (d, 2H, *J* = 5.0 Hz), 3.01 (s, 3H), 2.03–1.86 (m, 4H), 1.47 (s, 9H); ^{13}C NMR (126 MHz, DMSO-d6) δ 154.1, 79.4, 70.2, 55.9, 47.0, 37.4, 28.6, 28.1, 23.4; LRMS (EI, M = $C_{11}H_{21}NO_5S$) *m/z* 279 (1.5%, M^+), 170 (66), 114 (97), 70 (100), 57 (73); HRMS (EI) calcd for $C_{11}H_{21}NO_5S$ (M^+) 279.1140, found 279.1135.

tert-Butyl (*S*)-2-(azidomethyl)pyrrolidine-1-carboxylate (9b-B)

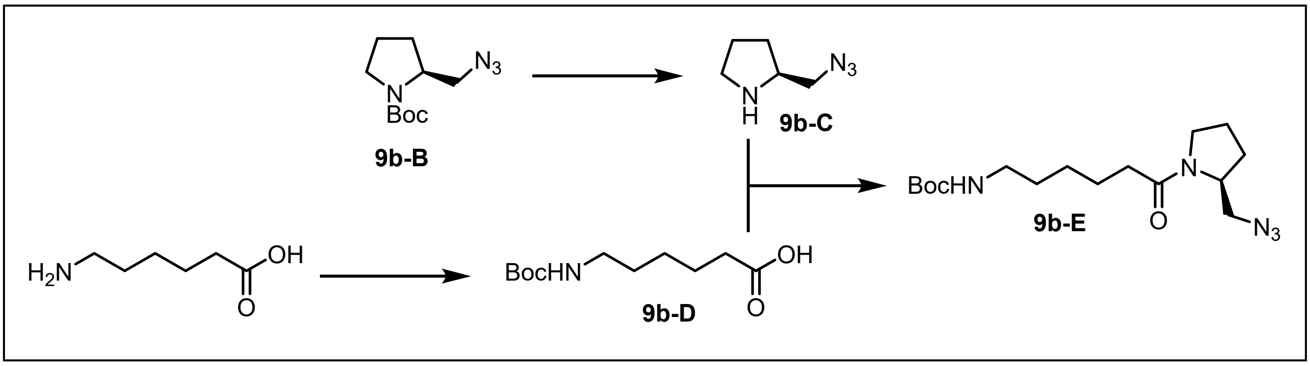


9b-B

To a stirred solution of *tert*-butyl (*S*)-2-(((methylsulfonyl)oxy)methyl)pyrrolidine-1-carboxylate **9b-B** (827 mg, 3 mmol) in DMF (10 mL), sodium azide (489.9mg, 7.5 mmol) was added and the mixture was stirred for 16 h at 80 °C. Then, the mixture was diluted with ethyl acetate and was washed with 1M $KHSO_4$ aq., water, and brine followed by drying over sodium sulfate. Concentration *in vacuo* followed by silica gel column chromatography (9% to 17% ethyl acetate in hexane) gave **9b-B** (651 mg, 96%) as a colorless oil.

Colorless oil; R_f value 0.40 (hexane / ethyl acetate = 5 / 1); $[\alpha]_D^{25}$ −51.0 (c = 0.25, $CHCl_3$); IR (NaCl, neat) ν_{max} 2975, 2878, 2100, 1693, 1392, 1365, 1275, 1165, 1106 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.95–3.88 (m, 1H), 3.46–3.29 (m, 4H), 1.99–1.84 (m 4H), 1.47 (s, 9H); ^{13}C NMR (126 MHz, DMSO-d6) δ 153.2, 78.5, 56.0, 52.5, 46.3, 28.4, 27.9, 22.7; HRMS (ESI) calcd for $C_{10}H_{18}N_4O_2Na$ $[M+Na]^+$ 249.1327, found 249.1318.

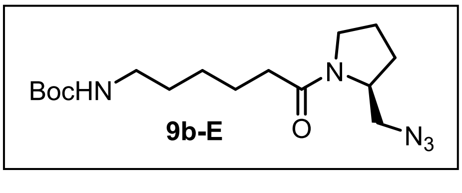
Synthesis of *tert*-Butyl (*S*)-(6-(2-(azidomethyl)pyrrolidin-1-yl)-6-oxohexyl)carbamate (9b-E)



9b-C was prepared by following the literature.[9] To a stirred solution of *tert*-butyl (*S*)-2-(azidomethyl)pyrrolidine-1-carboxylate **9b-B** (452.7 mg, 2.0 mmol) in dichloromethane (5 mL), trifluoroacetic acid (5.0 mL) was added at 0 °C under N_2 gas. The reaction mixture was warmed to room temperature and stirred for 2 h. 4 N NaOH aq. was added at 0°C to the reaction mixture and extracted with ethyl acetate followed by drying over sodium sulfate. Concentration *in vacuo* gave the crude product of **9b-C** as yellow oil. This compound was used soon in the next condensation step without further purification.

In a separated flask, **9b-D** was prepared by following the literature.[10] To a stirred solution of commercially available 6-aminohexanoic acid (657 mg, 5.0 mmol) in 1,4-dioxane (11.1 mL) and water (5.6 mL), 1M NaOH aq. (5 mL) and di-*tert*-butyl dicarbonate (1.26g, 5.8 mmol) were added at 0 °C and was stirred for 3 h. The aqueous residue was washed with ethyl acetate and added 1 M HCl aq. until pH 1. The aqueous layer was extracted with ethyl acetate and dried over sodium sulfate. Concentration *in vacuo* gave the crude product of **9b-D** as white crystal. This compound was used soon in next condensation step without further purification.

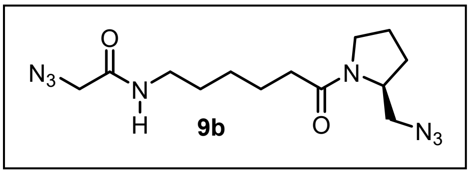
To a stirred solution of the crude (*S*)-2-(azidomethyl)pyrrolidine **9b-C** (252 mg, 2.0 mmol), hydroxybenzotriazole (310.0mg, 2 mmol), 1-(3-Dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (387.0 mg, 2 mmol), and *N*,*N* –diisopropylethylamine (0.51 mL, 3 mmol) in 1,2-dichloroethane (5 mL), the crude 6-((*tert*-butoxycarbonyl)amino)hexanoic acid **9b-D** (463 mg, 2.0 mmol) was added under nitrogen atmosphere and was stirred for 13 h. Then, saturated sodium bicarbonate aqueous solution was added to the reaction mixture. The mixture was extracted with dichloromethane and washed with brine, 1% citric acid aq., and brine followed by drying over sodium sulfate. Concentration *in vacuo* followed by silica gel column chromatography (17% to 25% to 33% to 50% ethyl acetate in hexane) gave **9b-E** (656 mg, 97% from **9b-C/D**) as a light-yellow oil.



tert-Butyl (*S*)-(6-(2-(azidomethyl)pyrrolidin-1-yl)-6-oxohexyl)carbamate (9b-E)

Light-yellow oil; R_f value 0.40 (hexane / ethyl acetate = 1 / 1); $[\alpha]_D^{25}$ −44.1

(c = 1.0, $CHCl_3$); IR (NaCl, neat) ν_{max} 3332, 2974, 2934, 2870, 2102, 1705, 1633, 1523, 1423, 1364, 1274, 1251, 1172 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 4.59 (br-s, 1H), 4.23–4.20 (m, 1H), 3.68 (dd, 1H, *J* = 12.0, 5.5 Hz), 3.51–3.42 (m, 2H), 3.37 (dd, 1H, *J* = 12.0, 2.5 Hz), 3.14–3.11 (m, 2H), 2.28 (t, 2H, *J* = 7.5 Hz), 2.08–1.88 (m, 4H), 1.69–1.63 (m, 2H), 1.54–1.44 (m, 11H), 1.39–1.33 (m, 2H) ; ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.2, 156.0, 79.0, 56.3, 52.2, 47.5, 40.4, 34.8, 29.9, 28.4, 28.0, 26.5, 24.3, 24.2; LRMS (EI, M = $C_{16}H_{29}N_5O_3$) *m/z* 339 (0.9%, M^+), 283 (13), 183 (27), 70 (100); HRMS (EI) calcd for $C_{16}H_{29}N_5O_3$ (M^+) 339.2270, found 339.2272.



9b

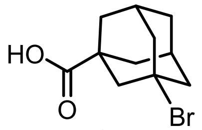
(*S*)-2-Azido-*N*-(6-(2-(azidomethyl)pyrrolidin-1-yl)-6-oxohexyl)acetamide (9b)

To a stirred solution of *tert*-butyl (*S*)-(6-(2-(azidomethyl)pyrrolidin-1-yl)-6-oxohexyl)carbamate **9b-E** (365 mg, 1.07 mmol) in dichloromethane, trifluoroacetic acid (0.33 mL, 4.3 mmol) was added at 0 °C under nitrogen atmosphere. The reaction mixture was warmed to room temperature and stirred for 4 h. The reaction mixture was diluted with dichloromethane and washed with 4N NaOH aq. and brine followed by drying over sodium sulfate. The concentration *in vacuo* gave the crude material of deBoc product (234 mg, 91%). This material was used in the next step without further purification.

To a stirred solution of the crude material of (*S*)-6-amino-1-(2-(azidomethyl)pyrrolidin-1-yl)hexan-1-one obtained above (crude, 0.98 mmol), in dichloromethane, trimethylamine (0.2 mL, 1.47 mmol) and bromoacetyl bromide (0.12 mL, 1.37 mmol) were added at 0 °C under nitrogen atmosphere. The reaction mixture was warmed to room temperature and stirred for 2 h. The reaction was quenched by 1N HCl aq., extracted with dichloromethane, and washed with saturated sodium bicarbonate aqueous solution and brine, followed by drying over sodium sulfate. The concentration *in vacuo* gave the crude material of bromoacetamide (428 mg, >99%). This material was used in the next step without further purification.

To a stirred solution of the crude material of (*S*)-*N*-(6-(2-(azidomethyl)pyrrolidin-1-yl)-6-oxohexyl)-2-bromoacetamide obtained above (crude, 0.98 mmol) in *N*, *N*-dimethylformamide (3.3 mL), sodium azide (159.4 mg, 2.45 mmol) was added at room temperature and was stirred for 3 h. The reaction mixture was poured into ice water, extracted with ethyl acetate and washed with brine followed by drying over sodium sulfate. The concentration *in vacuo* followed by silica gel column chromatography (33% to 50% to 75%) gave **9b** (251 mg, 73 % over 3 steps) as yellow oil.

Yellow oil; R_f value 0.44 (ethyl acetate); $[\alpha]_D^{25}$ −45.7 (c = 0.5, $CHCl_3$); IR (NaCl, neat) ν_{max} 3422, 2939, 2870, 2103, 1625, 1556, 1428, 1274 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 6.49 (br-s, 1H), 4.23–4.20 (m, 1H), 3.98 (s, 2H), 3.70 (dd, 1H *J* = 12.0, 5.5 Hz), 3.50–3.43 (m, 2H), 3.38–3.30 (m, 3H), 2.29 (t, 2H, *J* = 7.5 Hz), 2.08–1.88 (m, 4H), 1.70–1.64 (m, 2H), 1.57 (tt, 2H, *J* = 7.5, 6.5 Hz), 1.39 (tt, 2H, *J* = 8.5, 4.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.1, 166.5, 56.4, 52.7, 52.2, 47.5, 39.0, 34.6, 29.0, 28.0, 26.4, 24.3, 23.8; LRMS (EI, M = $C_{13}H_{22}N_8O_2$) *m/z* 322 (0.4%, M^+), 266 (41), 154 (11), 70 (100), 69 (10); HRMS (EI) calcd for $C_{13}H_{22}N_8O_2$ (M^+) 322.1866, found 322.1865.

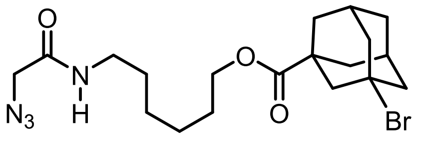


9c-A

3-Bromoadamantane-1-carboxylic acid (9c-A)

The compound was commercially available. However, we prepared this compound from commercially available 3-hydroxyadamantane-1-carboxylic acid by the reported procedure.[11]

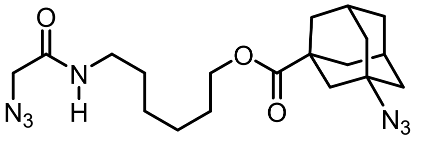
6-(2-Azidoacetamido)hexyl 3-bromoadamantane-1-carboxylate (9c-B)


9c-B

To a stirred solution of 2-azido-*N*-(6-hydroxyhexyl)acetamide **9a-B** (200 mg, 1.0 mmol) and 3-bromoadamantane-1-carboxylic acid **9c-A** (259 mg, 1 mmol) in dichloromethane (5 mL) under N_2 gas atmosphere, *N*-(3-dimethylaminopropyl)-*N'*-ethylcarbodiimide hydrochloride (239 mg, 1.2 mmol) and 4-(dimethylamino)pyridine (5 mg, 0.04 mmol) were added at room temperature and was stirred for 85 h. Additional 4-(dimethylamino)pyridine (142 mg, 1.16 mmol) was added and kept stirred for another 26 h. The mixture was diluted with dichloromethane and washed with water and brine, followed by drying over sodium sulfate. Concentration of the organic components *in vacuo,* followed by silica gel column chromatography (25% to 50% ethyl acetate in hexane), gave **9c-B** (316 mg, 72%) as a colorless oil.

Colorless oil; R_f value 0.42 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3299, 2935, 2858, 2104, 1724, 1658, 1547, 1453, 1310, 1253, 1244, 1105, 1709 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.34 (br-s, 1H), 4.06 (t, 2H, J =6.5 Hz), 4.00 (s, 2H), 3.30 (dt, 2H, J = 7.0, 6.5 Hz), 2.47 (s, 2H), 2.35–2.29 (m,4H), 2.22 (t, 2H, J = 3.0 Hz), 1.88 (d, 4H, J = 3.0 Hz), 1.71–1.54 (m, 6H), 1.38–1.36 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 175.5, 166.4, 64.4, 63.9, 52.7, 49.6, 48.1, 44.9, 39.3, 37.1, 34.4, 31.7, 29.3, 28.4, 26.4, 25.5; HRMS (DART) calcad for $C_{19}H_{30}{}^{79}BrN_4O_3$ $[M+H]^+$ 441.1496, found 441.1498.

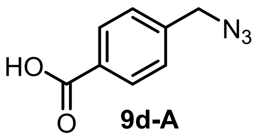
6-(2-Azidoacetamido)hexyl 3-azidoadamantane-1-carboxylate (9c)


9c

The azidation of bromoadamantane was carried out by following the reported method.[11] To a stirred solution of 6-(2-azidoacetamido)hexyl 3-bromoadamantane-1-carboxylate **9c-B** (316 mg, 0.715 mmol) in dichloromethane under N_2 gas atmosphere, trimethylsilyl azide (0.28 mL, 2.15 mmol) and tin(IV) chloride (0.1 mL, 0.858 mmol) were added at room temperature. Then, the mixture was heated under reflux conditions and stirred for 19 h. After cooling to room temperature, the reaction was quenched by a dropwise addition of water. The mixture was extracted with dichloromethane, followed by drying over sodium sulfate. The concentration of the organic components *in vacuo* followed by purification by silica gel column chromatography (25% to 50 % ethyl acetate in hexane) gave **9c** (110 mg, 38%) as a colorless oil.

Colorless oil; R_f value 0.55 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3309, 2933, 2859, 2090, 1725, 1659, 1544, 1454, 1247, 1089 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.35 (br-s, 1H), 4.07 (t, 2H, J = 7.0 Hz), 4.00 (s, 2H), 3.30 (dt, 2H, J = 6.5, 7.0 Hz), 2.28 (d, 2H, J = 2.5 Hz), 1.92 (s, 2H), 1.86–1.79 (m, 8H), 1.65–1.54 (m, 6H), 1.38–1.36 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 176.0, 166.4, 64.3, 58.8, 52.7, 43.0, 42.6, 40.5, 39.3, 37.5, 34.8, 29.3, 28.4, 26.4, 25.5; HRMS (ESI) calcad for $C_{19}H_{28}N_7O_3$ $[M-H]^-$ 402.2259, found 402.2249.

4-(Azidomethyl)benzoic acid (9d-A)

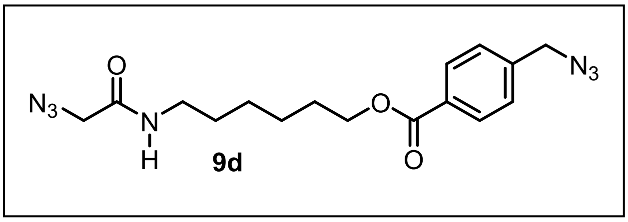

9d-A

The compound was prepared by following the previous reports.[12]

To a stirred solution of commercially available 4-(chloromethyl)benzoic acid (512 mg, 3.0 mmol) in dimethyl sulfoxide (15 mL, 0.2M), sodium azide (395 mg, 6.1 mmol) was added at room temperature and was stirred for 5 h. Water (50 mL) was added to the mixture and the resulting precipitate was vacuum-filtered and washed with water. Concentration in vacuo gave the product **9d-A** (277 mg, 52%) as white solid.

White solid; R_f value 0.30 (hexane / ethyl acetate = 1 / 1); m.p. 135.4–136.5 °C; IR (KBr, neat) ν_{max} 3357, 2907, 2837, 2662, 2548, 2227, 2109, 1683, 1610, 1426, 1293 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.14 (d, 2H, J = 8.0 Hz), 7.44 (d, 2H, J = 9.0 Hz), 4.45 (s, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.8, 141.4, 130.7, 129.1, 128.0, 54.3; LRMS (EI, M = $C_8H_7N_3O_2$) *m/z* 177 (32%, M$^+$), 149 (32), 148 (72), 135 (100); HRMS (EI) calcd for $C_8H_7N_3O_2$ (M$^+$) 177.0538, found 177.0536.

6-(2-Azidoacetamido)hexyl 4-(azidomethyl)benzoate (9d)



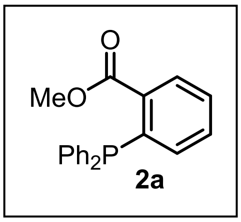
9d

To a stirred solution of 2-azido-*N*-(6-hydroxyhexyl)acetamide **9a-B** (250 mg, 1.2 mmol) and 4-(azidomethyl)benzoic acid **9d-A** (213 mg, 1.2 mmol) in 1,2-dichloroethane, *N*-(3-dimethylaminopropyl)-*N'*-ethylcarbodiimide hydrochloride (278 mg, 1.4 mmol) and 4-(dimethylamino)pyridine (6.6 mg, 0.05 mmol) ware added at room temperature under N_2 gas atmosphere and was stirred for 14.5 h. The mixture was diluted with dichloromethane and washed with 1 M HCl, saturated $NaHCO_3$ aq, water, and brine, followed by drying over sodium sulfate. Concentration in vacuo followed by silica gel column chromatography (25 % ethyl acetate in hexane) gave the product **9d** (294 mg, 68%) as colorless oil.

Colorless oil; R_f value 0.43 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3303, 2935, 2862, 2103, 1715, 1661, 1539, 1277 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.06 (d, 2H, J = 8.5 Hz), 7.40 (d, 2H, J = 8.0 Hz), 6.32 (br-s, 1H), 4.42 (s, 2H), 4.33 (t, 2H, J = 6.5 Hz), 3.99 (s, 2H), 3.31 (dt, 2H, J = 7.0, 7.0 Hz), 1.79 (tt, 2H, J = 7.0, 7.0 Hz), 1.58 (m, 2H), 1.50–1.39 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.4, 166.2, 140.3, 130.3, 130.1, 127.9, 64.9, 54.3, 52.7, 39.3, 29.3, 28.6, 26.4, 25.6; LRMS (EI, M = $C_{16}H_{21}N_7O_3$) *m/z* 359 (0.26%, M$^+$), 275 (27), 178 (35), 160 (100); HRMS (EI) calcad for $C_{16}H_{21}N_7O_3$ (M$^+$) 359.1706, found 359.1704.

Preparation of Other Substrates

Methyl 2-(diphenylphosphaneyl)benzoate (2a)



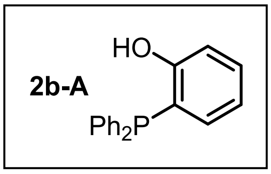
2a

The compound was prepared by following the reported procedure.[13]

To a stirred solution of 1,3-bis(diphenylphosphino)propane (16.7 mg, 0.04 mmol) and palladium (II) acetate (9.2 mg, 0.04 mmol), and methyl 2-iodobenzoate (0.59 mL, 4 mmol) in acetonitrile (4 mL) under nitrogen gas atmosphere, triethylamine (0.62 mL, 4.5 mmol) and diphenylphosphine (0.69 mL, 4 mmol) were added at room temperature. Then, the stirred mixture was heat under reflux condition for 7 h. The concentration of the mixture *in vacuo* followed by silica gel column chromatography (10% ethyl acetate in hexane) gave **2a** (852.2 mg, 67%) as a white crystal.

White crystal; R_f value 0.33 (hexane / ethyl acetate = 10 / 1); m.p. 99.8–101.0 °C; IR (KBr, neat) ν_{max} 3065, 3054, 3007, 2999, 2952, 1715, 1583, 1477, 1465, 1432, 1300, 1288, 1279 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07–8.04 (m, 1H), 7.40–7.26 (m, 12H), 6.95–6.93 (m, 1H), 3.74 (s, 3H)); ^{13}C NMR (126 MHz, $CDCl_3$) δ 167.2, 140.3 (d, J = 10.1 Hz), 137.6 (d, J = 8.4 Hz), 134.3, 134.1 (d, J = 18.0 Hz), 133.8 (d, J = 20.4 Hz), 132.0, 130.7 (d, J = 2.4 Hz), 128.7, 128.5 (d, J = 7.2 Hz), 128.3, 52.1; ^{31}P NMR (202 MHz, $CDCl_3$) δ –3.9; LRMS (EI, M = $C_{20}H_{17}O_2P$) *m/z* 320 (1.7%, M$^+$), 306 (20), 305 (100); HRMS (EI) calcd for $C_{20}H_{17}O_2P$ (M$^+$) 320.0966, found 320.0966.

2-(Diphenylphosphanyl)phenol (2b-A)



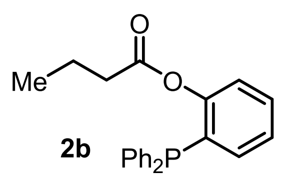
2b-A

The compound was prepared by following the reported procedure.[14]

To a stirred solution of 2-iodophenol (1.16 g, 5 mmol), Palladium(II) acetate (11.6 mg, 0.05 mmol), and sodium acetate (451.0 mg, 5.5 mmol) in anhydrous dimethylacetamide (16.7 mL, 0.3 M), diphenylphosphine (0.96 mL, 5 mmol) was added at room temperature under N_2 gas atmosphere. Then, the resulting mixture was warmed to 110 °C and was stirred for 16 h. The mixture was filtered through a pad of celite and was washed with ethyl acetate. Then, the filtrate was extracted with ethyl acetate and the organic layer was washed with water and brine, followed by drying over sodium sulfate. Concentration *in vacuo* followed by silica gel column chromatography (5 % to 6 % to 17 % ethyl acetate in hexane) gave the product **2b-A** (932.8 mg, 67%) as white solid.

White solid; R_f value 0.58 (dichloromethane); m.p. 148.2–149.4 °C; IR (KBr, neat) ν_{max} 3517, 3244, 3057, 3012, 2928, 2828, 2682, 1590, 1476, 1434, 1346, 1284 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38–7.32 (m, 11H), 6.99–6.88 (m, 3H), 6.32 (br-s, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 159.1 (d, *J* = 19.3 Hz), 134.9 (d, *J* = 4.8 Hz), 134.7 (d, *J* = 4.8 Hz), 133.4 (d, *J* = 19.2 Hz), 131.6, 129.0, 128.7 (d, *J* = 7.2 Hz), 121.1 (d, *J* = 2.4), 120.9 (d, *J* = 4.8 Hz), 115.5; ^{31}P NMR (202 MHz, $CDCl_3$) δ -28.4; LRMS (EI, M = $C_{18}H_{15}OP$) *m/z* 278 (100%, M^+), 277 (49), 199 (52), 183 (31); HRMS (EI) calcd for $C_{18}H_{15}OP$ (M^+) 278.0861, found 278.0861.

2-(Diphenylphosphaneyl)phenyl butyrate (2b)

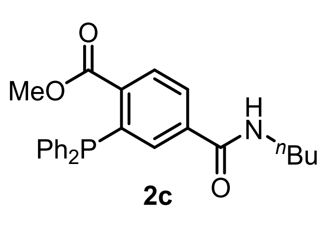

2b

The compound was prepared by following the reported procedure.[15]

To a stirred solution of 2-(diphenylphosphino)phenol **2b-A** (250.4 mg, 0.9 mmol) and triethylamine (0.138 mL, 0.99 mmol) in dichloromethane (9 mL, 0.1 M), butyryl chloride (0.103 mL, 0.99 mmol) was added dropwise at room temperature and was stirred for 1.5 h. The mixture was diluted with dichloromethane (35 mL) and washed with 5% $NaHCO_3$ aq (20 mL), followed by drying over sodium sulfate. Concentration *in vacuo* followed by purification by silica gel column chromatography (9% to 50% ethyl acetate in hexane) gave the product **2b** (290.4 mg, 93%) as white solid.

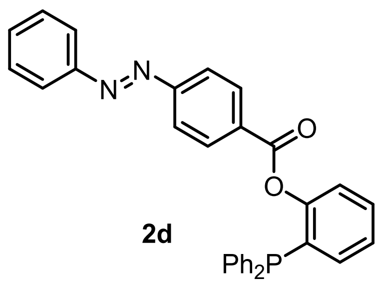
White solid; R_f value 0.55 (hexane / ethyl acetate = 10 / 1); m.p. 77.7–78.3 °C; IR (NaCl, neat) ν_{max} 3056, 2964, 1760, 1466, 1434, 1136, 1095 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39–7.29 (m, 11H), 7.15–7.12 (m, 2H), 6.82–6.79 (m, 1H), 2.22 (t, 2H, *J* = 7.5 Hz), 1.53 (qt, 2H, *J* = 7.5, 7.5 Hz), 0.87 (t, 3H, *J* = 7.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.5, 152.7 (d, *J* = 16.8 Hz), 135.5 (d, *J* = 9.6 Hz), 134.0, 133.9, 133.6, 129.9, 129.0, 128.6 (d, *J* = 7.2 Hz), 126.0, 122.5, 35.8, 18.0, 13.6; LRMS (EI, M = $C_{22}H_{21}O_2P$) *m/z* 348 (33%, M^+), 305 (100), 278 (88), 277 (96), 199 (67); ^{31}P NMR (202 MHz, $CDCl_3$) δ -15.6; HRMS (EI) calcd for $C_{22}H_{21}O_2P$ (M^+) 348.1279, found 348.1279.

Methyl 4-(butylcarbamoyl)-2-(diphenylphosphaneyl)benzoate (2c)


2c

The compound was prepared by following our previous reports.[4]

2-(Diphenylphosphaneyl)phenyl (*E*)-4-(phenyldiazenyl)benzoate (2d)


2d

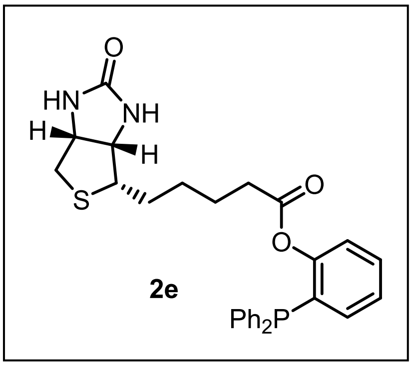
The compound was prepared by following the reported procedure.[16]

To a stirred solution of 2-(diphenylphosphino)phenol **2b-A** (196 mg, 0.7 mmol), *N*,*N*'-dicyclohexylcarbodiimide (436 mg, 2.1 mmol), and 4-dimethylaminopyridine (346 mg, 2.8 mmol) in dichloromethane (10 mL) under

N_2 gas atmosphere, 4-(phenylazo)benzoic acid (409 mg, 1.8 mmol) was added at room temperature. After 15 h, the mixture was filtered through a pad of celite, and the filtrate was concentrated *in vacuo*. The obtained crude material was purified by silica gel column chromatography (0% to 5% ethyl acetate in hexane) to give **2d** (295 mg, 87%) as an orange amorphous oil.

Orange amorphous oil; R_f value 0.20 (hexane / ethyl acetate = 15 / 1); IR (NaCl, neat) ν_{max} 3055, 3011, 1739, 1602, 1466, 1435, 1408, 1255, 1193, 1072 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.98–7.95 (m, 4H), 7.87–7.85 (m, 2H), 7.57–7.52 (m, 3H), 7.45 (dt, 1H, *J* = 2.0, 8.0 Hz), 7.38–7.32 (m, 11H), 7.20 (t, 1H, *J* = 7.5 Hz), 6.88–6.85 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 163.7, 155.3, 152.5 (overlapping two signals), 139.2, 135.2 (d, *J* = 9.7 Hz), 134.2, 134.0, 133.5, 131.8, 131.2, 130.7 (d, *J* = 3.5 Hz), 129.9, 129.2, 129.1, 128.6 (d, *J* = 7.2 Hz), 126.3, 123.2, 122.5 (overlapping two signals); ^{31}P NMR (202 MHz, $CDCl_3$) δ -14.7; LRMS (EI, M = $C_{31}H_{23}N_2O_2P$) *m/z* 486 (5.9%, M^+), 209 (47), 199 (42), 104 (54), 77 (100); HRMS (EI) calcd for $C_{31}H_{23}N_2O_2P$ (M^+) 486.1497, found 486.1495.

2-(Diphenylphosphaneyl)phenyl 5-((4*R*)-2-oxohexahydro-1*H*-thieno[3,4-*d*]imidazol-4-yl)pentanoate (2e)



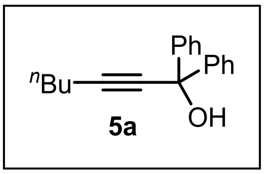
2e

The compound was prepared by following the reported procedure.[16]

To a stirred solution of biotin (177 mg, 0.72 mmol) in *N*,*N*-dimethyl formamide (3 mL) under N_2 gas atmosphere, 4-dimethylaminopyridine (111 mg, 0.9 mmol), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (140 mg, 0.9 mmol), and 2-(diphenylphosphino)phenol **2b-A** (168 mg, 0.6 mmol) were added at room temperature successively. After 4 h at room temperature, the mixture was poured into water, and the organic components were extracted with ethyl acetate followed by wash with brine. The collected organic layer was dried over sodium sulfate. The concentration of the organic components *in vacuo* followed by silica gel column chromatography (4% methanol in dichloromethane) gave **2e** (277 mg, 91%) as a white amorphous oil.

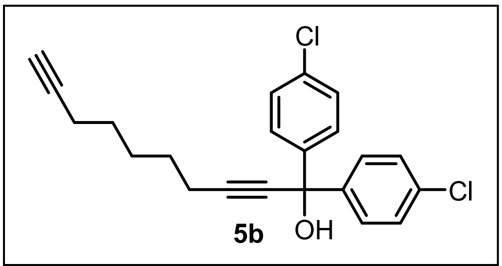
White amorphous oil; R_f value 0.19 (dichloromethane / methanol = 25 / 1) $[\alpha]_D^{23}$ +32.1 (c = 0.25, $CHCl_3$); IR (NaCl, neat) ν_{max} 3232, 3063, 2927, 2858, 1757, 1702, 1465, 1434 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.39–7.27 (m, 11H), 7.16–7.13 (m, 2H), 6.81–6.79 (m, 1H), 4.53–4.50 (m, 1H), 4.29 (dd, 1H, *J* = 4.5, 3.5 Hz), 3.14–3.10 (m, 1H), 2.92 (dd, 1H, *J* = 5.0, 8.0 Hz), 2.75–2.72 (m, 1H), 2.30 (t, 2H, *J* = 7.5 Hz), 1.62–1.36 (m, 4H), 1.40–1.33 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.6, 163.7, 152.6 (d, *J* =16.8 Hz), 135.4 (d, *J* = 6.0 Hz), 135.3 (d, *J* = 5.9 Hz), 134.0 (d, *J* = 4.8 Hz), 133.8 (d, *J* = 4.8 Hz), 133.6, 130.0 (d, *J* = 14.5 Hz), 129.9, 129.0 (d, *J* = 2.4 Hz), 128.6 (d, *J* = 7.2 Hz), 126.1, 122.5, 61.8, 60.0, 55.4, 40.5, 33.5, 28.12, 28.06, 24.3; ^{31}P NMR (202 MHz, $CDCl_3$) δ −16.0; LRMS (EI, M = $C_{28}H_{29}N_2O_3PS$) *m/z* 504 (0.57%, M^+), 278 (100), 277 (49), 199 (51) ; HRMS (EI) calcd for $C_{28}H_{29}N_2O_3PS$ (M^+) 504.1637, found 504.1637.

1,1-Diphenylhept-2-yn-1-ol (5a)



5a

The compound was prepared by following our previous reports.[17]



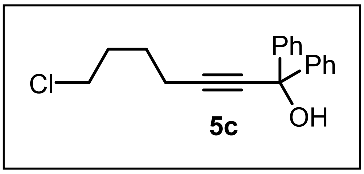
5b

1,1-Bis(4-chlorophenyl)deca-2,9-diyn-1-ol (5b)

To a stirred solution of lithium bis(trimethylsilyl)amide (1.0 M in tetrahydrofuran, 6.0 mL, 6.0 mmol) in tetrahydrofuran (20 mL), 4, 4'-dichlorobenzophenone (1.0 g, 4.0 mmol) and 1,8-nonadiyne (0.88 mL, 6.0 mmol) were added at 0 °C. Then, the reaction mixture was warmed up to room temperature and was stirred for 8 h. The reaction mixture was diluted with ethyl acetate, and was washed with water and brine, followed by drying over sodium sulfate. Concentration *in vacuo* followed by silica gel column chromatography (5% to 6% to 9% ethyl acetate in hexane) gave **5b** (534 mg, 48%) as a light-yellow oil.

Light yellow oil; R_f value 0.13 (hexane / ethyl acetate = 10 / 1); IR (NaCl, neat) ν_{max} 3438, 3302, 2939, 2861, 1488, 1092, 1013 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.51–7.49 (m, 4H), 7.30–7.26 (m, 4H), 2.73 (s, 1H), 2.35 (t, 2H, J = 7.0 Hz), 2.22–2.19 (m, 2H), 1.93 (t, 1H, J = 3.0 Hz), 1.63–1.54 (m, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 143.6, 133.6, 128.4, 127.3, 88.7, 84.3, 82.3, 73.5, 68.4, 27.90, 27.88, 27.79, 18.7, 18.3; LRMS (EI, M = $C_{22}H_{20}Cl_2O$) *m/z* 370 (4%, M^+), 289 (24), 275 (30), 253 (27); HRMS (EI) calcd for $C_{22}H_{20}{}^{35}Cl_2O$ (M^+) 370.0891, found 370.0891.

7-Chloro-1,1-diphenylhept-2-yn-1-ol (5c)

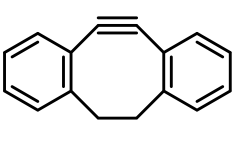


5c

To a stirred solution of lithium hexamethyldisilazide (1.3 mol/L, in tetrahydrofuran, 2.3 mL, 3 mmol) in tetrahydrofuran (10 mL), 6-chloro-1-hexyne (0.29 mL, 2.4 mmol) and benzophenone (370 mg, 2 mmol) were added at 0 °C under N_2 gas atmosphere. Then, the reaction mixture was stirred at room temperature for 4 h. After 4h, the reaction mixture was diluted with ethyl acetate, and was washed with water and brine, followed by drying over sodium sulfate. The concentration of the collected organic components *in vacuo* followed by silica gel column chromatography (4% to 9% ethyl acetate in hexane) gave **5c** (593 mg, 99%) as a colorless oil.

Colorless oil; R_f value 0.15 (hexane / ethyl acetate = 10 / 1); IR (NaCl, neat) ν_{max} 3543, 3435, 3060, 3029, 2952, 1598, 1490, 1449, 1333, 1204 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.61–7.59 (m, 4H), 7.34–7.31 (m, 4H), 7.28–7.24 (m, 2H), 3.58 (t, 2H, J = 6.5 Hz), 2.72 (s, 1H), 2.40 (t, 2H, J = 6.5 Hz), 1.95–1.90 (m, 2H), 1.79–1.73 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 145.2, 128.2, 127.6, 125.9, 87.2, 83.6, 74.4, 44.5, 31.6, 25.7, 18.2; LRMS (EI, M = $C_{19}H_{19}ClO$) *m/z* 298 (15%, M^+), 221 (100), 207 (99), 105 (50), 77 (30) ; HRMS (EI) calcd for $C_{19}H_{19}{}^{35}ClO$ (M^+) 298.1124, found 298.1132.

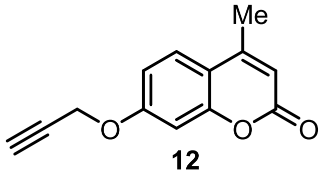
5,6-Didehydro-11,12-dihydrodibenzo[a,e]cyclooctyne (7, dibenzocyclooctyne)



7

This compound was prepared from 5-dibenzosuberenone by following the reported procedure.[18]

4-Methyl-7-(prop-2-yn-1-yloxy)-2*H*-chromen-2-one (12)



12

This compound was prepared from 5-dibenzosuberenone by following the reported procedure.[19]

To a stirred solution of 7-hydroxy-4-methyl coumarine (4-methylumbelliferone, 0.35g, 2 mmol), sodium carbonate (1.7g, 16 mmol), and potassium iodide (0.33g, 2 mmol) in *N*,*N*-dimethyl formamide (4 mL), propargyl bromide (0.15 mL, 2 mmol) was added at room temperature. Then, the mixture was heated at 65 °C for 5 h. After that, the reaction mixture was poured into 50 mL of water, and the formed precipitate was collected by vacuuming filtration, and the solid was washed with 5% NaOH aq. and water. Drying the solid under vacuum at 40 °C gave **12** (418 mg, 99%) as a light brown solid.

Light brown solid; R$_f$ value 0.55 (hexane / ethyl acetate = 1 / 1); m.p. 135.3–136.4 °C; IR (KBr, neat) ν_{max} 3303, 3069, 2962, 2925, 1765, 1721, 1620, 1583, 1511, 1426, 1390, 1281, 1208, 1155, 1141, 1169, 1017 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.55–7.53 (m, 1H), 6.95–6.93 (m, 2H), 6.17 (d, 1H, *J* = 1.0 Hz), 4.77 (d, 2H, *J* = 3.0 Hz), 2.58 (t, 1H, *J* = 3.0 Hz), 2.41 (d,3H, *J* = 1.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.2, 160.3, 155.0, 152.4, 125.6, 114.2, 112.7, 112.4, 102.1, 77.3, 76.5, 56.1, 18.7; LRMS (EI, M = $C_{13}H_{10}O_3$) *m/z* 214 (100%), 158 (41), 147 (63); HRMS (EI) calcd for $C_{13}H_{10}O_3$ (M^+) 214.0630, found 214.0631.

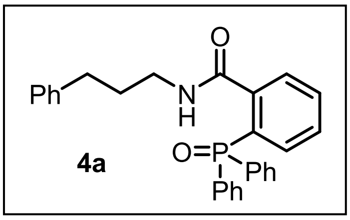
[3] Staudinger-Bertozzi Ligation Reactions

General Preparation Method to Obtain Authentic Ligated Products

To a stirred solution of organic azide **3** (0.1 mmol) in methanol (1 mL) and water (1 mL) was added phosphine **2** (0.12 mmol, 1.2 equiv.) at room temperature. After completion of the reaction, the mixture was concentrated *in vacuo*. The obtained residue was purified by silica gel column chromatography to give ligation product amide **4**. When not purified, ^{1}H NMR yields were measured using 1,1,2,2-tetrachloroethane (10.5 μL, 0.1 mmol, 1 equiv. to the starting materials) as an internal standard.

To obtain the products as authentic samples for calculating ^{1}H NMR-based yields in competitive reactions, we set the general solvents (MeOH / H_2O = 1 / 1) as common conditions that were not optimized for each compound.

2-(Diphenylphosphoryl)-*N*-(3-phenylpropyl)benzamide (4a)



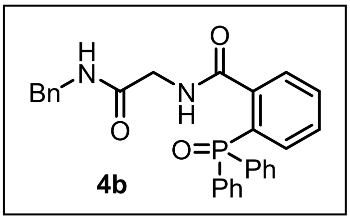
4a

A reaction (2 d) with azide **3a** (16.1 mg, 0.1 mmol) and phosphine **2a** (38.4 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (20% to 50% ethyl acetate in hexane) gave **4a** (43.1 mg, 98%) as a colorless oil.

In toluene/H$_2$O condition: A reaction (21 h) with azide **3a** (16.0 mg, 0.1 mmol) and phosphine **2a** (38.4 mf, 0.12 mmol) in toluene (1 mL) and water (0.1 mL) gave **4a** (80%, ^{1}H NMR yield).

colorless oil; R_f value 0.20 (hexane / ethyl acetate = 2 / 1); IR (NaCl, neat) ν_{max} 3260, 3063, 2927, 1654, 1550, 1437, 1306, 1185, 1119 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.71 (t, 1H, *J* = 5.0 Hz), 8.00 (ddd, 1H, *J* = 8.0, 4.0, 1.5 Hz), 7.67–7.03 (m, 19H), 2.94 (m, 2H), 2.56 (t, 2H, *J* = 7.5 Hz), 1.71–1.65 (m, 1H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 167.4 (d, *J* = 3.7 Hz), 141.6, 141.3 (d, *J* = 8.4 Hz), 133.3 (d, *J* = 12.1 Hz), 132.7, 132.3 (d, *J* = 2.4 Hz), 131.71 (d, *J* = 10.8 Hz), 131.67 (d, *J* = 9.6 Hz), 131.1 (d, *J* = 107 Hz), 129.7 (d, *J* = 12.0 Hz), 129.2 (d, *J* = 118 Hz), 128.7 (d, *J* = 12.0 Hz), 128.4, 128.2, 125.7, 39.7, 33.2, 30.2; ^{31}P NMR (202 MHz, CDCl$_3$) δ 36.3; LRMS (EI, M= $C_{28}H_{26}NO_2P$) *m*/*z* 439 (29%, M$^+$), 305 (100), 91 (68); HRMS (EI) calcd for $C_{28}H_{26}NO_2P$ (M$^+$) 439.1701, found 439.1702.

N-(2-(Benzylamino)-2-oxoethyl)-2-(diphenylphosphryl)benzamide (4b)



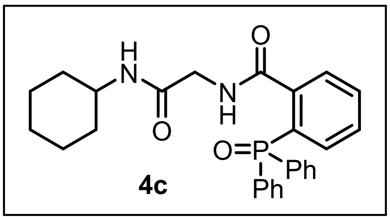
4b

A reaction (2 d) with azide **3b** (19.0 mg, 0.1 mmol) and phosphine **2a** (38.4 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (20% to 50% to 100% ethyl acetate in hexane) gave **4b** (45.9 mg, 98%) as a colorless oil.

In toluene/H$_2$O condition: A reaction (3 h) with azide **3b** (19.2 mg, 0.1 mmol) and phosphine **2a** (38.5 mg, 0.12 mmol) in toluene (1 mL) and water (0.1 mL) gave **4b** (93%, ^{1}H NMR yield).

Colorless oil; R_f value 0.33 (ethyl acetate); IR (NaCl, neat) ν_{max} 3435, 3060, 2931, 2862, 1654, 1550, 1437, 1309, 1173, 1119 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.50 (s, 1H), 7.73–7.07 (m, 21H), 4.44 (d, 2H, *J* = 6.5 Hz), 3.90 (d, 2H, *J* = 6.0 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 168.89 (d, *J* = 4.8 Hz), 168.87, 140.9 (d, *J* = 8.4 Hz), 138.8, 133.3 (d, *J* = 12.1 Hz), 132.41, 132.36 (d, *J* = 2.4 Hz), 131.8 (d, *J* = 10.8 Hz), 131.3 (d, *J* = 109 Hz), 130.0 (d, *J* = 9.6 Hz), 129.6 (d, *J* = 12.0 Hz), 129.4 (d, *J* = 100 Hz), 128.7 (d, *J* = 12.0 Hz), 128.3, 127.8, 126.9, 44.2, 43.2; ^{31}P NMR (202 MHz, CDCl$_3$) δ 34.3; LRMS (EI, M = $C_{28}H_{25}N_2O_3P$) *m*/*z* 468 (2%, M$^+$), 86 (70), 84 (100); HRMS (EI) calcd for $C_{28}H_{25}N_2O_3P$ (M$^+$) 468.1603, found 468.1604.

N-(2-(Cyclohexylamino)-2-oxoethyl)-2-(diphenylphosphoryl)benzamide (4c)

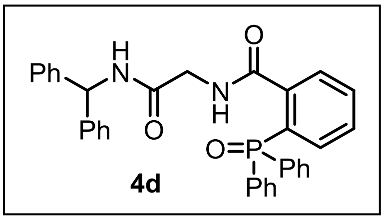


4c

A reaction (5 d) with azide **3c** (18.4 mg, 0.1 mmol) and phosphine **2a** (38.5 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (33% ethyl acetate in hexane to 33% methanol in hexane) gave **4c** (39.1 mg, 85%) as a white solid.

In toluene/H_2O condition: A reaction (3 h) with azide **3c** (18.2 mg, 0.1 mmol) and phosphine **2a** (38.5 mg, 0.12 mmol) in toluene (1 mL) and water (0.1 mL) gave **4c** (88%, ^{1}H NMR yield).

White solid; R_f value 0.10 (ethyl acetate); m.p. 198.5–199.8 °C; IR (NaCl, neat) ν_{max} 3264, 2931, 2852, 1660, 1642, 1550, 1437, 1308, 1184 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.91 (s, 1H), 7.81 (dd, 1H, *J* = 4.0, 3.5 Hz), 7.66–7.58 (m, 7H), 7.53–7.41 (m, 6H), 7.11 (dd, 1H, *J* = 7.5, 6.5 Hz), 3.77–3.72 (m, 3H), 1.86 (d, 2H, *J* = 12 Hz), 1.72–1.69 (m, 2H), 1.61–1.58 (m, 1H), 1.37–1.12 (m, 5H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 168.7 (d, *J* = 3.7 Hz), 167.7, 140.7 (d, *J* = 7.2 Hz), 133.3 (d, *J* = 12.0 Hz), 132.5, 132.4 (d, *J* = 2.4 Hz), 131.8 (d, *J* = 9.7 Hz), 131.2 (d, *J* = 107 Hz), 130.5 (d, *J* = 9.7 Hz), 129.9 (d, *J* = 3.7 Hz), 129.4 (d, *J* = 81.6 Hz), 128.8 (d, *J* = 12.1 Hz), 48.4, 44.3, 32.7, 25.5, 25.0; ^{31}P NMR (202 MHz, CDCl$_3$) δ 34.3; LRMS (EI, M = $C_{27}H_{29}N_2O_3P$) *m/z* 460 (14%, M$^+$), 334 (58), 305 (100), 277 (37); HRMS (EI) calcd for $C_{27}H_{29}N_2O_3P$ (M$^+$) 460.1916, found 460.1918.

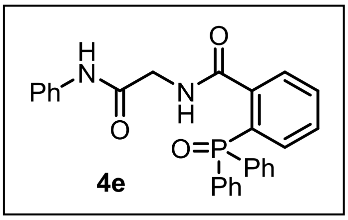


4d

N-(2-(Benzhydrylamino)-2-oxoethyl)-2-(diphenylphosphoryl)benzamide (4d)

A reaction (3 days) with azide **3d** (26.8 mg, 0.1 mmol) and phosphine **2a** (38.4 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (17% to 100% ethyl acetate in hexane) gave **4d** (53.9 mg, 99%) as a white solid.

White solid; R_f value 0.30 (ethyl acetate); m.p. 237.6–239.0 °C; IR (NaCl, neat) ν_{max} 3232, 3059, 1649, 1538, 1437, 1301, 1260, 1190, 1119 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.84 (s, 1H), 7.74–7.09 (m, 25H), 6.38 (t, 1H, *J* = 9.0 Hz), 3.90 (t, 2H, *J* = 8.5 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 169.0, 168.1, 141.8 (overlapping two signals), 133.1 (d, *J* = 12.1 Hz), 132.4, 132.3, 131.7 (d, *J* = 10.8 Hz), 131.3 (d, *J* = 109 Hz), 130.1, 130.0 (d, *J* = 7.3 Hz), 129.2 (d, *J* = 123 Hz), 128.7 (d, *J* = 13.2 Hz), 128.3, 128.0, 127.0, 56.7, 44.4; ^{31}P NMR (202 MHz, CDCl$_3$) δ 33.2; LRMS (EI, M = $C_{34}H_{29}N_2O_3P$) *m/z* 544 (11%, M$^+$), 305 (100), 277 (36); HRMS (EI) calcd for $C_{34}H_{29}N_2O_3P$ (M$^+$) 544.1916, found 544.1918.



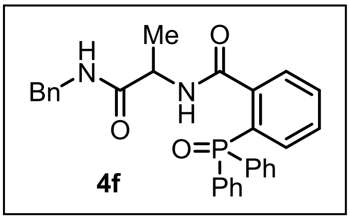
4e

2-(Diphenylphosphoryl)-*N*-(2-oxo-2-(phenylamino)ethyl)benzamide (4e)

A reaction (5 h) with azide **3e** (17.6 mg, 0.1 mmol) and phosphine **2a** (38.4 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (33% to 100% ethyl acetate in hexane) gave **4e** (44.5 mg, 98%) as a colorless oil.

Colorless oil; R_f value 0.43 (ethyl acetate); IR (NaCl, neat) ν_{max} 3283, 3061, 1652, 1600, 1550, 1499, 1304, 1257, 1183, 1119 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 10.02 (s, 1H), 7.81 (t, 1H, *J* = 5.5 Hz), 7.73–7.69 (m, 3H), 7.61–7.57 (m, 5H), 7.53–7.49 (m, 2H), 7.44–7.38 (m, 5H), 7.25–7.22 (m, 2H), 7.12 (dd, 1H, *J* = 7.5, 13.5 Hz), 7.04 (dd, 1H, *J* = 7.0 Hz), 4.00 (d, 2H, *J* = 6.0 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 169.1 (d, *J* = 3.5 Hz), 167.5, 140.9 (d, *J* = 7.2 Hz), 138.4, 133.2 (d, *J* = 12.1 Hz), 132.4, 131.7 (d, *J* = 10.1 Hz), 131.2 (d, *J* = 85 Hz), 129.7 (d, *J* = 9.6 Hz), 129.5 (d, *J* = 12.1 Hz), 129.3 (d, *J* = 101 Hz), 128.7 (d, *J* = 12.1 Hz), 128.5, 123.8, 120.5, 44.9; ^{31}P NMR (202 MHz, CDCl$_3$) δ 34.1; LRMS (EI, M = $C_{27}H_{23}N_2O_3P$) *m/z* 454 (17%, M$^+$), 334 (84), 305 (100); HRMS (EI) calcd for $C_{27}H_{23}N_2O_3P$ (M$^+$) 454.1446, found 454.1443.

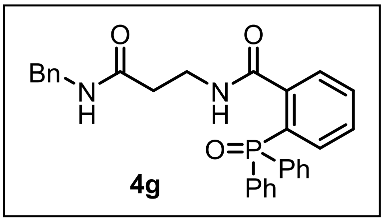
N-(1-(benzylamino)-1-oxopropan-2-yl)-2-(diphenylphosphoryl)benzamide (4f)


4f

A reaction (23 h) with azide **3f** (20.6 mg, 0.1 mmol) and phosphine **2a** (38.6 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (50% to 100% ethyl acetate in hexane) gave **4f** (46.8 mg, 97%) as a white solid.

White solid; R_f value 0.42 (ethyl acetate); m.p. 197–198 °C; IR (NaCl, neat) ν_{max} 3419, 3276, 3063, 2246, 1650, 1546, 1437, 1177 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (s, 1H), 7.84–7.80 (m, 2H), 7.63–7.37 (m, 12H), 7.28–7.20 (m, 4H), 7.06 (ddd, 1H, *J* = 13.5, 6.5, 1.0 Hz), 4.44–4.30 (m, 3H), 1.34 (d, 3H, *J* = 6.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.6, 168.1 (d, *J* = 3.7Hz), 140.9 (d, *J* = 7.2Hz), 138.9, 133.4 (d, *J* = 12.0 Hz), 132.5, 132.4 (d, *J* = 2.4 Hz), 131.9 (d, *J* = 9.7 Hz), 131.0 (d, *J* = 107 Hz), 130.8 (d, *J* = 9.6Hz), 129.7 (d, *J* = 12.1 Hz), 129.0 (d, *J* = 99 Hz), 128.8 (d, *J* = 12.0 Hz), 128.7 (d, *J* = 12.0 Hz), 128.4, 127.6, 126.9, 50.3, 43.2, 17.2; ^{31}P NMR (202 MHz, $CDCl_3$) δ 35.4; LRMS (EI, M = $C_{29}H_{27}N_2O_3P$) *m*/*z* 482 (13%, M^+), 305 (100); HRMS (EI) calcd for $C_{29}H_{27}N_2O_3P$ (M^+) 482.1759, found 482.1750.

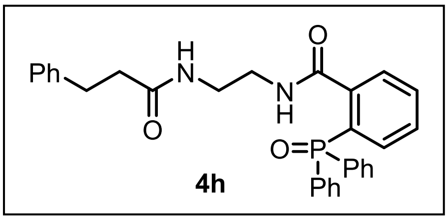
***N*-(3-(Benzylamino)-3-oxopropyl)-2-(diphenylphosphoryl)benzamide (4g)**


4g

A reaction (7 days) with azide **3g** (20.8 mg, 0.1 mmol) and phosphine **2a** (38.4 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (50% to 100% ethyl acetate in hexane to 9% methanol in ethyl acetate) gave **4g** (45.8 mg, 95%) as a white amorphous material.

White amorphous; R_f value 0.28 (ethyl acetate / methanol = 10 / 1) ; IR (NaCl, neat) ν_{max} 3271, 3061, 2935, 1651, 1555, 1438, 1310, 1184 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 (s, 1H), 7.76 (s, 1H), 7.69–7.37 (m, 13H), 7.20 (d, 2H, *J* = 7.0 Hz), 7.14–7.05 (m, 4H), 4.39 (d, 2H, *J* = 5.5 Hz), 3.39 (dt, 2H, *J* = 6.5 Hz), 2.44 (t, 2H, *J* = 6.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.6, 168.4, 141.0 (d, *J* = 7.2 Hz), 138.7, 133.6 (d, *J* = 10.8 Hz), 132.3, 132.0, 131.7 (d, *J* = 107 Hz), 131.6 (d, *J* = 10.8 Hz), 129.8 (d, *J* = 100 Hz), 129.6 (d, *J* = 9.6 Hz), 129.5 (d, *J* = 13.2 Hz), 128.5 (d, *J* = 12.0 Hz), 128.3, 127.6, 126.9, 43.3, 37.1, 35.8; ^{31}P NMR (202 MHz, $CDCl_3$) δ 34.4; LRMS (EI, M = $C_{29}H_{27}N_2O_3P$) *m*/*z* 482 (37%, M^+), 305 (100); HRMS (EI) calcd for $C_{29}H_{27}N_2O_3P$ (M^+) 482.1759, found 482.1766.

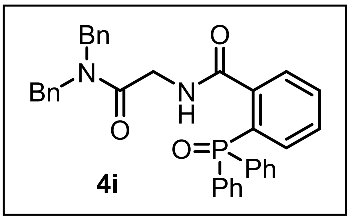
2-(Diphenylphosphoryl)-*N*-(2-(3-phenylpropanamido)ethyl)benzamide (4h)


4h

A reaction (11 days) with azide **3h** (21.9 mg, 0.1 mmol), phosphine **2a** (38.7 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (20% to 50% to 100% ethyl acetate in hexane) gave **4h** (48.5 mg, 98%) as colorless oil.

Colorless oil; R_f value 0.083 (ethyl acetate) ; IR (NaCl, neat) ν_{max} 3273, 3061, 2931, 1651, 1547, 1437, 1308, 1177, 1119 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80–7.76 (m, 2H), 7.65 (t, 1H, *J* = 8.0 Hz), 7.59–7.55 (m, 6H), 7.50–7.46 (m, 4H), 7.41 (t, 1H, *J* = 7.5 Hz), 7.32 (m, 1H), 7.24 (d, 2H, *J* = 7.5 Hz), 7.12 (t, 2H, *J* = 7.5 Hz), 7.08–7.02 (m, 2H), 3.16–3.11 (m, 4H), 2.99 (t, 2H, *J* = 8.0 Hz), 2.56 (t, 2H, *J* = 8.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.3, 168.4 (d, *J* = 4.8 Hz), 141.5 (d, *J* = 7.2 Hz), 141.2, 133.6 (d, *J* = 12.0 Hz), 132.6, 132.5, 131.8 (d, *J* = 10.8 Hz), 131.2 (d, *J* = 107 Hz), 130.5 (d, *J* = 9.6 Hz), 129.6 (d, *J* = 12.0 Hz), 128.8 (d, *J* = 12.0 Hz), 128.64 (d, *J* =101 Hz), 128.60, 128.2, 125.9, 40.0, 38.4, 38.3, 31.9; ^{31}P NMR (202 MHz, $CDCl_3$) δ 35.4; LRMS (EI, M = $C_{30}H_{29}N_2O_3P$) *m*/*z* 496 (11%, M^+), 334 (29), 305 (100), 277 (29); HRMS (EI) calcd for $C_{30}H_{29}N_2O_3P$ (M^+) 496.1916, found 496.1916.

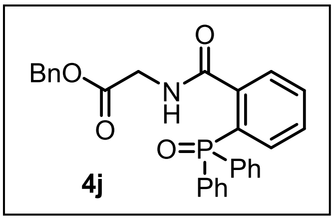
***N*-(2-Dibenzylamino)-2-oxoethyl)-2-(diphenylphosphoryl)benzamide (4i)**


4i

A reaction (4 h) with azide **3i** (28.1 mg, 0.1 mmol) and phosphine **2a** (38.4 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (33% to 100% ethyl acetate in hexane) gave **4i** (55.8 mg, 99%) as a colorless oil.

Colorless oil; R_f value 0.55 (ethyl acetate); IR (NaCl, neat) ν_{max} 3398, 3060, 3031, 2926, 2243, 1647, 1451, 1437, 1221, 1178, 1119 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.19 (t, 1H, *J* = 4.0 Hz), 7.79–7.77 (dd, 1H, *J* = 7.5, 3.5 Hz), 7.73–7.65 (m, 4H), 7.62–7.59 (m, 1H), 7.54–7.50 (m, 1H), 7.47–7.27 (m, 13H), 7.23–7.22 (d, 2H, *J* = 7.0 Hz), 7.18–7.05 (d, 2H, *J* = 7.0 Hz), 4.61 (s, 2H), 4.29 (s, 2H), 3.77 (d, 2H, *J* = 4.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 167.9, 167.7 (d, *J* = 3.7 Hz), 140.3 (d, *J* = 8.4 Hz), 136.6, 135.4, 133.7 (d, *J* = 10.8 Hz), 132.3, 131.86 (d, *J* = 106 Hz), 131.85, 131.81 (d, *J* = 9.6 Hz), 130.3 (d, *J* = 100 Hz), 129.83 (d, *J* = 12.0 Hz), 129.78 (d, *J* = 9.7 Hz), 129.0, 128.6, 128.4, 128.3 (d, *J* = 14.4 Hz), 127.8, 127.6, 126.4, 48.7, 48.4, 41.8; ^{31}P NMR (202 MHz, $CDCl_3$) δ 32.3; LRMS (EI, M = $C_{35}H_{31}N_2O_3P$) *m/z* 558 (7%, M$^+$), 362 (25), 305 (100), 91 (27); HRMS (EI) calcd for $C_{35}H_{31}N_2O_3P$ (M$^+$) 558.2072, found 558.2076.

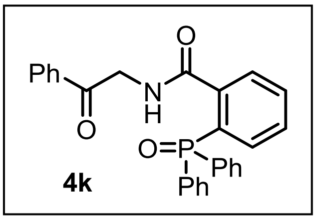
Benzyl(2-(diphenylphosphoryl)benzoyl)glycinate (4j)


4j

A reaction (8 h) with azide **3j** (19.5 mg, 0.1 mmol) and phosphine **2a** (38.5 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (50% to 100% ethyl acetate in hexane) gave **4j** (43.2 mg, 72%).

Colorless oil; R_f value 0.45 (ethyl acetate); IR (NaCl, neat) ν_{max} 3250, 3060, 2246, 1478, 1666, 1588, 1549, 1438, 1173 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.84 (t, 1H, *J* = 5.0 Hz), 7.94 (dd, 1H, *J* = 7.0, 4.0 Hz), 7.69–7.61 (m, 5H), 7.56–7.39 (m, 7H), 7.37–7.30 (m, 5H), 7.17 (m, 1H), 5.15 (s, 2H), 3.67 (d, 2H, *J* = 5.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.0, 167.6 (d, *J* = 2.0 Hz), 140.1 (d, *J* = 8.4 Hz), 135.3, 133.3 (d, *J* = 12 Hz), 132.6 (d, *J* = 2.4 Hz), 132.2 (d, *J* = 2.5 Hz), 131.6 (d, *J* = 9.6 Hz), 131.4 (d, *J* = 9.7 Hz), 131.1 (d, *J* = 107 Hz), 130.0 (d, *J* = 12.0 Hz), 129.7 (d, *J* = 99 Hz), 128.7, 128.6, 128.5 (d, *J* = 12.0 Hz), 128.3, 66.8, 41.6; ^{31}P NMR (202 MHz, $CDCl_3$) δ 34.6; LRMS (EI, M = $C_{28}H_{24}NO_4P$) *m/z* 469 (3%, M$^+$), 320 (39), 305 (100); HRMS (EI) calcd for $C_{28}H_{24}NO_4P$ (M$^+$) 469.1443, found 469.1438.

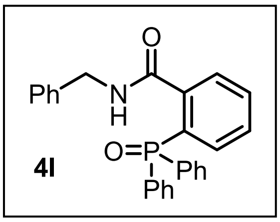
2-(Diphenylphosphoryl)-*N*-(2-oxo-2-phenylethyl)benzamide (4k)


4k

A reaction (19 h) with azide **3k** (16.1 mg, 0.1 mmol) and phosphine **2a** (38.4 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (6.7% to 20% to 100% ethyl acetate in hexane) gave **4k** (42.5 mg, 97%) as a yellow amorphous material.

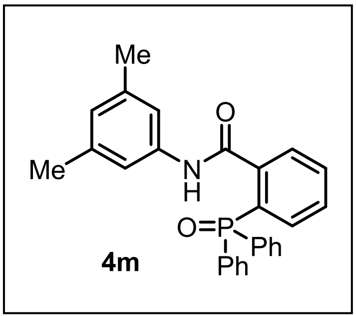
Yellow amorphous; R_f value 0.58 (ethyl acetate); IR (NaCl, neat) ν_{max} 3409, 3060, 1659, 1438, 1225, 1175, 1119 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.65 (s, 1H), 7.92–7.87 (m, 3H), 7.74–7.44 (m, 15H), 7.34–7.30 (m, 1H), 4.34 (d, 2H, *J* = 4.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.1, 167.9 (d, *J* = 3.5 Hz), 140.4 (d, *J* = 8.4 Hz), 134.5, 133.7, 133.6 (d, *J* = 12.0 Hz), 132.4, 132.0 (d, *J* = 2.4 Hz), 131.7 (d, *J* = 10.8 Hz), 131.6 (d, *J* = 107 Hz), 130.5 (d, *J* = 9.6 Hz), 130.1 (d, *J* = 100 Hz), 129.9 (d, *J* = 12.1 Hz), 128.7, 128.5 (d, *J* = 13.2 Hz), 127.9, 46.8; ^{31}P NMR (202 MHz, $CDCl_3$) δ 33.1; HRMS (CI) calcd for $C_{27}H_{23}NO_3P$ [M+H]$^+$ 440.1416, found 440.1410.

N-Benzyl-2-(diphenylphosphoryl)benzamide (4l)


4l

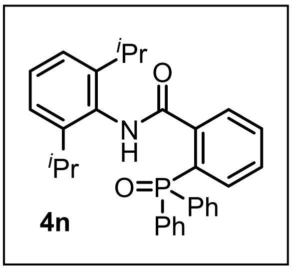
A reaction (2.5 h) with azide **3l** (13.7 mg, 0.1 mmol) and phosphine **2a** (38.3 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (9% to 50% ethyl acetate in hexane) **4l** (17.1 mg, 42%) as a white amorphous.
White amorphous; R_f value 0.18 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3258, 3060, 1655, 1588, 1546, 1438, 1306, 1172, 1119 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 9.03 (t, 1H, *J* = 7.5 Hz), 8.03 (dd, 1H, *J* = 7.0, 3.0 Hz), 7.67 – 7.62 (m, 5H), 7.59 – 7.56 (m, 2H), 7.50 – 7.47 (m, 4H), 7.40 – 7.37 (m, 1H), 7.28 – 7.20 (m, 5H), 7.07 (ddd, 1H, *J* = 14.0, 8.0, 1.0 Hz), 4.08 (d, 2H, *J* = 5.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 167.3, 141.0 (d, *J* = 8.4 Hz), 137.5, 133.3 (d, *J* = 12.0 Hz), 132.6, 132.3, 131.8, 131.7 (d, *J* = 9.6 Hz), 131.0 (d, *J* = 107 Hz), 129.8 (d, *J* = 12.0 Hz), 129.3 (d, *J* = 98.5 Hz), 128.7 (d, *J* = 12.0 Hz), 128.5, 127.9, 127.1, 44.0; ^{31}P NMR (202 MHz, $CDCl_3$) δ 35.7; HRMS (ESI) calcd for $C_{26}H_{22}NO_2NaP$ 434.1280 $[M+Na]^+$, found 434.1286.

N-(3,5-Dimethylphenyl)-2-(diphenylphosphoryl)benzamide (4m)


4m

A reaction (6 h) with azide **3m** (14.9 mg, 0.1 mmol) and phosphine **2a** (38.6 mg, 0.12 mmol) in methanol (1 mL) and water (1 mL) followed by silica gel column chromatography (25% to 100% ethyl acetate in hexane) gave **4m** (42.1 mg, 99%) as a colorless oil.
Colorless oil; R_f value 0.30 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3256, 3059, 2917, 1669, 1618, 1561, 1465, 1438, 1329, 1297, 1153, 1178, 1119 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 10.41 (s, 1H), 8.07 (ddd, 1H, *J* = 8.0, 4.0, 1.5 Hz), 7.68–7.64 (m, 5H), 7.53–7.50 (m, 2H), 7.44–7.40 (m, 5H), 7.11 (ddd, 1H, *J* = 14, 7.5, 1.0 Hz), 7.01 (s, 2H), 6.68 (s, 1H), 2.23 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.3, 141.4 (d, *J* = 8.4 Hz), 138.0, 137.5, 133.2 (d, *J* = 12.0 Hz), 132.7, 132.3 (d, *J* = 2.4 Hz), 132.2 (d, *J* = 9.6 Hz), 131.5 (d, *J* = 9.6 Hz), 130.5 (d, *J* = 107 Hz), 130.0 (d, *J* = 12.0 Hz), 129.4 (d, *J* = 99 Hz), 128.7 (d, *J* = 12.1 Hz), 125.9, 118.0, 21.3; ^{31}P NMR (202 MHz, $CDCl_3$) δ 35.9; LRMS (EI, M = $C_{27}H_{24}NO_2P$) *m/z* 425 (6%, M^+), 305 (100); HRMS (EI) calcd for $C_{27}H_{24}NO_2P$ (M^+) 425.1545, found 425.1545.

N-(2,6-Diisopropylphenyl)-2-(diphenylphosphoryl)benzamide (4n)


4n

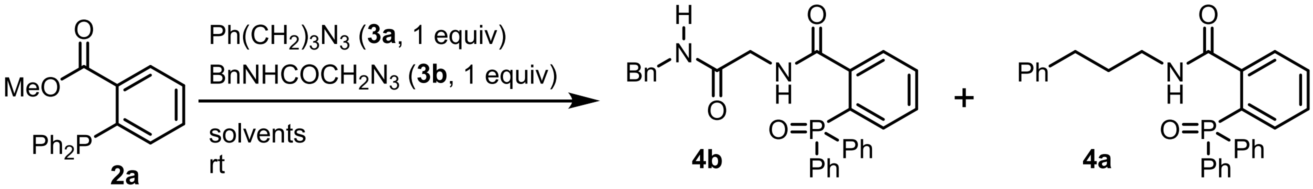
A reaction (10 days) with azide **3n** (102 mg, 0.5 mmol) and phosphine **2a** (192 mg, 0.6 mmol) in toluene (5 mL) and water (0.5 mL) followed by silica gel column chromatography (9% to 17% to 20% ethyl acetate in hexane) gave material. To further purify to remove aniline byproducts, the material was dissolved in ethyl acetate and was washed with 1M HCl aq. and brine. The collected organic layer was dried over sodium sulfate. Then, concentration *in vacuo* gave **4n** (48.0 mg, 20%) as a light yellow amorphous.
Light yellow amorphous; R_f value 0.42 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3169, 3060, 2964, 2931, 2868, 1656, 1541, 1467, 1438, 1300, 1170, 1119 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 10.99 (s, 1H), 8.36–8.33 (m, 1H), 7.72–7.69 (m, 1H), 7.63–7.58 (m, 6H), 7.52–7.49 (m, 4H), 7.44–7.40 (m, 1H), 7.21 (t, 1H, *J* = 7.5 Hz), 7.10–7.02 (m, 3H), 2.63 (qq, 2H, *J* = 7.0, 6.5 Hz), 0.98 (d, 12H, *J* = 7.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 167.0, 145.9, 141.2 (d, *J* = 8.4 Hz), 133.8 (d, *J* = 12.0 Hz), 133.5 (d, *J* = 9.6 Hz), 132.8, 132.5, 132.3 (d, *J* = 9.6 Hz), 131.9, 131.5 (d, *J* = 107 Hz), 130.0 (d, *J* = 12.1 Hz), 128.8 (d, *J* = 12.0 Hz), 127.8 (d, *J* = 98.5 Hz), 127.7, 123.2, 28.6, 24.1, 23.5; ^{31}P NMR (202 MHz, $CDCl_3$) δ 39.4; LRMS (EI, M = $C_{31}H_{32}NO_2P$) *m/z* 481 (19%, M^+), 438 (33), 305 (100); HRMS

(EI) calcd for $C_{31}H_{32}NO_2P$ (M^+) 481.2171, found 481.2171.

General Procedure of Competitive Reactions

To a stirred solution of 3-phenylpropyl azide **3a** (0.1 mmol) and the azide substrate to be compared (0.1 mmol) in toluene (1 mL) and water (0.1 mL) was added phosphine **2a** (0.1 mmol) at room temperature. After completion of the reaction, the mixture was concentrated *in vacuo*. The obtained crude residue was analyzed by ^{1}H NMR spectroscopy in the presence of 1,1,2,2-tetrachloroethane (10.5 µL, 0.1 mmol, 1 equiv. to the starting materials, 5.96 ppm on ^{1}H NMR, 2H) as an internal standard to determine the material yields. When difficulty was encountered to determine due to the overlap of the NMR signals, the crude material was purified by short-path silica gel column chromatography. Then, each fraction was submitted to ^{1}H NMR yield determination as above. If isolable as a pure material at this stage, isolated yields were measured. For somewhat volatile azides such as **3a**, **3l**, and **3m**, the recovery yields were determined from the crude residue before purification. The experiments were conducted at least in duplicate.

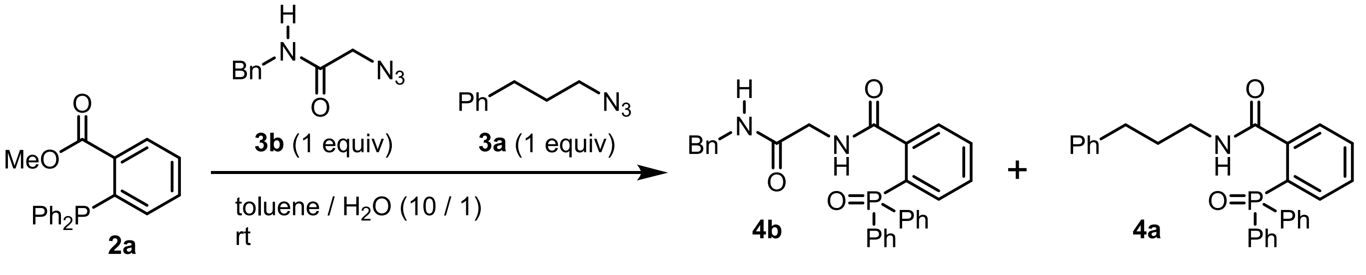
Table S1. Scope of solvent conditions



Entry	Solvents	Yields determined from ^{1}H NMR spectra[a] **4b** (recovered **3b**)	 **4a** (recovered **3a**)	Ratio (**4b** : **4a**)
1	MeOH	47% (6%)	11% (70%)	4.3 : 1
2	CH_3CN	86% (21%)	14% (73%)	6.1 : 1
3	THF	63% (20%)	10% (76%)	6.3 : 1
4	CH_2Cl_2	78% (5%)	4% (95%)	19 : 1
5	toluene	81% (8%)	5% (77%)	18 : 1
6	toluene / H_2O (10 / 1)	93% (7%)	4% (69%)	>20 : 1

[a] 1,1,2,2-Tetrachloroethane (1 equiv) as an internal standard.

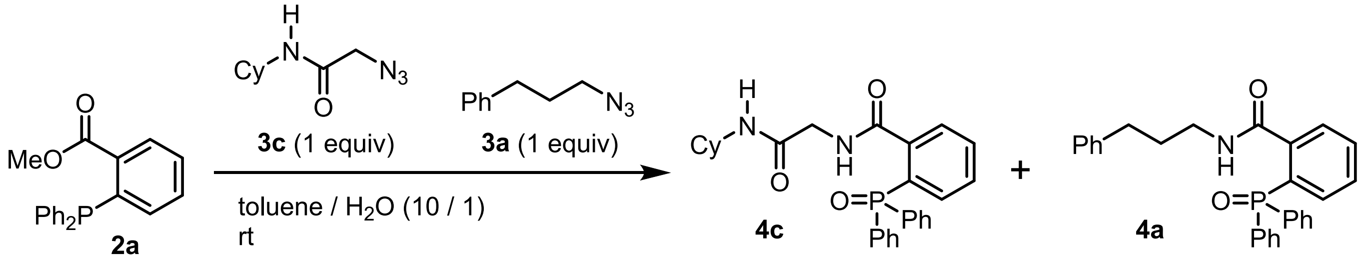
Competitive reaction with 3a and 3b



A reaction (4.5 h) with phosphine **2a** (32.1 mg, 0.10 mmol), azides **3b** (19.1 mg, 0.10 mmol) and **3a** (16.2 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4b**: 93%, **4a**: 4%) and recovered azides (**3b**: 7%, **3a**: 69%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4b**: 3.88 ppm (d, 2H), **4a**: 2.54 ppm (t, 2H), **3b**: 3.93 ppm (s, 2H), **3a**: 1.90 ppm (tt, 2H).

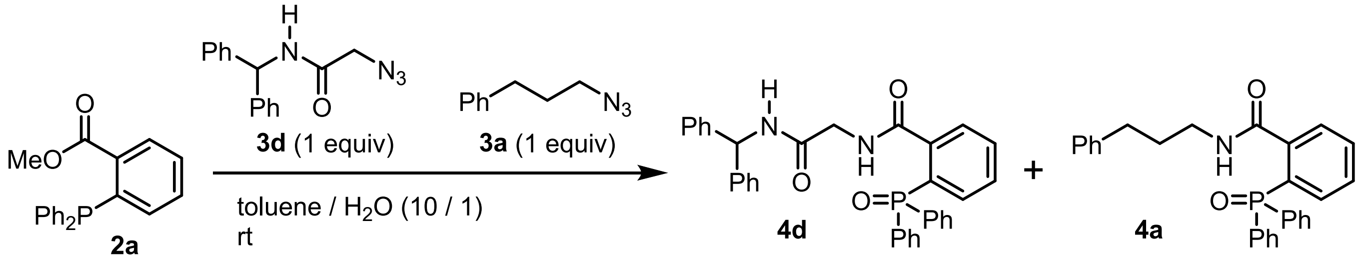
Competitive reaction with 3a and 3c



A reaction (28 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3c** (18.3 mg, 0.10 mmol) and **3a** (16.3 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave crude material which was submitted to ^{1}H NMR to measure NMR yields of phosphine oxide **4a** (6%) and recovered azides (**3c**: 9%, **3a**: 70%). Because it was hard to determine the yield of **4c** due to the signal overlap, silica gel column chromatography (hexane elution to hexane / ethyl acetate = 2 / 1 to 1 / 1 to ethyl acetate / methanol = 2 / 1) to obtain **4c** (88%). Then, **4c** was again submitted to ^{1}H NMR for NMR yield determination.

Used peaks to measure ^{1}H NMR yields: **4c**: 7.13 ppm (dd, 1H), **4a**: 2.93 ppm (m, 2H), **3c**: 3.93 ppm (s, 2H), **3a**: 3.28 ppm (t, 2H).

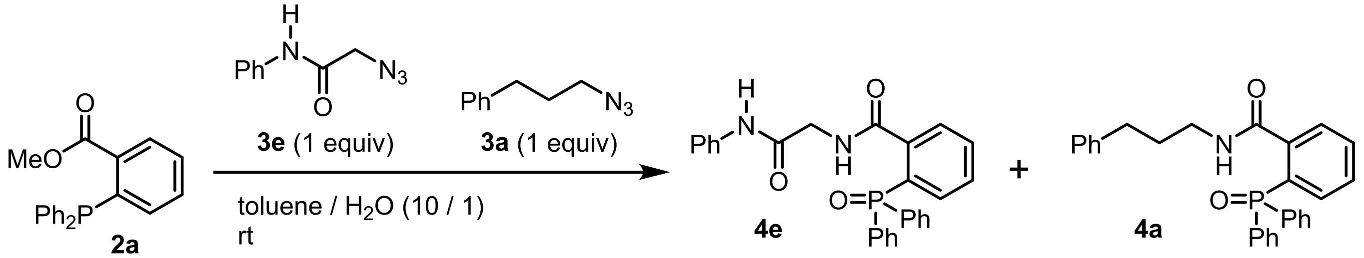
Competitive reaction with 3a and 3d



A reaction (7 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3d** (26.8 mg, 0.10 mmol) and **3a** (16.4 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4d**: 91%, **4a**: 3%) and recovered azides (**3d**: 7%, **3a**: 58%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4d**: 3.90 ppm (d, 2H), **4a**: 2.56 ppm (t, 2H), **3d**: 4.06 ppm (s, 2H), **3a**: 3.29 ppm (t, 2H).

Competitive reaction with 3a and 3e

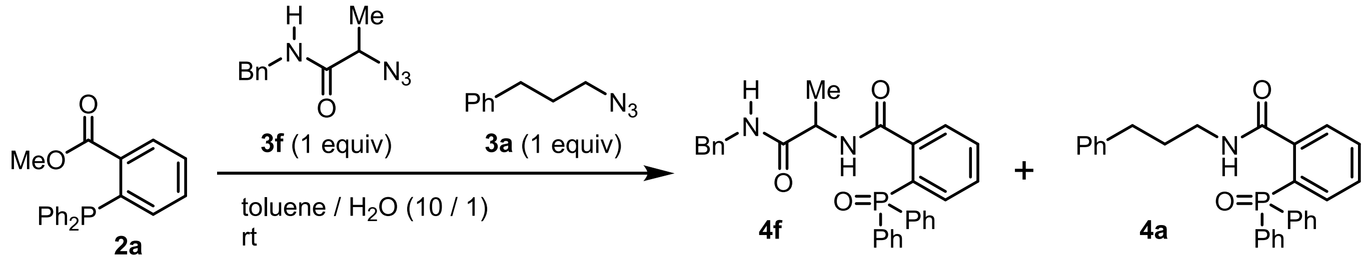


A reaction (4.5 h) with phosphine **2a** (32.1 mg, 0.10 mmol), azides **3e** (17.6 mg, 0.10 mmol) and **3a** (16.2 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4e**: 96%, **4a**: 3%) and recovered azides (**3e**: 3%, **3a**: 88%), measured by ^{1}H NMR of the obtained crude material. The yields of **3a** and **4a** were determined from the initial crude material. Because of the signal overlap, the yields of **3e** and **4e** were determined after short-path silica gel column chromatography (hexane / ethyl acetate = 1 / 1 to ethyl acetate elution).

Used peaks to measure ^{1}H NMR yields: **4e**: 4.00 ppm (d, 2H), **4a**: 2.70 ppm (t, 2H), **3e**: 4.16 ppm (s, 2H), **3a**:

1.67 ppm (m, 2H).

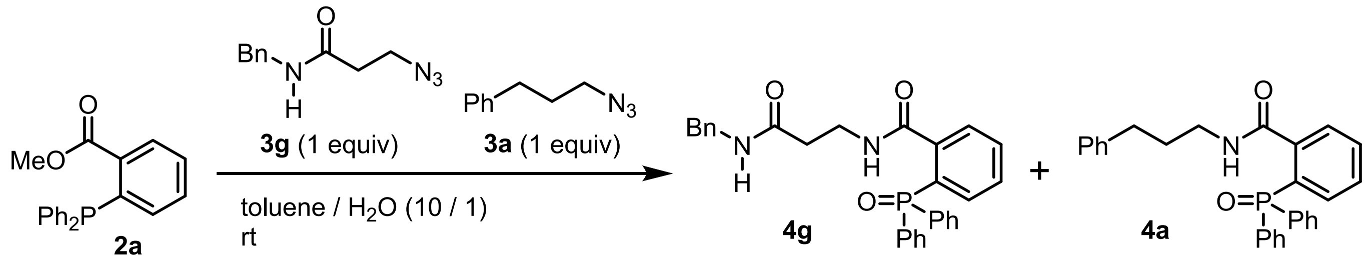
Competitive reaction with 3a and 3f



A reaction (7.5 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3f** (20.6 mg, 0.10 mmol) and **3a** (16.4 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4f**: 76%, **4a**: 14%) and recovered azides (**3f**: 17%, **3a**: 39%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4f**: 1.32 ppm (d, 3H), **4a**: 2.55 ppm (t, 2H), **3f**: 1.54 ppm (d, 3H), **3a**: 2.70 ppm (t, 2H).

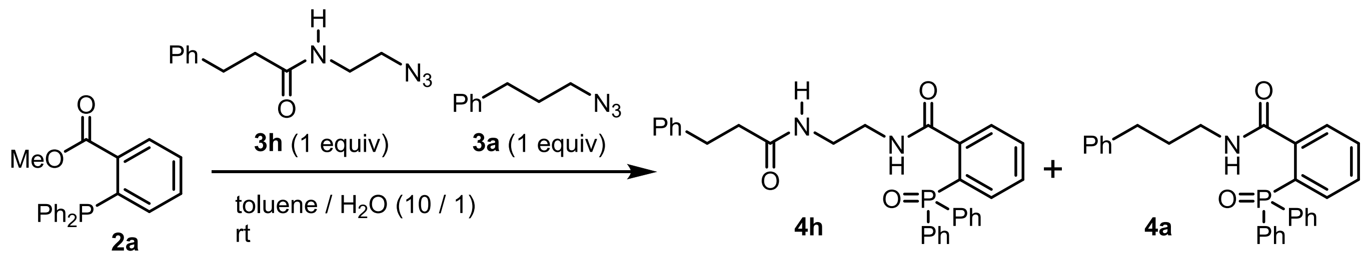
Competitive reaction with 3a and 3g



A reaction (27 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3g** (20.4 mg, 0.10 mmol) and **3a** (16.5 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4g**: 60%, **4a**: 32%) and recovered azides (**3g**: 33%, **3a**: 50%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4g**: 3.37 ppm (dt, 2H), **4a**: 2.55 ppm (t, 2H), **3g**: 3.59 ppm (t, 2H), **3a**: 3.27 ppm (t, 2H).

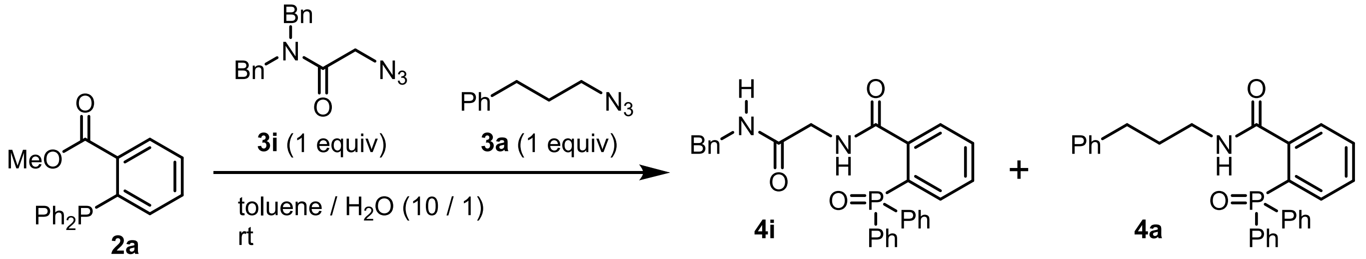
Competitive reaction with 3a and 3h



A reaction (23 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3h** (21.8 mg, 0.10 mmol) and **3a** (16.1 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4h**: 74%, **4a**: 27%) and recovered azides (**3h**: 21%, **3a**: 64%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4h**: 3.16–3.11 ppm (m, 4H), **4a**: 1.71–1.65 ppm (m, 2H), **3h**: 2.47 ppm (t, 2H), **3a**: 1.90 ppm (tt, 2H).

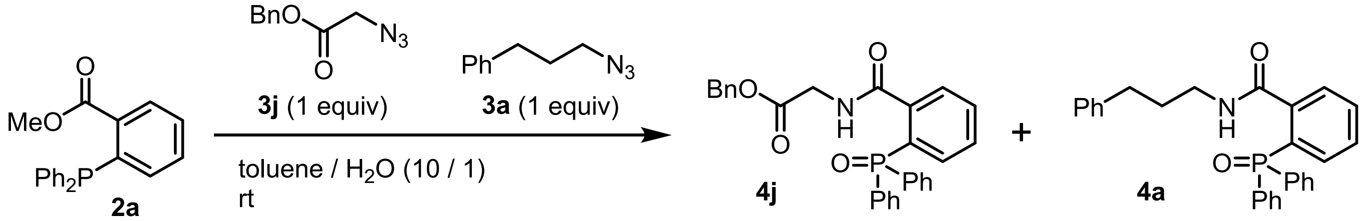
Competitive reaction with 3a and 3i



A reaction (11 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3i** (28.3 mg, 0.10 mmol) and **3a** (16.2 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4i**: 76%, **4a**: 16%) and recovered azides (**3i**: 14%, **3a**: 63%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4i**: 3.77 ppm (d, 2H), **4a**: 2.55 ppm (t, 2H), **3f**: 3.96 ppm (s, 2H), **3a**: 1.90 ppm (tt, 2H).

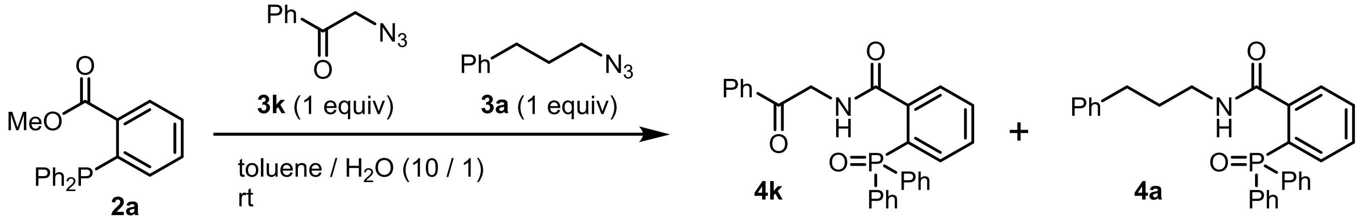
Competitive reaction with 3a and 3j



A reaction (11 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3j** (19.3 mg, 0.10 mmol) and **3a** (16.2 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4j**: 54%, **4a**: 10%) and recovered azides (**3b**: 16%, **3a**: 62%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4j**: 3.67 ppm (d, 2H), **4a**: 2.55 ppm (t, 2H), **3j**: 5.22 ppm (s, 2H), **3a**: 2.70 ppm (t, 2H).

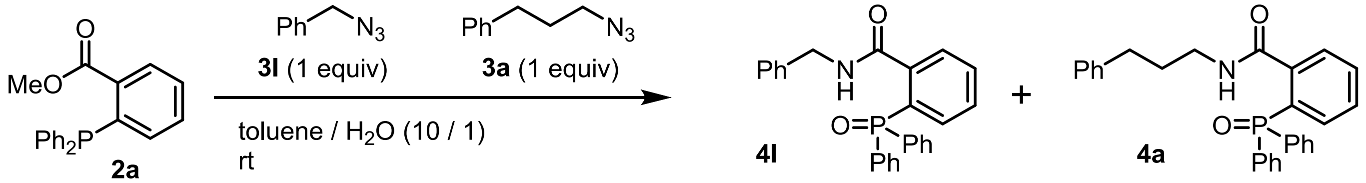
Competitive reaction with 3a and 3k



A reaction (4 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3k** (16.2 mg, 0.10 mmol) and **3a** (16.2 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4k**: 48%, **4a**: 11%) and recovered azides (**3k**: 38%, **3a**: 54%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4k**: 4.35 ppm (d, 2H), **4a**: 2.56 ppm (t, 2H), **3k**: 4.56 ppm (s, 2H), **3a**: 1.91 ppm (tt, 2H).

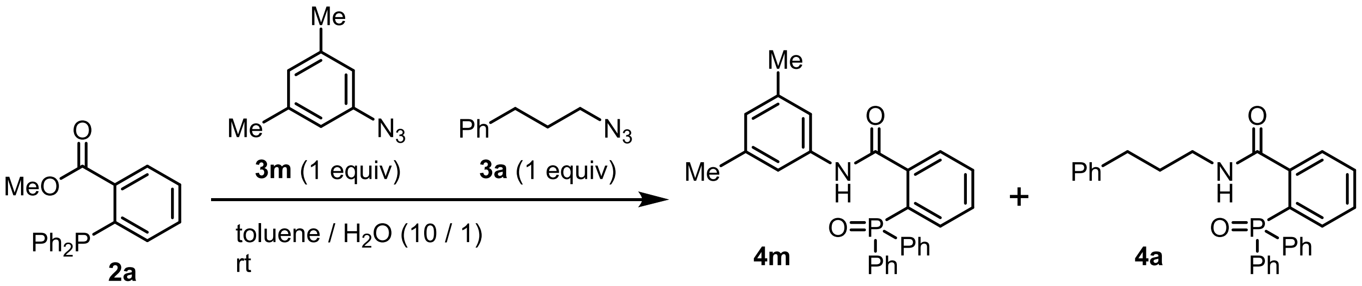
Competitive reaction with 3a and 3l



A reaction (24 h) with phosphine **2a** (32.3 mg, 0.10 mmol), azides **3l** (13.1 mg, 0.10 mmol) and **3a** (16.1 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave phosphine oxides (**4l**: 61%, **4a**: 35%) and recovered azides (**3l**: 0% due to its volatility, **3a**: 38%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4l**: 4.08 ppm (d, 2H), **4a**: 2.55 ppm (t, 2H), **3a**: 3.29 ppm (t, 2H).

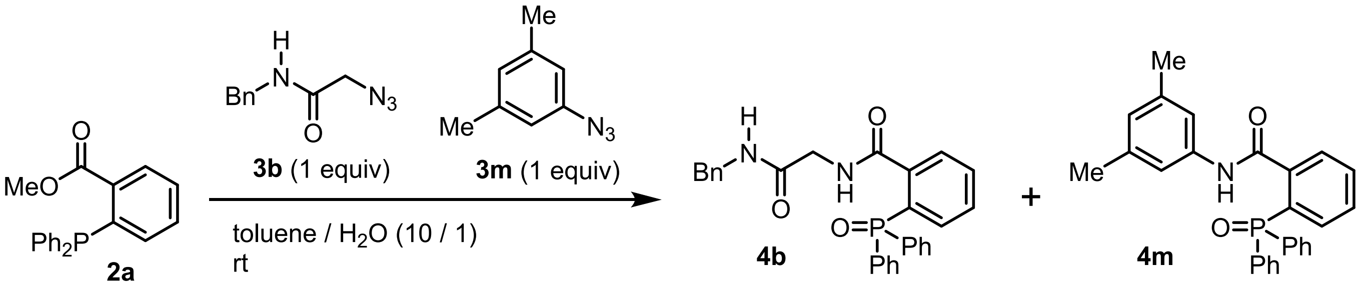
Competitive reaction with 3a and 3m



A reaction (7 days) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3m** (14.7 mg, 0.10 mmol) and **3a** (16.4 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature followed by short-path silica gel column chromatography (hexane elution to ethyl acetate elution) to separate phosphine oxide products (**4m**: 68%, **4a**: 29%) and recovered azides (**3m**: 3%, **3a**: 8%) due to the NMR signal overlap. Each fraction was submitted to ^{1}H NMR to determine the ^{1}H NMR yields. Low recovery yield of **3m** is due to the volatile characteristics.

Used peaks to measure ^{1}H NMR yields: **4m**: 2.23 ppm (s, 6H), **4a**: 2.56 ppm (t, 2H), **3m**: 2.29 ppm (s, 6H), **3a**: 1.92 ppm (tt, 2H).

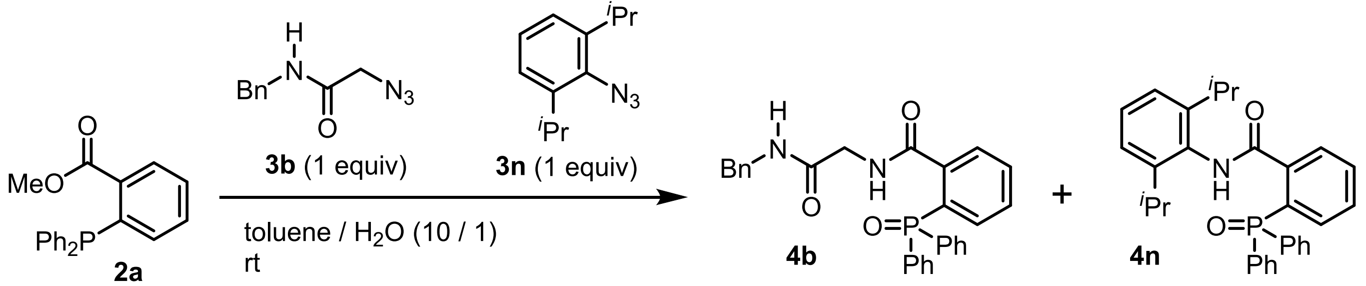
Competitive reaction with 3b and 3m



A reaction (3 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3b** (15.1 mg, 0.10 mmol) and **3m** (19.4 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature followed by short-path silica gel column chromatography (hexane elution to hexane / ethyl acetate = 2 / 1 to ethyl acetate elution) gave phosphine oxide products (**4b**: 86%, **4m**: 2%) and recovered azides **3b** (14%) and **3m** (3%) due to the NMR signal overlap. Each fraction was submitted to ^{1}H NMR to determine the ^{1}H NMR yields. Low recovery yield of **3m** is due to the volatile characteristics.

Used peaks to measure ^{1}H NMR yields: **4b**: 3.89 ppm (d, 2H), **4m**: 10.4 ppm (s, 1H), **3b**: 4.48 ppm (d, 2H), **3m**: 6.65 ppm (br, 2H).

Competitive reaction with 3b and 3n

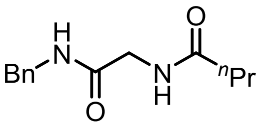


A reaction (23 h) with phosphine **2a** (32.0 mg, 0.10 mmol), azides **3b** (19.3 mg, 0.10 mmol) and **3n** (20.7 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature followed by silica gel column chromatography (hexane elution to hexane / ethyl acetate = 2 / 1 to ethyl acetate elution) gave phosphine oxide products (**4b**: 94%, **4n**: trace, only observable on TLC) and recovered azides **3b** (1.1 mg, 6%) and **3n** (16.5 mg, 81%). The yields of the phosphine oxides **4b** and **4n** were measured by ^{1}H NMR. Those of the recovered **3b** and **3n** were shown as isolated yields.

Used peaks to measure ^{1}H NMR yields: **4b**: 3.89 ppm (d, 2H).

Traceless Staudinger ligation

N-(2-(Benzylamino)-2-oxoethyl)butyramide (4ob)

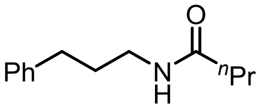


4ob

To a stirred solution of 2-azido-*N*-benzylacetamide **3b** (19.0 mg, 0.1 mmol) in toluene (1 mL) and water (0.1 mL), 2-(diphenylphosphaneyl)phenyl butyrate **2b** (42.0 mg, 0.12 mmol) was added at room temperature under N$_2$ gas and stirred for 19 h. The reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (33% to 50% ethyl acetate in hexane) to give the product **4ob** (17.5 mg, 75%) as white solid.

White solid; R$_f$ value 0.48 (ethyl acetate); IR (KBr, neat) ν_{max} 2359, 3070, 3032, 2963, 2931, 2873, 1633, 1551, 1496, 1423, 1383, 1247 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.33–7.30 (m, 2H), 7.28–7.24 (m, 3H), 6.91 (br-s, 1H), 6.52 (br-s, 1H), 4.42 (d, 2H, *J* = 6.0 Hz), 3.95 (d, 2H, *J* = 5.0 Hz), 2.19 (t, 2H, *J* = 7.5 Hz), 1.62 (qt, 2H, *J* = 7.5, 7.5 Hz), 0.91 (t, 3H, *J* = 7.5 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 173.8, 168.9, 137.7, 128.6, 127.6, 127.5, 43.5, 43.3, 38.1, 18.9, 13.7; LRMS (EI, M =$C_{13}H_{18}N_2O_2$) *m/z* 234 (31%, M$^+$), 128 (38), 106 (100), 91 (76); HRMS (EI) calcd for $C_{13}H_{18}N_2O_2$ (M$^+$) 234.1368, found 234.1360.

N-(3-Phenylpropyl)butyramide (4oa)

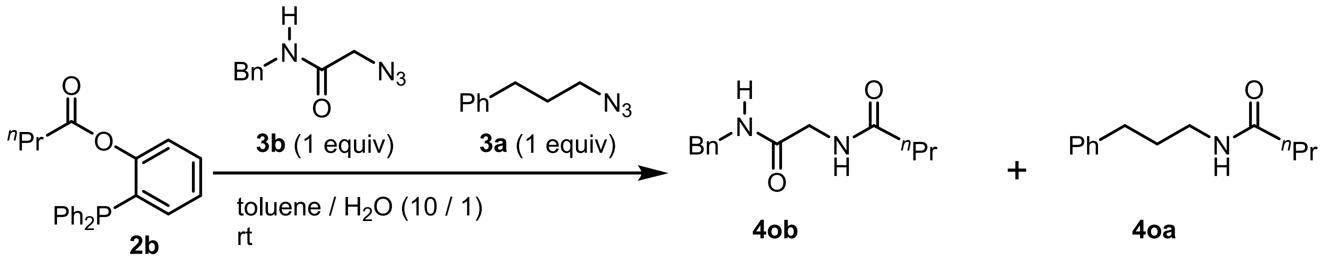


4oa

To a stirred solution of (3-azidopropyl)benzene **3a** (16.1 mg, 0.1 mmol) in toluene (1 mL) and water (0.1 mL), 2-(diphenylphosphaneyl)phenyl butyrate **2b** (41.9 mg, 0.12 mmol) was added at room temperature under N$_2$ gas and stirred for 19 h. The reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (20% to 33% ethyl acetate in hexane) to give the product **4oa** (9.0 mg, 44%) as colorless oil.

Colorless oil; R$_f$ value 0.25 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3286, 3084, 3029, 2961, 2873, 1644, 1555, 1496, 1454, 1282 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.30–7.26 (m, 2H), 7.21–7.18 (m, 3H), 5.37 (br-s, 1H), 3.30 (dt, 2H, J = 6.0, 7.0 Hz), 2.66 (t, 2H, J = 8.0 Hz), 2.11 (t, 2H, J = 7.0 Hz), 1.85 (tt, 2H, J = 7.0, 7.5 Hz), 1.67–1.60 (m, 2H), 0.94 (t, 3H, J = 7.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.9, 141.4, 128.4, 128.3, 126.0, 39.1, 38.7, 33.3, 31.3, 19.2, 13.8; LRMS (EI, M = $C_{13}H_{19}NO$) *m/z* 205 (100%, M^+), 108 (59), 101 (89), 91 (55), 73 (63); HRMS (EI) calcd for $C_{13}H_{19}NO$ (M^+) 205.1467, found 205.1465.

Competitive reaction with 3b and 3a



A reaction (6.5 h) with phosphine **2b** (34.9 mg, 0.10 mmol), azides **3b** (19.2 mg, 0.10 mmol) and **3a** (16.4 mg, 0.10 mmol) in toluene (1 mL) and water (0.1 mL) at room temperature gave amides (**4ob**: 57%, **4oa**: 1%) and recovered azides (**3b**: 13%, **3a**: 80%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **4ob**: 3.95 ppm (d, 2H), **4oa**: 2.66 ppm (t, 2H), **3b**: 4.00 ppm (s, 2H), **3a**: 2.71 ppm (t, 2H).

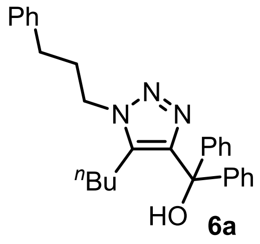
[4] Propargyl Cation-Mediated Triazole Synthesis

General Preparation Method to Obtain Authentic Triazole Products

To obtain the authentic samples of triazole products, general reaction conditions, especially the equivalents of the used materials, are modified from those we previously reported[17] due to the suppressed reactivity of α-AzSA compounds. This condition was also used in the competitive reactions.

To a stirred solution of propargyl alcohol **5** (26.4 mg, 0.1 mmol) and organic azide **3** (0.2 mmol, 2 equiv.) in dichloromethane (1 mL) was added trimethylsilyl trifluoromethanesulfonate (TMSOTf, 45 μL, 0.25 mmol, 2.5 equiv.) at −78 °C under nitrogen atmosphere. After 5 min, the reaction was quenched with saturated sodium bicarbonate aqueous solution at the same temperature. The mixture was extracted with ethyl acetate and was washed with saturated sodium bicarbonate aqueous solution and brine. The organic layer was then dried over sodium sulfate followed by concentration *in vacuo*. The obtained residue was purified by silica gel column chromatography to give triazole product.

To obtain the products as authentic samples to determine the yields based on ^{1}H NMR in the competitive reactions, we set the reaction time to 5 min that was not optimized for each compound.

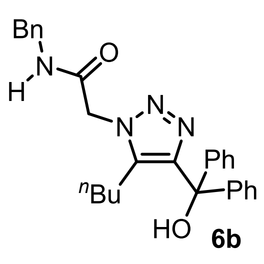


6a

(5-Butyl-1-(3-phenylpropyl)-1*H*-1,2,3-triazol-4-yl)diphenylmethanol (6a)

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3a** (32.2 mg, 0.20 mmol) and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (hexane / ethyl acetate = 4 / 1) gave **6a** (29.9 mg, 70 %) as a yellow oil.

Yellow oil; R$_f$ 0.60 (hexane / ethyl acetate = 2 / 1); IR (NaCl, neat) 3412, 3060, 3026, 2956, 2930, 2870, 1493, 1448 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.33–7.27 (m, 12H), 7.23–7.18 (m, 3H), 4.33 (s, 1H), 4.15 (t, 2H, *J* = 7.5 Hz), 2.73 (t, 2H, *J* = 7.5 Hz), 2.28 (tt, 2H, *J* = 7.5, 7.5 Hz), 1.95 (m, 2H), 0.93–0.80 (m, 4H), 0.64 (t, 3H, *J* = 7.5 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 148.2, 145.4, 140.2, 134.4, 128.5, 128.4, 127.9, 127.5, 126.3, 77.7, 46.9, 32.6, 31.4, 30.7, 22.59, 22.56, 13.4; HRMS (ESI) calcd for $C_{28}H_{31}N_3NaO$ [M+Na]$^+$ 448.2360, found 448.2365.



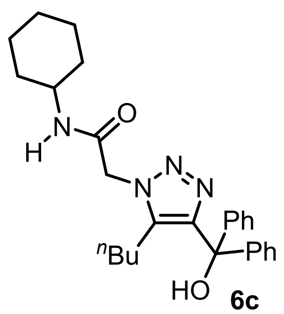
6b

N-Benzyl-2-(5-butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)acetamide (6b)

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3b** (38.0 mg, 0.20 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (hexane / ethyl acetate = 4 / 1 to 1 / 1) gave **6b** (19.4 mg, 36%) as a colorless oil.

Colorless oil; R$_f$ 0.10 (hexane / ethyl acetate = 2 / 1); IR (NaCl, neat) 3300, 2957, 2931, 2871, 1673, 1551 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.31–7.22 (m, 13H), 7.15 (d, 2H, *J* = 7.5 Hz) 6.42 (br-s, 1H), 4.93 (m, 2H), 4.41 (m, 2H), 4.01 (m, 1H), 2.12 (dd, 2H, *J* = 8.5, 8.0 Hz), 1.00–0.87 (m, 4H), 0.67 (t, 3H, *J* = 7.0 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.2, 149.3, 145.0, 137.1, 136.2, 128.8, 128.0, 127.8, 127.7, 127.5, 77.8, 51.0, 43.6, 30.6, 22.6, 13.4; LRMS (EI) *m/z* 454 (M$^+$, 77%), 377 (23), 105 (82), 91 (100), 77 (21); HRMS (EI) calcd for $C_{28}H_{30}N_4O_2$ (M$^+$) 454.2369, found 454.2368.

2-(5-Butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)-*N*-cyclohexylacetamide (6c)

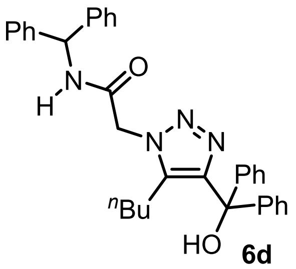


6c

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.1 mmol), azide **3c** (36.4 mg, 0.2 mmol) and TMSOTf (45 µL, 0.25 mmol), in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (9% to 13% to 17% to 25% to 38% ethyl acetate in hexane) gave **6c** (6.6 mg, 15%) as white amorphous.

White amorphous; R*f* value 0.33 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3299, 2931, 2855, 1665, 1550, 1448 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35–7.25 (m, 10H), 5.71 (d, 1H, *J* = 7.5 Hz), 4.90 (s, 2H), 4.12 (s, 1H), 3.78–3.77 (m, 1H), 2.15–2.11 (m, 2H), 1.82–1.78 (m, 2H), 1.63–1.56 (m, 2H), 1.39–1.25 (m, 3H), 1.20–0.87 (m, 7H), 0.69 (t, 3H, *J* = 7.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 164.4, 149.3, 145.0, 136.1, 128.0, 127.8, 127.7, 77.8, 51.2, 48.4, 32.5, 30.4, 25.3, 24.4, 22.6, 13.4; LRMS (EI, M = $C_{27}H_{34}N_4O_2$) *m/z* 446 (72%, M$^+$), 369 (21), 292 (19), 77(33); HRMS (EI) calcd for $C_{27}H_{34}N_4O_2$ (M$^+$) 446.2682, found 446.2675.

***N*-Benzhydryl-2-(5-butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)acetamide (6d)**

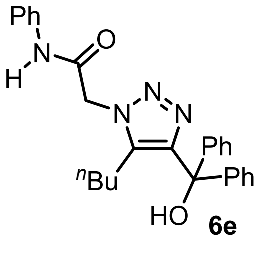


6d

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3d** (53.5 mg, 0.20 mmol) and TMSOTf (45 µL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (9% to 17% to 50% ethyl acetate in hexane) gave **6d** (22.3 mg, 42%) as a white solid.

White solid; R*f* value 0.48 (hexane / ethyl acetate = 1 / 1); m.p. 193.5–194.3 °C; IR (NaCl, neat) ν_{max} 3299, 3060, 2927, 1672, 1535, 1494, 1448, 1250 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32–7.23 (m, 16H), 7.11–7.09 (m, 4H), 6.66 (d, 1H *J* = 8.0 Hz), 6.22 (d, 1H *J* = 8.5 Hz), 4.98 (s, 2H), 3.97 (s, 1H), 2.13 (t, 2H, *J* = 8.0 Hz), 0.97–0.84 (m, 4H), 0.63 (t, 3H, *J* = 7.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 164.5, 149.4, 145.0, 140.5, 136.3, 128.8, 128.1, 127.8, 127.73, 127.68, 127.1, 77.8, 57.0, 51.1, 30.6, 22.6, 13.4; LRMS (EI, M = $C_{34}H_{34}N_4O_2$) *m/z* 530 (20%, M$^+$), 167 (100), 105 (61); HRMS (EI) calcd for $C_{34}H_{34}N_4O_2$ (M$^+$) 530.2682, found 530.2682.

2-(5-Butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)-*N*-phenylacetamide (6e)

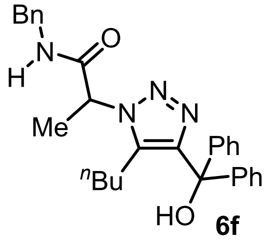


6e

A reaction (5 min) with propargyl alcohol **5a** (26.7 mg, 0.10 mmol), azide **3e** (35.3 mg, 0.20 mmol), and TMSOTf (45 µL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (9% to 17% to 50% ethyl acetate in hexane) gave **6e** (24.7 mg, 56%) as a yellow oil.

Yellow oil; R*f* value 0.42 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3423, 3143, 3087, 3061, 2959, 2932, 2871, 1682, 1603, 1556, 1498, 1446 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.45 (s, 1H), 7.39 (d, 2H, *J* = 8.5 Hz), 7.30–7.25 (m, 12H), 7.12–7.09 (m, 1H), 4.99 (s, 2H), 4.14 (s, 1H), 2.20 (t, 2H, *J* = 8.0 Hz), 1.00–0.97 (m, 4H), 0.67 (t, 3H, *J* = 7.0 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 163.3, 149.2, 145.1, 136.8, 136.7, 129.0, 128.0, 127.73, 127.66, 125.0, 120.2, 77.8, 51.5, 30.5, 22.64, 22.59, 13.4; LRMS (EI, M = $C_{27}H_{28}N_4O_2$) *m/z* 440 (100%, M$^+$), 363 (23); HRMS (EI) calcd for $C_{27}H_{28}N_4O_2$ (M$^+$) 440.2212, found 440.2209.

***N*-Benzyl-2-(5-butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)propenamide (6f)**

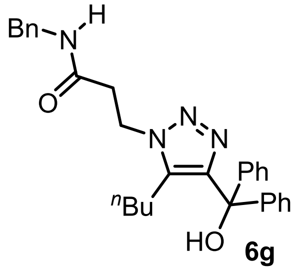


6f

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3f** (40.9 mg, 0.20 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (hexane / ethyl acetate = 5 / 1) gave **6f** (15.2 mg, 32%) as a colorless oil.

Colorless oil; R_f 0.47 (hexane/ethyl acetate = 2/1); IR (NaCl, neat) 3302, 3061, 3031, 2958, 2931, 1669, 1543, 1448 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31–7.21 (m, 13H), 7.14 (d, 2H, *J* = 6.5 Hz) 6.78 (br-s, 1H), 4.93 (q, 1H, *J* = 7.5 Hz), 4.45 (dd, 1H, *J* = 15.0, 6.5 Hz), 4.37 (dd, 1H, *J* = 15.0, 6.0 Hz), 4.02 (br-s, 1H), 2.15 (m, 2H), 1.97 (d, 3H, *J* = 7.0 Hz), 1.01–0.87 (m, 4H), 0.68 (t, 3H, *J* = 7.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.2, 149.0, 145.10, 145.06, 137.4, 136.0, 128.7, 128.0, 127.73, 127.69, 127.65, 127.6, 127.3, 77.8, 58.4, 43.4, 30.8, 22.6, 19.5, 13.4; LRMS (EI) 468 (M$^+$, 93%), 306 (64), 105 (100), 91 (77), 77 (23); HRMS (EI) calcd 468.2525 for $C_{29}H_{32}N_4O_2$ (M$^+$), found 468.2518.

N-Benzyl-3-(5-butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)propenamide (6g)

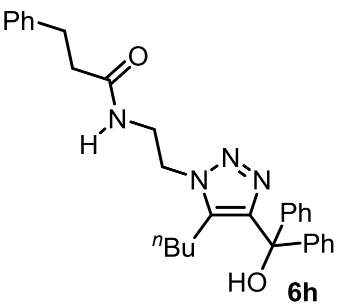


6g

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3g** (40.5 mg, 0.20 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane at -78 °C followed by silica gel column chromatography (hexane / ethyl acetate = 5 / 1 to 2 / 1 to 1 / 2) gave **6g** (30.6 mg, 65%) as a white solid.

White solid; R_f value 0.12 (hexane / ethyl acetate = 2 / 1); m.p. 140–141 °C; IR (NaCl, neat) 3299, 3061, 2957, 2927, 2870, 1653, 1550, 1448 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31–7.25 (m, 13H), 7.18 (d, 2H, *J* = 6.5 Hz), 6.10 (br-s, 1H), 4.46 (t, 2H, *J* = 6.0 Hz), 4.37 (d, 2H, *J* = 5.5 Hz), 4.18 (s, 1H), 2.99 (t, 2H, *J* = 6.0 Hz), 2.18–2.14 (m, 2H), 1.03–0.91 (m, 4H), 0.70 (t, 3H, *J* = 7.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.3, 148.3, 145.4, 137.8, 135.5, 128.6, 127.9, 127.8, 127.6, 127.4, 77.7, 43.6, 43.5, 35.8, 30.7, 22.7, 22.5, 13.5; LRMS (EI, M = $C_{29}H_{32}N_4O_2$) *m/z* 468 (M$^+$, 63%), 391 (23), 162 (37), 91 (100), 77 (17); HRMS (EI) calcd for $C_{29}H_{32}N_4O_2$ [M$^+$] 468.2525, found 468.2518.

N-(2-(5-butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)ethyl)-3-phenylpropanamide (6h)

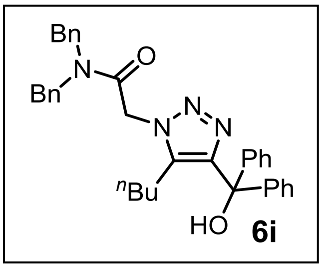


6h

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3h** (43.8 mg, 0.20 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane at -78 °C followed by silica gel column chromatography (17% to 25% to 50% ethyl acetate in hexane) gave **6h** (25.0 mg, 52%) as a white amorphous.

White amorphous; R_f value 0.12 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3302, 3061, 3028, 2958, 2930, 2871, 1653, 1541, 1495, 1448, 1376, 1274, 1168 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33–7.24 (m, 12H), 7.19–7.16 (m, 3H), 6.23 (s, 1H), 4.17 (t, 2H, *J* = 5.0 Hz), 4.10 (s, 1H), 3.80 (dt, 2H, *J* = 5.5, 5.0 Hz), 2.92 (t, 2H, *J* = 7.5 Hz), 2.45 (t, 2H, *J* = 8.0 Hz), 2.09 (t, 2H, *J* = 8.0 Hz), 1.04–0.87 (m, 4H), 0.71 (t, 3H, *J* = 7.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.6, 148.5, 145.3, 140.5, 135.5, 128.5, 128.3, 128.0, 127.73, 127.68, 126.2, 77.8, 47.0, 38.4, 38.2, 31.5, 30.7, 22.6, 22.5, 13.5; LRMS (EI, M = $C_{30}H_{34}N_4O_2$) *m/z* 482 (30%, M$^+$), 305 (100), 176 (76), 105 (78), 91 (70); HRMS (EI) calcd for $C_{30}H_{34}N_4O_2$ (M$^+$) 482.2682, found 482.2679.

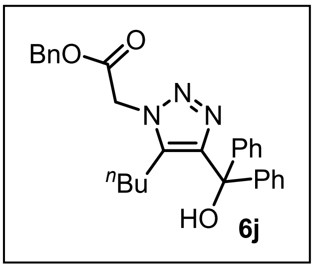
N,N-Dibenzyl-2-(5-butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)acetamide (6i)


6i

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3i** (56.1 mg, 0.20 mmol), and TMSOTf (45 µL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (hexane / ethyl acetate = 4 / 1) gave **6i** (32.8 mg, 60%) as a white solid.

White solid; R_f 0.25 (hexane / ethyl acetate = 2 / 1); m.p. 49–50 °C; IR (NaCl, neat) 3420, 3030, 2956, 2871, 1669, 1449 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.40–7.26 (m, 16H), 7.23 (d, 2H, *J* = 6.0 Hz) 7.18 (d, 2H, *J* = 7.0), 5.11 (s, 2H), 4.69 (s, 2H), 4.56 (s, 2H), 4.33 (br-s, 1H), 2.03 (m, 2H), 0.91–0.77 (m, 4H), 0.64 (t, 3H, *J* = 6.5 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 165.7, 148.4, 145.4, 136.14, 136.09, 135.4, 129.3, 128.8, 128.4, 128.1, 127.95, 127.91, 127.5, 126.0, 77.7, 49.64, 49.61, 49.4, 30.3, 22.8, 22.7, 13.5; LRMS (EI) 544 (M$^+$, 36%), 453 (49), 105 (63), 91 (100), 77 (13); HRMS (EI) calcd for $C_{35}H_{36}N_4O_2$ (M$^+$) 544.2838, found 544.2832.

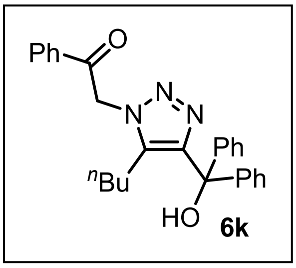
Benzyl 2-(butyl-4-(hydroxydiphenyl)-1*H*-1,2,3-triazol-1-yl)acetate (6j)


6j

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3j** (38.2 mg, 0.20 mmol), and TMSOTf (45 µL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (hexane / ethyl acetate = 4 / 1) gave **6j** (32.0 mg, 70%) as a white solid.

White solid; R_f value 0.32 (hexane/ethyl acetate = 2/1); m.p. 108.3–109.8 °C; IR (NaCl, neat) 2956, 1750, 1456, 1196 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.37–7.36 (m, 3H), 7.32–7.26 (m, 12H), 5.22 (s, 2H), 5.08 (s, 2H), 4.16 (s, 1H), 1.99 (m, 2H), 0.92–0.89 (m, 4H), 0.63 (t, 3H, *J* = 6.5 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 166.2, 148.6, 145.2, 135.7, 134.4, 128.8, 128.7, 128.5, 127.94, 127.87, 127.6, 77.7, 67.9, 49.0, 30.4, 22.6, 13.4; LRMS (EI, M = $C_{28}H_{29}N_3O_3$) *m/z* 455 (M$^+$, 64%), 378 (19), 105 (58), 91 (100); HRMS (EI) calcd for $C_{28}H_{29}N_3O_3$ [M$^+$] 455.2209, found 455.2209.

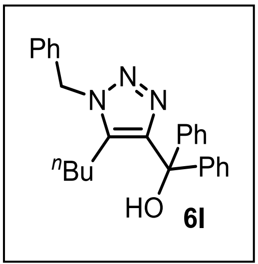
2-(5-Butyl-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)-1-phenylethan-1-one (6k)


6k

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azide **3k** (32.2 mg, 0.20 mmol), and TMSOTf (45 µL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C followed by silica gel column chromatography (dichloromethane elution to dichloromethane / methanol = 20 / 1) gave **6k** (35.3 mg, 83%) as a white solid.

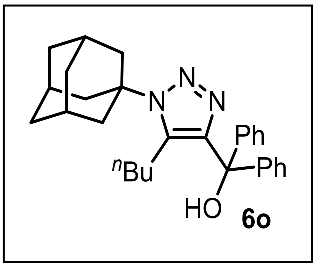
White solid; R_f value 0.32 (hexane / ethyl acetate = 2 / 1); m.p. 189.0–191.0 °C; IR (NaCl, neat) ν_{max} 3260, 2955, 1699, 1597, 1579, 1447 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.00 (d, 2H, *J* = 7.5 Hz), 7.68 (t, 1H, *J* = 7.0 Hz), 7.55 (dd, 2H, *J* = 7.5, 7.5 Hz), 7.33–7.29 (m, 10H), 5.72 (s, 2H), 4.28 (s, 1H), 2.00 (m, 2H), 0.89 (m, 4H), 0.62 (t, 3H, *J* = 6.0 Hz); ^{13}C NMR (126 MHz, CDCl$_3$) δ 190.4, 148.6, 145.4, 136.2, 134.5, 134.0, 129.2, 128.1, 128.0, 127.6, 77.8, 53.9, 30.5, 22.8, 22.6, 13.4; LRMS (EI, M = $C_{27}H_{27}N_3O_2$) *m/z* 425 (M$^+$, 77), 348 (24), 292 (29), 105 (100), 91 (35), 77 (30); HRMS (EI) calcd for $C_{27}H_{27}N_3O_2$ [M$^+$] 425.2103, found 425.2106.

(1-Benzyl-5-butyl-1*H*-1,2,3-triazol-4-yl)diphenylmethanol (6l)


6l

We reported this compound in our previous report.[17] The ^{1}H NMR spectrum data of **6l** from our previous report was used for comparison in the competitive reaction was used.

1-Adamantyl-5-butyl-1*H*-1,2,3-triazol-4-yl]diphenylmethanol (6o)

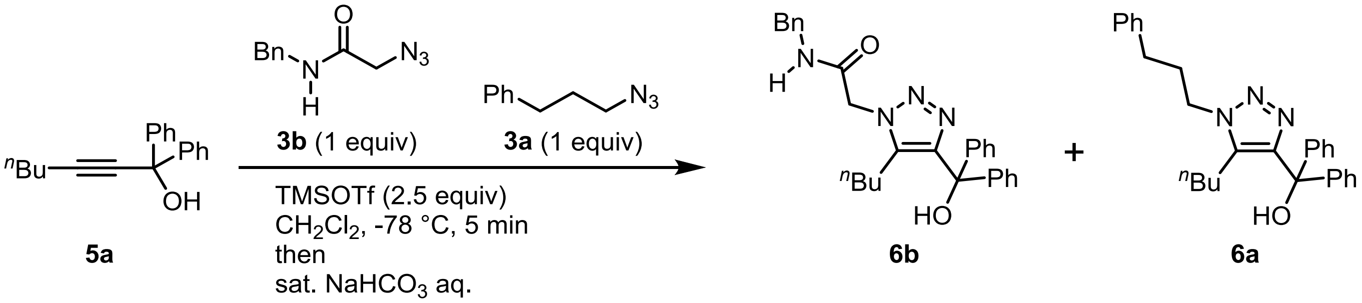


We have synthesized **6o** previously,[17] and the ^{1}H NMR spectra of competitive reaction with **3b** and **3o** was analyzed based on our previously obtained data of **6o**.

General Procedure of Competitive Reactions

To a stirred solution of 3-phenylpropyl azide **3a** (0.1 mmol), the azide substrate to be compared (0.1 mmol), and 1,1-diphenylhept-2-yn-1-ol **5a** (0.1 mmol) in dichloromethane (1 mL, 0.1 M) was added trimethylsilyl trifluoromethanesulfonate (TMSOTf, 45 μL, 0.25 mmol, 2.5 equiv) at −78 °C under nitrogen atmosphere. After 5 min, the reaction was quenched with saturated sodium bicarbonate aqueous solution. The mixture was extracted with ethyl acetate and was washed with saturated sodium bicarbonate aqueous solution and brine. The organic layer was then dried over sodium sulfate followed by concentration *in vacuo*. The obtained crude residue was analyzed by ^{1}H NMR spectroscopy in the presence of 1,1,2,2-tetrachloroethane (10.5 μL, 0.1 mmol, 1 equiv. to the starting materials, 5.96 ppm on ^{1}H NMR, 2H) as an internal standard to determine the material yields except for the reaction with **3a** and **3g** (1,4-benzoquinone, 10.8 mg, 0.1 mmol, 1 equiv. to the starting materials, 6.75 ppm on ^{1}H NMR, 4H). When difficulty was encountered to determine due to the overlap of the NMR signals, the crude materials were separated by silica gel column chromatography. Then, each fraction was submitted to ^{1}H NMR yield determination as above. If isolable as a pure material, isolated yields were determined. For somewhat volatile azides such as **3a**, the recovery yields were determined from the crude residue before further separation. The experiments were conducted at least in duplicate.

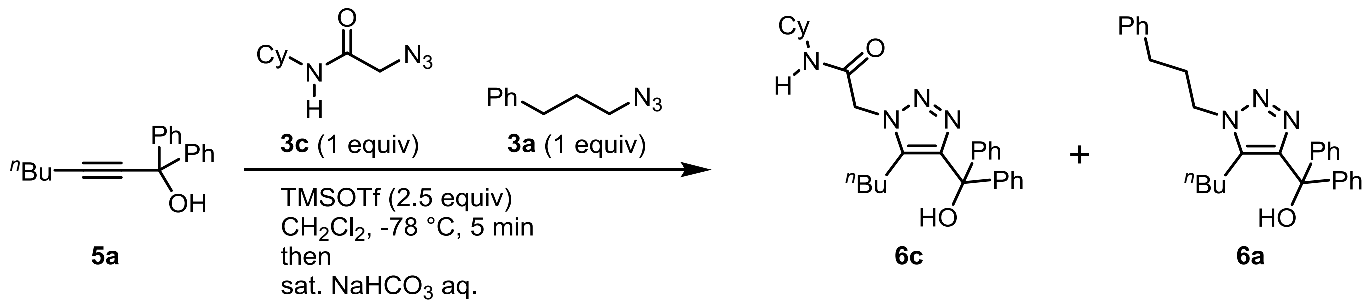
Competitive reaction with 3a and 3b



A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azides **3b** (19.0 mg, 0.10 mmol), **3a** (16.3 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at -78 °C gave triazoles (**6b**: 8%, **6a**: 86%) and recovered azides (**3b**: 93%, **3a**: 8%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **6b**: 4.93 ppm (m, 2H), **6a**: 4.31 ppm (s, 1H), **3b**: 4.01 ppm (s, 2H), **3a**: 3.28 ppm (t, 2H).

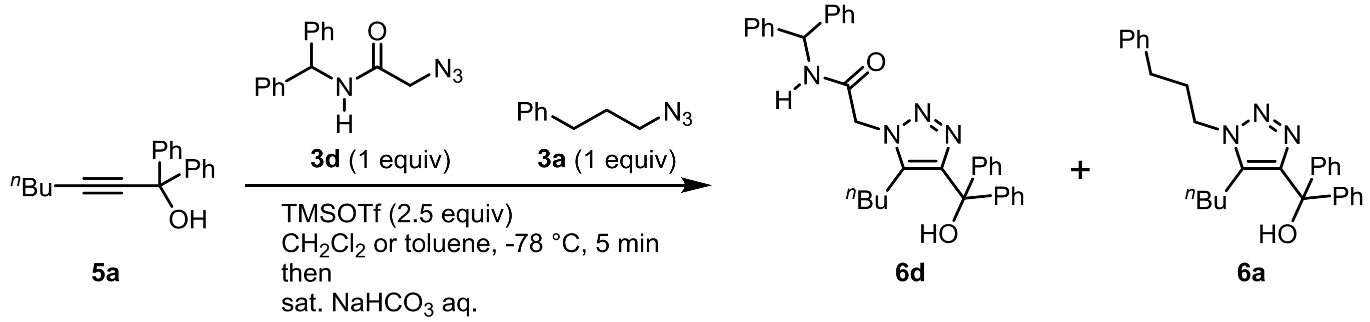
Competitive reaction with 3a and 3c



A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azides **3c** (18.2 mg, 0.10 mmol), **3a** (16.4 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6c**: 1%, **6a**: 89%) and recovered azides (**3c**: 98%, **3a**: 11%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **6c**: 4.86 ppm (s, 2H), **6a**: 4.13 ppm (t, 2H), **3b**: 3.91 ppm (s, 2H), **3a**: 3.28 ppm (t, 2H).

Competitive reaction with 3a and 3d



Reaction in dichloromethane:

A reaction (5 min) with propargyl alcohol **5a** (26.5 mg, 0.10 mmol), azides **3d** (26.7 mg, 0.10 mmol), **3a** (16.1 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6d**: 10%, **6a**: 83%) and recovered azides (**3d**: 70%, **3a**: 16%), measured by ^{1}H NMR of the obtained crude material.

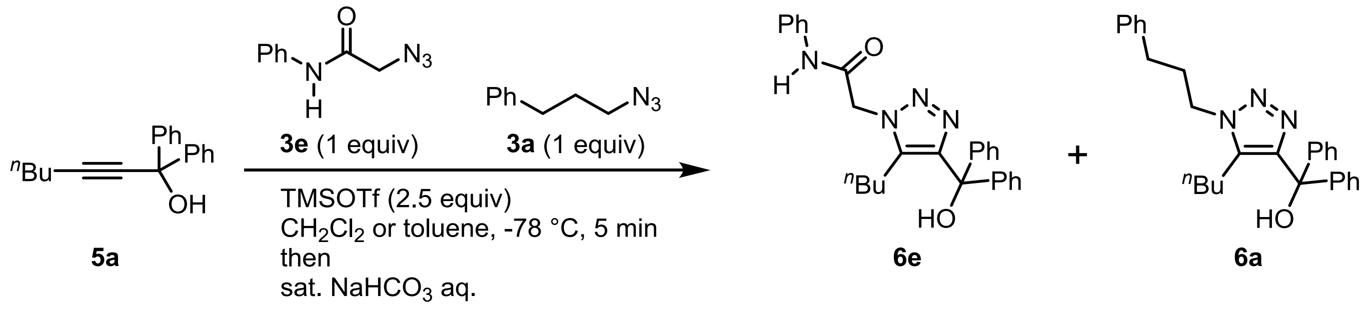
Used peaks to measure ^{1}H NMR yields: **6d**: 4.91 ppm (s, 2H), **6a**: 2.26 ppm (tt, 2H), **3d**: 6.25 ppm (d, 1H), **3a**: 3.27 ppm (t, 2H).

Reaction in toluene:

A reaction (5 min) with propargyl alcohol **5a** (26.3 mg, 0.10 mmol), azides **3d** (26.8 mg, 0.10 mmol), **3a** (16.0 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in toluene (1 mL) at −78 °C gave triazoles (**6d**: 2%, **6a**: 61%) and recovered azides (**3d**: 92%, **3a**: 20%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **6d**: 4.91 ppm (s, 2H), **6a**: 4.15 ppm (t, 2H), **3d**: 6.25 ppm (d, 1H), **3a**: 3.27 ppm (t, 2H).

Competitive reaction with 3a and 3e



Reaction in dichloromethane:

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azides **3e** (17.8 mg, 0.10 mmol), **3a** (16.4 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6e**: 31%, **6a**: 46%) and recovered azides (**3e**: 67%, **3a**: 48%), measured by ^{1}H NMR of the obtained crude material.

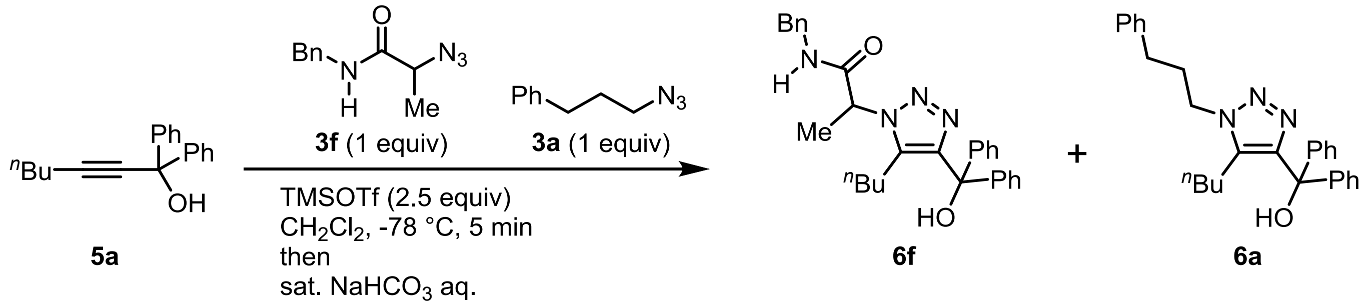
Used peaks to measure ^{1}H NMR yields: **6e**: 4.98 ppm (s, 2H), **6a**: 4.32 ppm (s, 1H), **3e**: 7.52 ppm (dd, 2H), **3a**: 3.27 ppm (t, 2H).

Reaction in toluene:

A reaction (5 min) with propargyl alcohol **5a** (26.5 mg, 0.10 mmol), azides **3e** (17.7 mg, 0.10 mmol), **3a** (16.2 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in toluene (1 mL) at −78 °C gave triazoles (**6e**: 8%, **6a**: 63%) and recovered azides (**3e**: 92%, **3a**: 32%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **6e**: 4.98 ppm (s, 2H), **6a**: 2.20 ppm (t, 2H), **3e**: 7.52 ppm (dd, 2H), **3a**: 3.27 ppm (t, 2H).

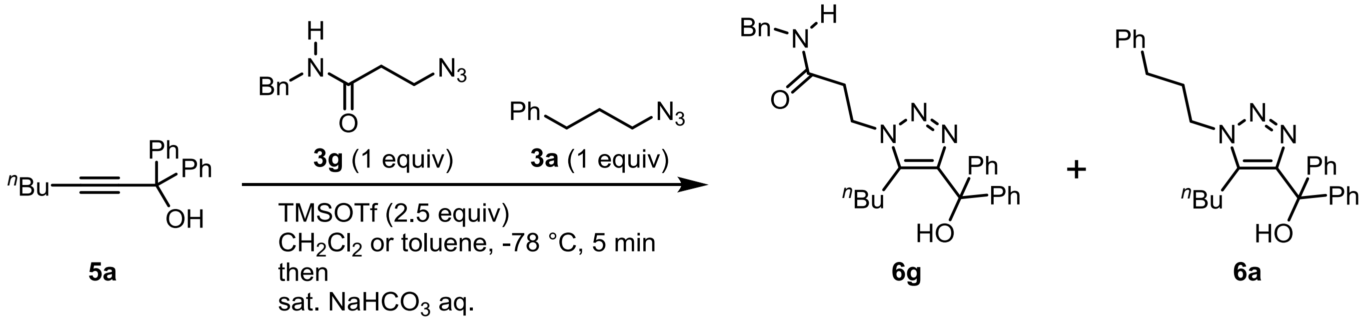
Competitive reaction with 3a and 3f



A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azides **3f** (20.5 mg, 0.10 mmol), **3a** (16.3 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave crude material. Because of NMR signal overlap, the crude material was purified by silica gel column chromatography (hexane elution to hexane / ethyl acetate = 20 / 1 to 4 / 1 to 1 / 1) to obtain **3a** (5%), mixture of **6a** and **3f** (**6a**: 86%, **3f**: 93%), and **6f** (5%). Each fraction was submitted to ^{1}H NMR to determine the ^{1}H NMR yields.

Used peaks to measure ^{1}H NMR yields: **6a**: 2.72 ppm (t, 2H), **3f**: 4.43 ppm (d, 2H).

Competitive reaction with 3a and 3g



A reaction (5 min) with propargyl alcohol **5a** (26.5 mg, 0.10 mmol), azides **3g** (20.6 mg, 0.10 mmol), **3a** (16.2 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6g**: 12%, **6a**: 84%) and recovered azides (**3g**: 84%, **3a**: 14%), measured by ^{1}H NMR of the obtained crude material.

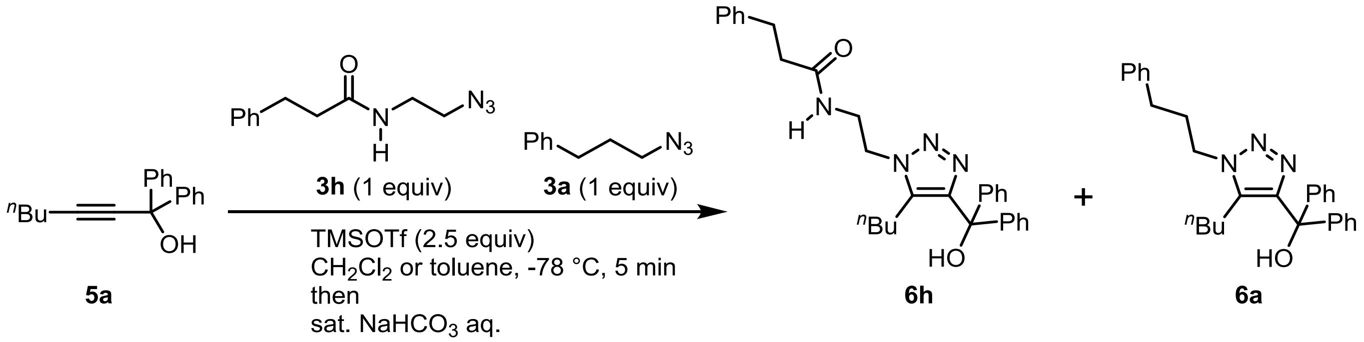
Used peaks to measure ^{1}H NMR yields: **6g**: 2.90 ppm (t, 2H), **6a**: 2.25 ppm (tt, 2H), **3g**: 2.39 ppm (t, 2H), **3a**: 3.27 ppm (t, 2H).

Reaction in toluene:

A reaction (5 min) with propargyl alcohol **5a** (27.0 mg, 0.10 mmol), azides **3g** (20.5 mg, 0.10 mmol), **3a** (16.3 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in toluene (1 mL) at −78 °C gave triazoles (**6g**: 33%, **6a**: 50%) and recovered azides (**3g**: 64%, **3a**: 47%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **6g**: 2.90 ppm (t, 2H), **6a**: 2.25 ppm (tt, 2H), **3g**: 2.39 ppm (t, 2H), **3a**: 3.27 ppm (t, 2H).

Competitive reaction with 3a and 3h



A reaction (5 min) with propargyl alcohol **5a** (26.5 mg, 0.10 mmol), azides **3h** (21.8 mg, 0.10 mmol), **3a** (16.1 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6h**: 9%, **6a**: 72%) and recovered azides (**3h**: 80%, **3a**: 7%), measured by ^{1}H NMR of the obtained crude material.

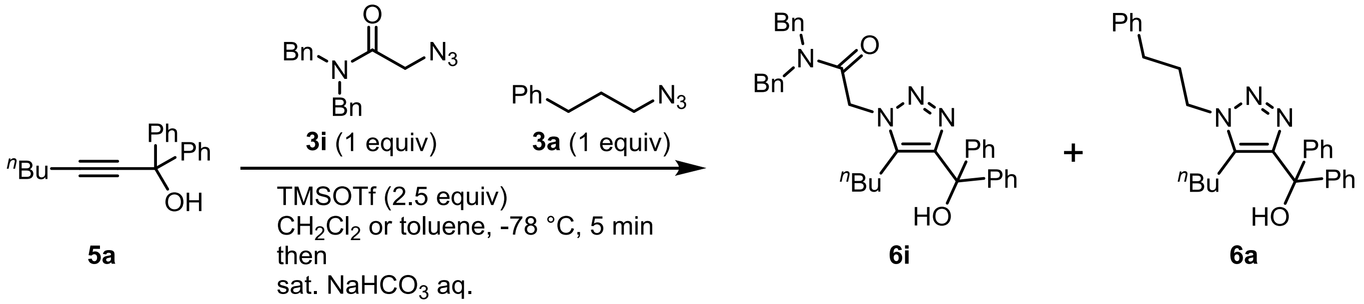
Used peaks to measure ^{1}H NMR yields: **6h**: 3.71 ppm (dt, 2H), **6a**: 0.64 ppm (t, 3H), **3h**: 3.31 ppm (s, 4H), **3a**: 1.90 ppm (tt, 2H).

Reaction in toluene:

A reaction (5 min) with propargyl alcohol **5a** (27.0 mg, 0.10 mmol), azides **3h** (22.0 mg, 0.10 mmol), **3a** (17.0 mg, 0.11 mmol), and TMSOTf (45 μL, 0.25 mmol) in toluene (1 mL) at −78 °C gave triazoles (**6h**: 20%, **6a**: 35%) and recovered azides (**3h**: 53%, **3a**: 33%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **6h**: 3.71 ppm (dt, 2H), **6a**: 0.64 ppm (t, 3H), **3h**: 3.31 ppm (s, 4H), **3a**: 3.30 ppm (t, 2H).

Competitive reaction with 3a and 3i



Reaction in dichloromethane:

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azides **3i** (28.0 mg, 0.10 mmol), **3a** (16.1 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6i**: 15%, **6a**: 80%) and recovered azides (**3i**: 85%, **3a**: 13%), measured by ^{1}H NMR of the obtained crude material.

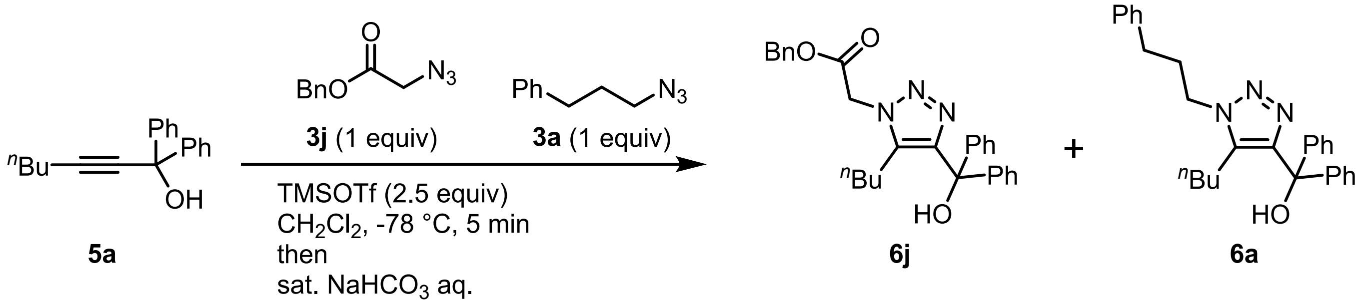
Used peaks to measure ^{1}H NMR yields: **6i**: 5.11 ppm (s, 2H), **6a**: 4.15 ppm (t, 2H), **3i**: 3.98 ppm (s, 2H), **3a**: 3.30 ppm (t, 2H).

Reaction in toluene:

A reaction (5 min) with propargyl alcohol **5a** (26.6 mg, 0.10 mmol), azides **3i** (28.1 mg, 0.10 mmol), **3a** (16.1 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in toluene (1 mL) at −78 °C gave triazoles (**6i**: 11%, **6a**: 58%) and recovered azides (**3i**: 69%, **3a**: 28%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **6i**: 5.11 ppm (s, 2H), **6a**: 4.15 ppm (t, 2H), **3i**: 3.98 ppm (s, 2H), **3a**: 3.30 ppm (t, 2H).

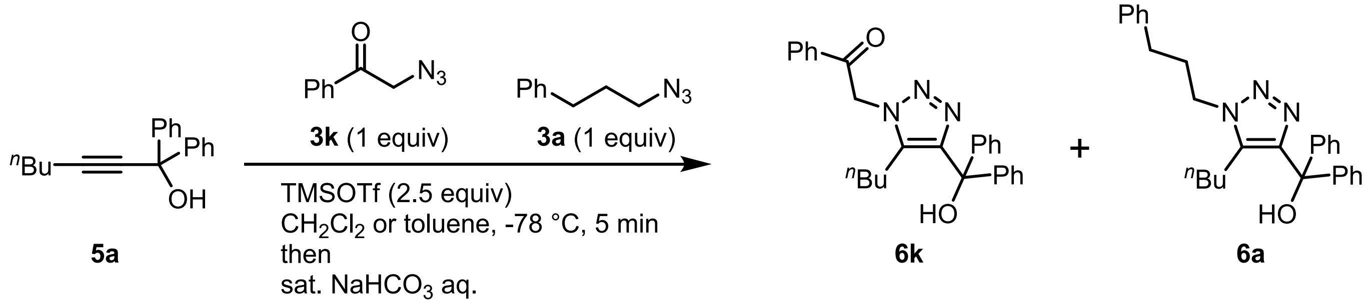
Competitive reaction with 3a and 3j



A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azides **3j** (19.1 mg, 0.10 mmol), **3a** (16.1 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6j**: 16%, **6a**: 61%) and recovered azides (**3j**: 74%, **3a**: 20%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: **6j**: 5.08 ppm (s, 2H), **6a**: 2.28 ppm (tt, 2H), **3j**: 3.92 ppm (s, 2H), **3a**: 3.30 ppm (t, 2H).

Competitive reaction with 3a and 3k



Reaction in dichloromethane:

A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azides **3k** (16.1 mg, 0.10 mmol), **3a** (16.1 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6k**: 42%, **6a**: 51%) and recovered azides (**3k**: 58%, **3a**: 49%), measured by ^{1}H NMR of the obtained crude material.

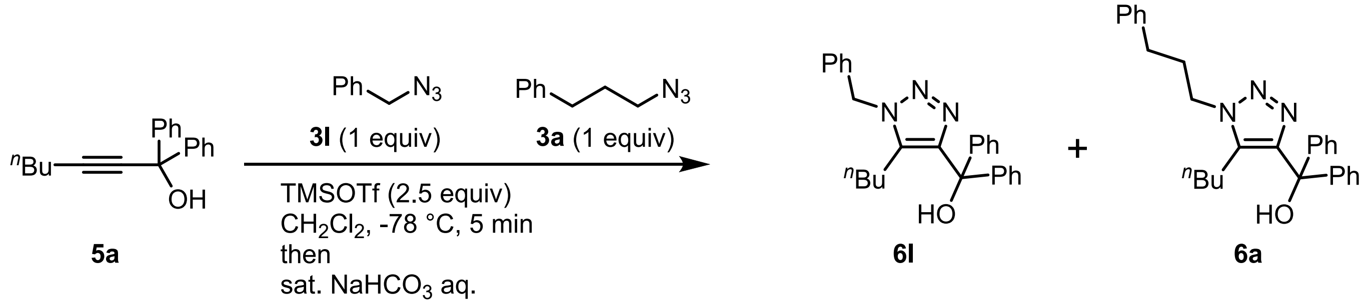
Used peaks to measure ^{1}H NMR yields: **6k**: 5.73 ppm (s, 2H), **6a**: 4.15 ppm (t, 2H), **3k**: 4.57 ppm (s, 2H), **3a**: 3.30 ppm (t, 2H).

Reaction in toluene:

A reaction (5 min) with propargyl alcohol **5a** (26.2 mg, 0.10 mmol), azides **3k** (16.1 mg, 0.10 mmol), **3a** (16.1 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in toluene (1 mL) at −78 °C gave triazoles (**6k**: 40%, **6a**: 30%) and recovered azides (**3k**: 35%, **3a**: 59%), measured by ^{1}H NMR of the obtained crude material.

Used peaks to measure ^{1}H NMR yields: Same as above.

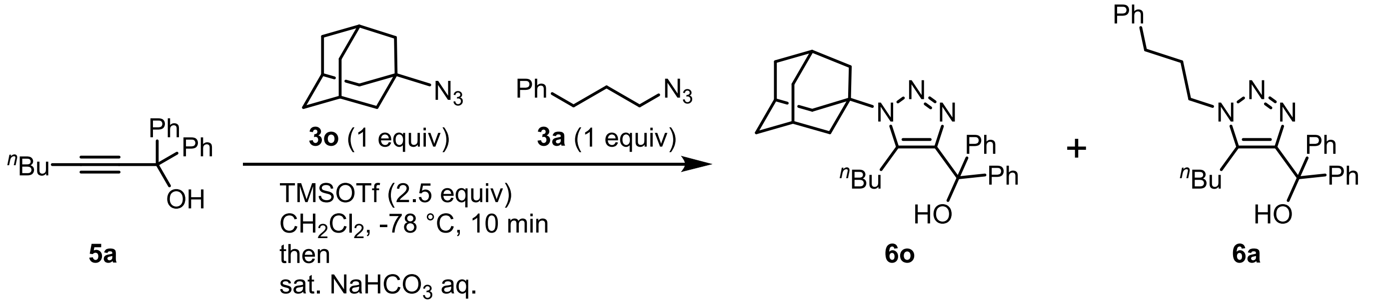
Competitive reaction with 3a and 3l



A reaction (5 min) with propargyl alcohol **5a** (26.4 mg, 0.10 mmol), azides **3l** (13.5 mg, 0.10 mmol), **3a** (16.5 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave triazoles (**6l**: 52%, **6a**: 41%) and recovered azide (**3a**: 53%), measured by ^{1}H NMR of the obtained crude material. The yield of recovered benzyl azide **3l** was not determined because of the difficulty by the overlap of ^{1}H NMR spectrum and its volatility.

Used peaks to measure ^{1}H NMR yields: **6l**: 5.45 ppm (s, 2H), **6a**: 2.28 ppm (tt, 2H),**3a**: 3.30 ppm (t, 2H).

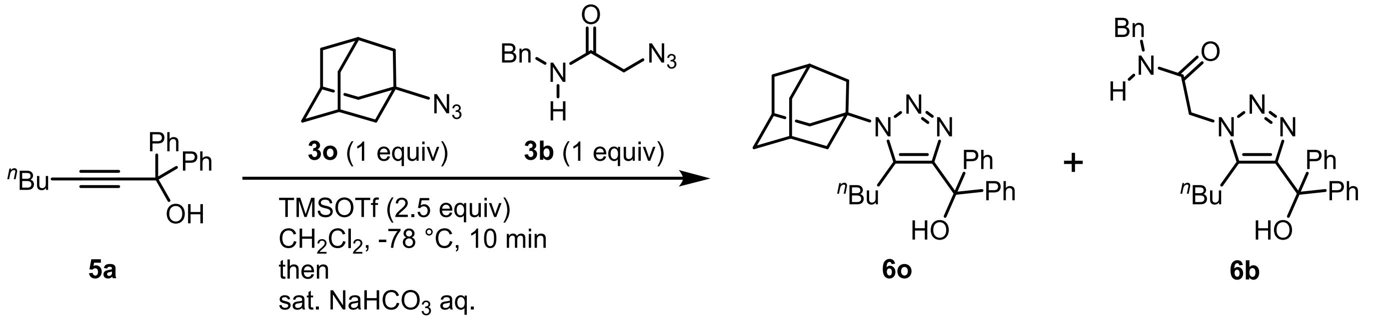
Competitive reaction with 3a and 3o



A reaction (10 min) with propargyl alcohol **5a** (26.7 mg, 0.10 mmol), azides **3o** (17.8 mg, 0.10 mmol), **3a** (16.3 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave crude material. Because of NMR signal overlap, the crude material was purified by silica gel column chromatography (hexane elution to hexane / ethyl acetate = 50 / 1 to 10 / 1 to 5 / 1) to obtain mixture fraction of **3a** and **3o** (**3a**: 7%, **3o**: 50%), pure triazoles **6o** (6.6 mg, 15%) and **6a** (32.7 mg, 77%). The yields of the recovered **3a** and **3o** were measured by ^{1}H NMR. Those of the triazole products **6a** and **6o** were as isolated yields.

Used peaks to measure ^{1}H NMR yields: **3a**: 3.30 ppm (t, 2H), **3o**: 2.16 ppm (br-s, 3H).

Competitive reaction with 3b and 3o

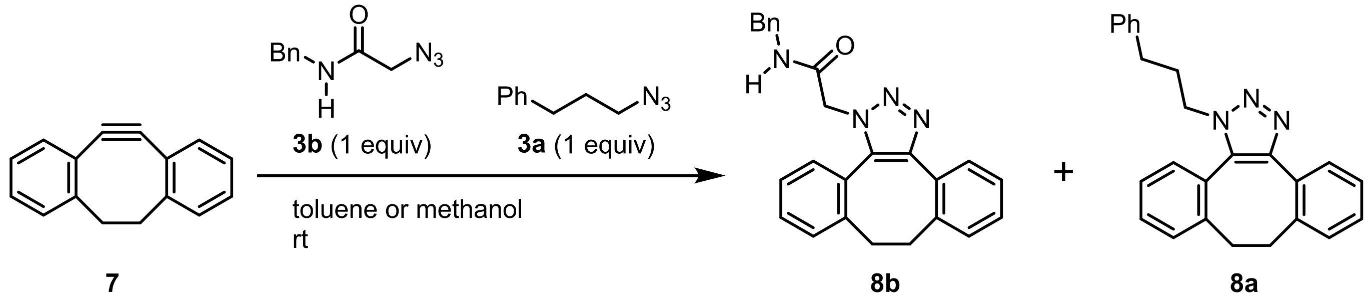


A reaction (10 min) with propargyl alcohol **5a** (26.7 mg, 0.10 mmol), azides **3o** (17.7 mg, 0.10 mmol), **3b** (19.0 mg, 0.10 mmol), and TMSOTf (45 μL, 0.25 mmol) in dichloromethane (1 mL) at −78 °C gave crude material. Because of NMR signal overlap, the crude material was purified by silica gel column chromatography (hexane elution to hexane / ethyl acetate = 50 / 1 to 10 / 1 to 3 / 1 to 1 / 1) to obtain triazoles **6o** (27.6 mg, 62%), **6b** (5.6 mg, 12%), and recovered azides **3o** (2% from ^{1}H NMR) and **3b** (16.6 mg, 87%). Because **3o** contains some impurity due to its highly less polar characteristics, the yield was determined from ^{1}H NMR.

Used peaks to measure ^{1}H NMR yields: **3o:** 2.15 ppm (br-s, 3H).

[5] Strain-Promoted Azide-Alkyne Cyclization Reactions

Competitive reaction with 3a and 3b

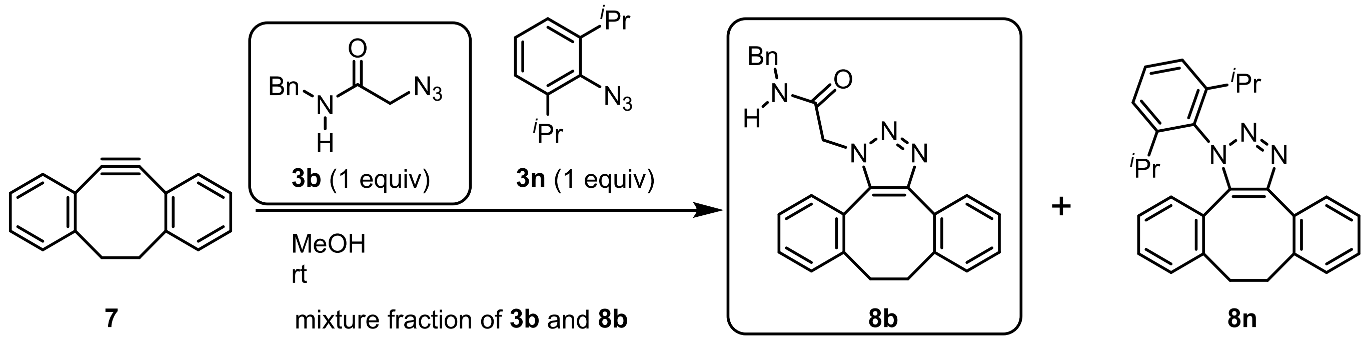


Reaction in toluene: **3a** (16.4 mg, 0.1 mmol) and **3b** (19.5 mg, 0.1 mmol) were dissolved in toluene (1 mL). To the stirred solution was added dibenzocyclooctyne **7** (20.4 mg, 0.1 mmol), and the reaction mixture was stirred for 1 h. The reaction mixture was concentrated *in vacuo* to obtain the crude material. ^{1}H NMR-based yields were measured with this crude material (**8b**: 50%, **8a**: 40%, recovered **2b**: 50%, recovered **2a**: 57%) with 1,1,2,2-tetrachloroethane (10.5 µL, 0.1 mmol, 1.0 equiv.) as an internal standard. Then, the crude material was purified by silica gel column chromatography (9% to 17% to 33% ethyl acetate in hexane to ethyl acetate elution) to give *N*-benzylacetamide triazole product **8b** (13.4 mg, 34%) and phenylpropyl triazole product **8a** (9.9 mg, 27%) as isolated products to collect the analytical data.

Reaction in methanol: A reaction (2.5 h) as above with **3a** (16.2 mg, 0.1 mmol), **3b** (19.4 mg, 0.1 mmol), and **7** (20.4 mg, 0.1 mmol) in methanol (1 mL) gave products (**8b**: 47%, **8a**: 47%, recovered **3b**: 53%, recovered **3a**: 47%). The yields were determined by ^{1}H NMR with 1,1,2,2-tetrachloroethane (10.5 µL, 0.1 mmol, 1.0 equiv., 5.92 ppm on ^{1}H NMR, 2H) as an internal standard.

Used peaks to measure ^{1}H NMR yields: **8b**: 5.14 ppm (d, 1H), **8a**: 2.95–2.92 ppm (m, 1H), **3b**: 4.00 ppm (s, 2H), **3a**: 2.71 (t, 2H).

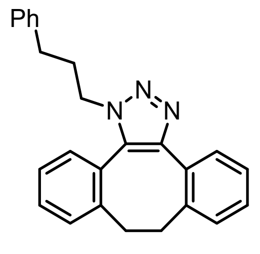
Competitive reaction with 3b and 3n



3b (19.2 mg, 0.1 mmol) and **3n** (20.4 mg, 0.1 mmol) were dissolved in methanol (1 mL). To the stirred solution, dibenzocyclooctyne **7** (20.4 mg, 0.1 mmol) was added, and the reaction mixture was stirred for 2 h. The reaction mixture was concentrated *in vacuo*. The obtained crude material was purified by short-path silica gel column chromatography (hexane elution to hexane /ethyl acetate = 5 / 1 to ethyl acetate elution) to separate the materials partially (a mixture of **3b** and **8b**, and **8n**). The yields of **8b** (18%), **3b** (82%) were determined by ^{1}H NMR with 1,1,2,2-tetrachloroethane (10.5 µL, 0.1 mmol, 1.0 equiv.) as an internal standard. **8n** (30.1 mg, 74%) was obtained as a pure material.

Used peaks to measure ^{1}H NMR yields: **8b**: 5.14 ppm (d, 1H), **7b**: 3.99 ppm (s, 2H).

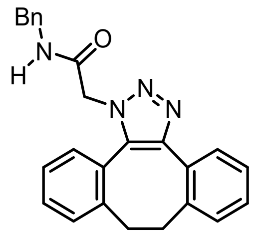
1-(3-Phenylpropyl)-8,9-dihydro-1*H*-dibenzo[3,4:7,8]cycloocta[1,2-*d*][1,2,3]triazole (8a)



8a

Colorless oil; R_f value 0.27 (hexane / ethyl acetate = 5 / 1); IR (NaCl, neat) ν_{max} 3420, 3060, 3025, 2929, 1636, 1496, 1454, 1351, 1211, 1027 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.53–7.52 (m, 1H), 7.38–7.33 (m, 2H), 7.26–7.15 (m, 7H), 7.10–7.05 (m, 3H), 4.48–4.30 (m, 2H), 3.45–3.40 (m, 1H), 3.19–3.09 (m, 2H), 2.95–2.92 (m, 1H), 2.67–2.51 (m, 2H), 2.21–2.08 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 146.7, 141.5, 140.3, 137.6, 133.6, 131.8, 130.8, 130.2, 129.9, 129.7, 128.7, 128.5, 128.3, 128.0, 126.5, 126.2, 126.0, 47.7, 36.6, 33.0, 32.5, 31.5; LRMS (EI, M = $C_{25}H_{23}N_3$) *m/z* 365 (3%, M$^+$), 337 (11), 218 (37), 91 (100); HRMS (EI) calcd for $C_{25}H_{23}N_3$ (M$^+$) 365.1892, found 365.1890.

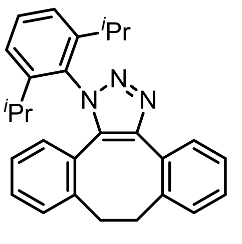
N-Benzyl-2-(8,9-dihydro-1*H*-dibenzo[3,4:7,8]cycloocta[1,2-*d*][1,2,3]triazol-1-yl)acetamide (8b)



8b

Colorless oil; R_f value 0.13 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3295, 3063, 2932, 1672, 1556, 1454, 1428, 1370, 1250 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.48–7.46 (dd, 1H, *J* = 7.0, 1.5 Hz), 7.38–7.12 (m, 12H), 6.68 (t, 1H, *J* = 5.0 Hz), 5.14 (d, 1H, *J* = 16.0 Hz), 5.01 (d, 1H, *J* = 16.5 Hz), 4.51 (dd, 1H, *J* = 14.5, 6.0 Hz), 4.40 (dd, 1H, *J* = 14.5, 5.5 Hz), 3.34–3.30 (m, 1H), 3.09 (d, 1H, *J* = 12.0 Hz), 3.04 (d, 1H, *J* = 11.5 Hz), 2.85–2.81 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.4, 147.0, 141.7, 137.8, 137.2, 135.1, 131.7, 130.9, 130.4, 130.2, 129.2, 129.0, 128.8, 128.4, 127.72, 127.67, 126.8, 126.1, 125.1, 51.3, 43.7, 36.3, 32.9; LRMS (EI, M = $C_{25}H_{22}N_4O$) *m/z* 394 (6%, M$^+$), 366 (32), 218 (100), 91 (53); HRMS (EI) calcd for $C_{25}H_{22}N_4O$ (M$^+$) 394.1794, found 394.1790.

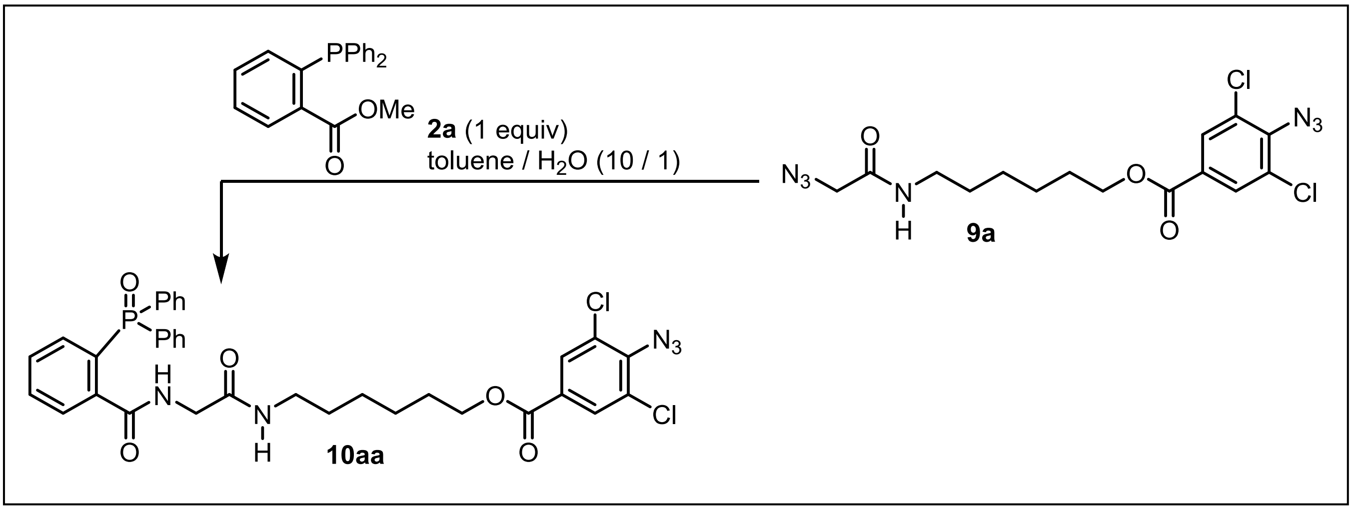
1-(2,6-Diisopropylphenyl)-8,9-dihydro-1*H*-dibenzo[3,4:7,8]cycloocta[1,2-*d*][1,2,3]triazole (8n)



8n

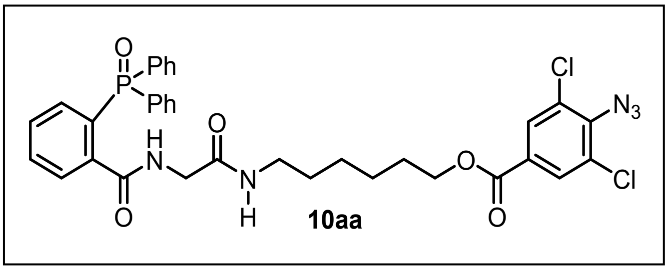
White solid; R_f value 0.45 (hexane / ethyl acetate = 5 / 1); m.p. 208.3–209.5 °C; IR (NaCl, neat) ν_{max} 3434, 3066, 2964, 2929, 2870, 1631, 1504, 1470, 1364 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70–7.68 (m, 1H), 7.43 (dd, 1H, *J* = 7.0 Hz), 7.31–7.17 (m, 7H), 6.94–6.91 (m, 1H), 6.70 (dd, 1H, *J* = 8.0, 1.0 Hz), 3.39 (s, 2H), 3.14 (s, 2H), 2.38 (s, 2H), 1.21–0.88 (m, 12H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 146.1, 141.5, 137.4, 135.0, 132.6, 131.8, 130.9, 130.6, 129.8, 129.6, 129.5, 128.7, 128.0, 126.0, 125.9, 123.9, 36.9, 32.6, 28.7, 25.5, 22.5; LRMS (EI, M = $C_{28}H_{29}N_3$) *m/z* 407 (13%, M$^+$), 379 (88), 364 (66), 186 (100); HRMS (EI) calcd for $C_{28}H_{29}N_3$ (M$^+$) 407.2361, found 407.2362.

[6] Site-selective Conjugation Using Diazides



Selective conjugation onto the α-AzSA position of 9a with 2a

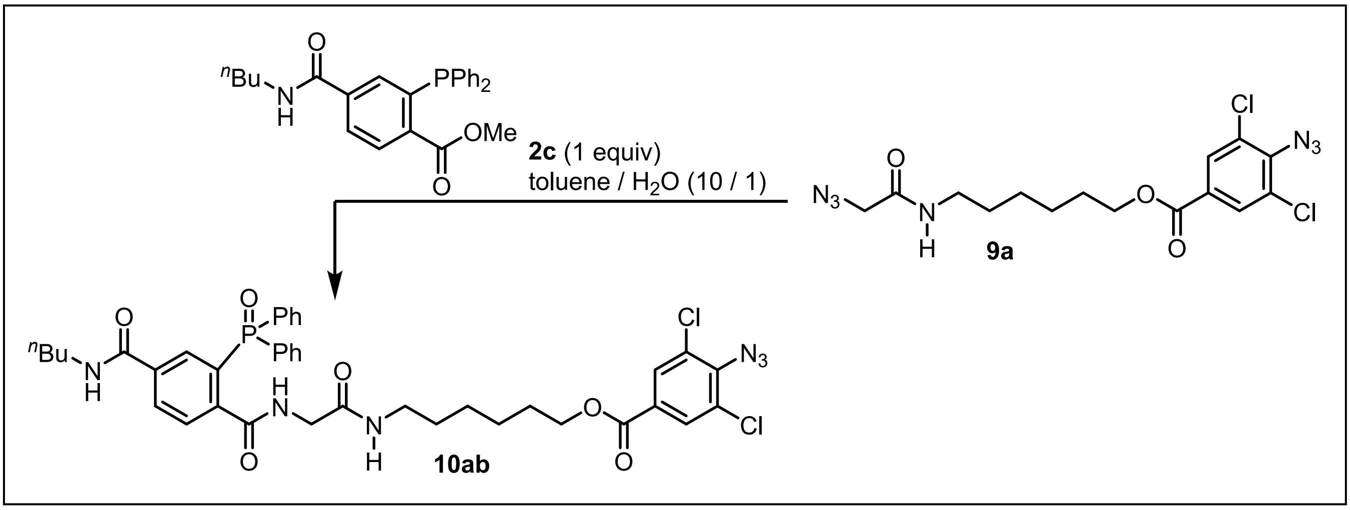
To a stirred solution of 6-(2-azidoacetamido)hexyl 4-azido-3,5-dichlorobenzoate **9a** (41.1 mg, 0.1 mmol) in toluene (1 mL) and water (0.1 mL), methyl 2-(diphenylphosphaneyl)benzoate **2a** (31.6 mg, 0.1 mmol) was added at room temperature under N_2 gas and stirred for 3 h. The reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (20% to 25% to 100% ethyl acetate in hexane) followed by recycling GPC for further purification to give **10aa** (63.3 mg, 91%) as colorless amorphous oil.



6-(2-(2-(Diphenylphosphoryl)benzamido)acetamido)hexyl 4-azido-3,5-dichlorobenzoate (10aa)

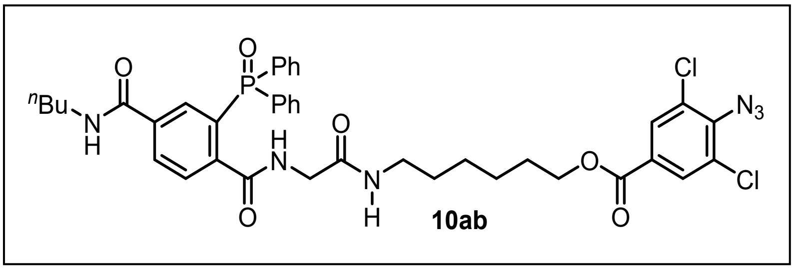
Colorless amorphous oil; R_f value 0.17 (ethyl acetate); IR (NaCl, neat) ν_{max} 3465, 3258, 3060, 2934, 2859, 2126, 1722, 1652, 1552, 1264 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.95–7.91 (m, 3H), 7.89–7.77 (m, 1H), 7.64–7.58 (m, 7H), 7.52–7.48 (m, 4H), 7.43–7.40 (m, 1H), 7.10 (dd, 1H, *J* = 7.5, 6.0 Hz), 4.28 (t, 2H, *J* = 6.5 Hz), 3.84 (d, 2H, *J* = 6.0 Hz), 3.24 (dt, 2H, *J* = 6.5 Hz), 1.77–1.71 (m, 2H), 1.57 (tt, 2H, *J* = 7.5, 7.0 Hz), 1.44–1.38 (m, 4H) ; ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.85, 168.80, 163.8, 140.9 (d, *J* = 7.2 Hz), 137.8, 133.4 (d, *J* = 10.8 Hz), 132.5, 131.8 (d, *J* = 9.6 Hz), 130.9, 130.2, 130.1, 129.7, 129.6, 129.1, 128.9, 128.8 (d, *J* = 12.0 Hz), 128.4, 65.9, 44.3, 39.4, 29.2, 28.4, 26.5, 25.6; ^{31}P NMR (202 MHz, $CDCl_3$) δ 34.5; HRMS (ESI) calcd for $C_{34}H_{32}{}^{35}Cl_2N_5O_5NaP$ $[M+Na]^+$ 714.1410, found 714.1426.

Selective conjugation onto the α-AzSA position of 9a with 2c



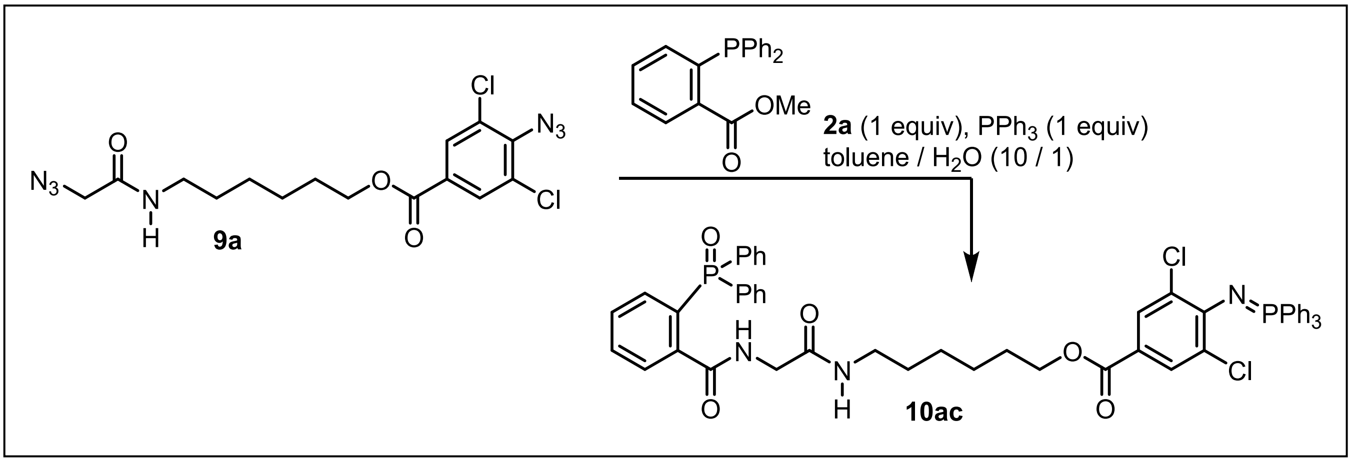
To a stirred solution of 6-(2-azidoacetamido)hexyl 4-azido-3,5-dichlorobenzoate **9a** (42.0 mg, 0.1 mmol) in toluene (1 mL) and water (0.1 mL), methyl 4-(butylcarbamoyl)-2-(diphenylphosphaneyl)benzoate **2c** (42.3 mg, 0.1 mmol) was added at room temperature under N_2 gas and stirred for 1 h. The reaction mixture was concentrated *in vacuo* and was purified by silicagel column chromatography (20% to 25% to 100% ethyl acetate in hexane to 14% methanol in ethyl acetate) to give **10ab** (48.0 mg, 61%) as a yellow oil and recovered **9a** (15.1 mg, 36%).

6-(2-(4-(Butylcarbamoyl)-2-(diphenylphosphoryl)benzamido)acetamido)hexyl 4-azido-3,5-dichlorobenzoate (10ab)


10ab

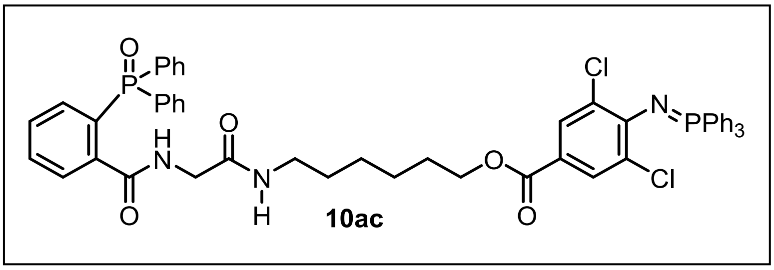
Yellow oil; R_f value 0.25 (ethyl acetate); IR (NaCl, neat) ν_{max} 3461, 3259, 3078, 2933, 2862, 2245, 2126, 1724, 1644, 1552, 1311, 1265 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.18 (s, 1H), 7.90 (s, 2H), 7.85 (d, 2H, $J = 8.0$ Hz), 7.64–7.55 (m, 7H), 7.48–7.44 (m, 4H), 6.97 (s, 1H), 4.26 (t, 2H, $J = 7.0$ Hz), 3.74 (d, 2H, $J = 5.5$ Hz), 3.32–3.28 (m, 2H), 3.22–3.18 (m, 2H), 2.23 (s, 1H), 1.72 (tt, 2H, $J = 7.0, 6.5$ Hz), 1.58–1.47 (m, 4H), 1.38–1.26 (m, 6H), 0.90 (t, 3H, $J = 7.5$ Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.8, 168.4, 165.6, 163.8, 143.0 (d, $J = 7.2$ Hz), 137.8, 135.9 (d, $J = 10.8$ Hz), 132.7 (d, $J = 13.2$ Hz), 132.6, 131.7 (d, $J = 9.7$ Hz), 131.0 (d, $J = 108$ Hz), 130.0 (overlapping two signals), 129.8, 129.6 (d, $J = 9.7$ Hz), 129.1, 128.8 (d, $J = 12.0$ Hz), 128.3, 65.8, 44.0, 39.9, 39.5, 31.3, 29.1, 28.4, 26.5, 25.5, 20.0, 13.7; ^{31}P NMR (202 MHz, $CDCl_3$) δ 33.8; HRMS (ESI) calcd for $C_{39}H_{41}{}^{35}Cl_2N_6O_6NaP$ $[M+Na]^+$ 813.2094, found 813.2102.

Selective three-component coupling with 9a by one-pot Staudinger-Bertozzi ligation / Staudinger reaction



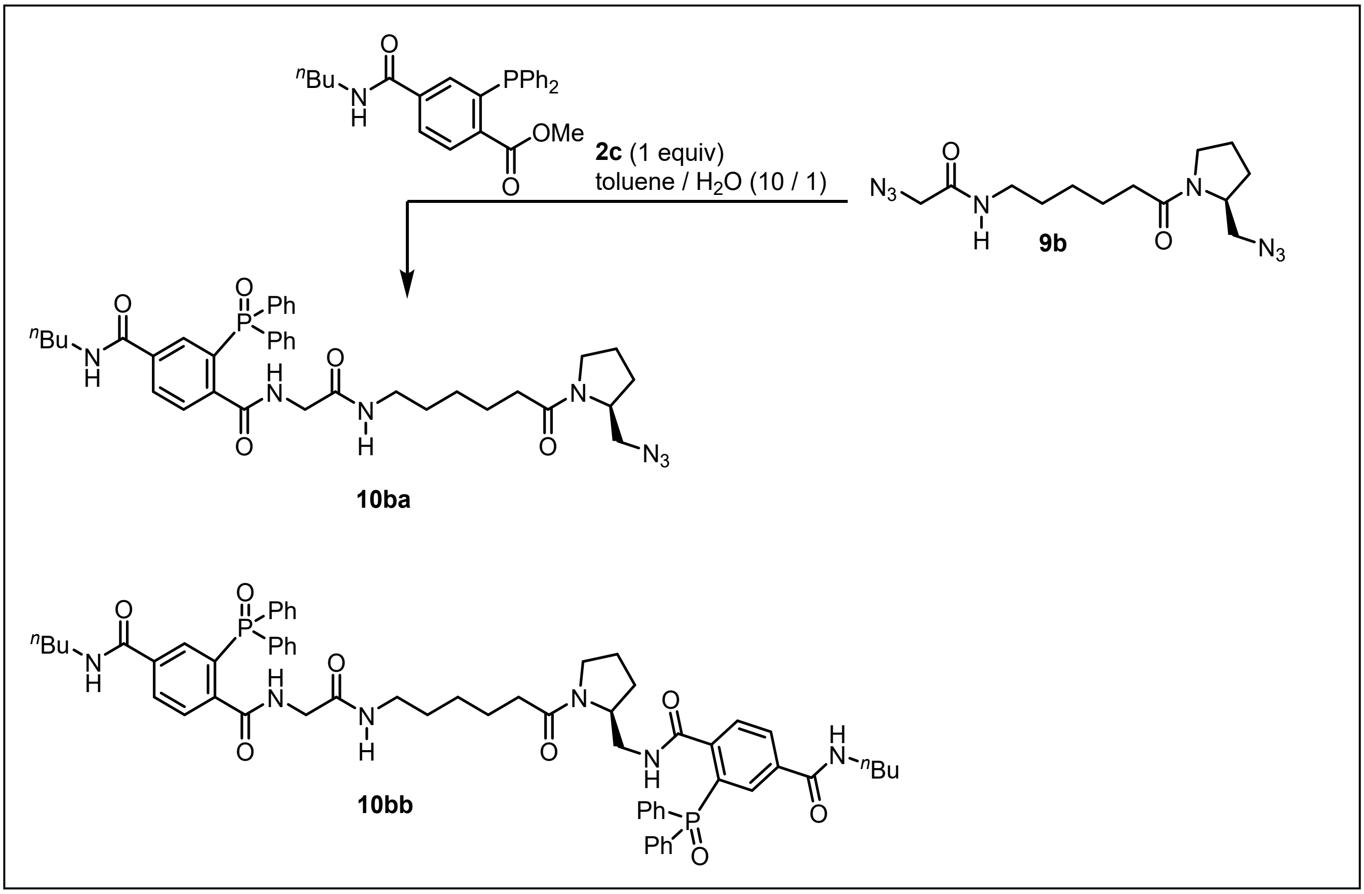
To a stirred solution of 6-(2-azidoacetamido)hexyl 4-azido-3,5-dichlorobenzoate **9a** (41.3 mg, 0.1 mmol) in toluene (1 mL) and water (0.1 mL), methyl 2-(diphenylphosphaneyl)benzoate **2a** (32.0 mg, 0.1 mmol) and triphenylphosphine (26.1 mg, 0.1 mmol) were added at room temperature under N_2 gas and stirred for 2 h. The reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (50% to 100% ethyl acetate in hexane to 67% methanol in ethyl acetate) to give **10ac** (79.5 mg, 86%) as colorless amorphous oil.

6-(2-(2-(Diphenylphosphoryl)benzamido)acetamido)hexyl 3,5-dichloro-4-((triphenyl-λ⁵-phosphaneylidene)amino)benzoate (10ac)


10ac

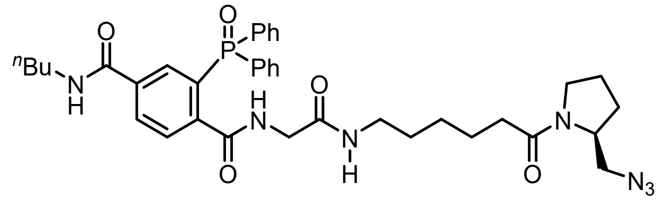
Colorless amorphous oil; R_f value 0.22 (ethyl acetate); IR (NaCl, neat) ν_{max} 3262, 3060, 2935, 2859, 2245, 1706, 1660, 1496, 1437, 1392, 1367, 1256 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.05 (br-s, 1H), 7.79–7.72 (m, 8H), 7.67–7.36 (m, 22H), 7.09 (dd, 1H, J = 7.0, 7.0 Hz), 4.18 (t, 2H, J = 7.0 Hz), 3.85 (d, 2H, J = 5.5 Hz), 3.24–3.20 (m, 2H), 1.69 (tt, 2H, J = 7.0, 6.5 Hz), 1.54 (tt, 2H, J = 7.5, 6.5 Hz), 1.40–1.35 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.8, 165.3, 141.0 (d, J = 7.3 Hz), 133.3 (d, J = 12.0 Hz), 132.5, 132.43, 132.39, 131.8, 131.7 (d, J = 13.2 Hz), 131.4, 131.3, 131.0, 130.6 (d, J = 7.3 Hz), 130.0 (d, J = 8.3 Hz), 129.7, 129.5 (d, J = 13.2 Hz), 129.1, 128.9, 128.7 (d, J = 13.2 Hz), 128.3 (d, J = 12.1 Hz), 64.8, 44.2, 39.4, 29.0, 28.5, 26.4, 25.6; ^{31}P NMR (202 MHz, $CDCl_3$) δ 34.3, 2.73; HRMS (ESI) calcd for $C_{52}H_{47}{}^{35}Cl_2N_3O_5NaP_2$ $[M+Na]^+$ 948.2266, found 948.2263.

Selective conjugation onto the α-AzSA position of 9b with 2c



To a stirred solution of (*S*)-2-azido-*N*-(6-(2-(azidomethyl)pyrrolidin-1-yl)-6-oxohexyl)acetamide **9b** (32.2 mg, 0.1 mmol) in toluene (1 mL) and water (0.1 mL), methyl 4-(butylcarbamoyl)-2-(diphenylphosphaneyl)benzoate **2c** (42.0 mg, 0.1 mmol) was added at room temperature under N_2 gas and stirred for 13 h. The reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (20% to 50% to 100% ethyl acetate in hexane to 5% to 6% to 17% methanol in dichloromethane) to give **10ba** (49.3 mg 70%) as a light-yellow oil and **10bb** (12.1 mg, 11% based on **9b**) as a white solid. Due to the difficulty of purification, the recovery yield of the unreacted diazide **9b** was measured from ^{1}H NMR (12%, based on a signal δ 3.98 ppm for 2H) in the presence of 1,1,2,2-tetrachloroethane (10.5 μL, 0.1 mmol, 1 equiv. to the starting materials, δ 5.96 ppm on ^{1}H NMR, 2H) as an internal standard after the silica gel purification above.

(*S*)-*N*^{1}-(2-((6-(2-(Azidomethyl)pyrrolidin-1-yl)-6-oxohexyl)amino)-2-oxoethyl)-*N*^{4}-butyl-2-(diphenylphosphoryl)terephthalamide (10ba)

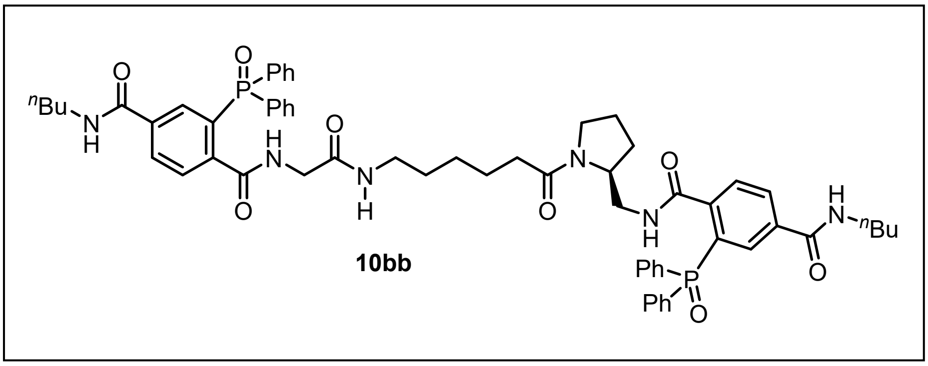


10ba

Light-yellow oil; R$_f$ value 0.43 (dichloromethane / methanol = 10 / 1); $[\alpha]_D^{25}$ -20.3 (c = 0.25, $CHCl_3$); IR (NaCl, neat) ν_{max} 3721, 3077, 2933, 2872, 2241, 2103, 1644, 1549, 1438, 1307, 1254, 1190, 1119 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.24 (s, 1H), 8.05 (s, 1H), 7.88 (d, 1H, *J* = 8.0 Hz), 7.67–7.55 (m, 7H), 7.49–7.46 (m, 4H), 7.05 (s, 1H), 4.13–4.10 (m, 1H), 3.76 (d, 2H, *J* = 5.5 Hz), 3.56 (dd, 1H, *J* = 12.5, 6.0 Hz), 3.46–3.29 (m, 5H), 3.22–3.18 (m, 2H), 2.29–2.21 (m, 3H), 2.03–1.84 (m, 4H), 1.62–1.47 (m, 6H), 1.37–1.28 (m, 4H), 0.90 (t, 3H, *J* = 7.5 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.3, 168.9, 168.5, 165.7, 143.2 (d, *J* = 7.3 Hz), 135.7 (d, *J* = 12.0), 132.7 (d, *J* = 12.0 Hz), 132.5, 131.8 (d, *J* = 9.7 Hz), 131.1 (d, *J* = 107 Hz), 130.2 (d, *J* = 98.5 Hz), 130.0, 129.5 (d, *J*

=6.0 Hz), 128.7 (d, 13.2 Hz), 56.2, 52.0, 47.4, 43.9, 39.9, 39.4, 34.7, 31.3, 28.8, 27.9, 26.6, 24.2, 24.1, 20.0, 13.7; ^{31}P NMR (202 MHz, CDCl$_3$) δ 33.5; HRMS (ESI) calcd for $C_{37}H_{46}N_7O_5NaP$ [M+Na]$^+$ 722.3196, found 722.3195.

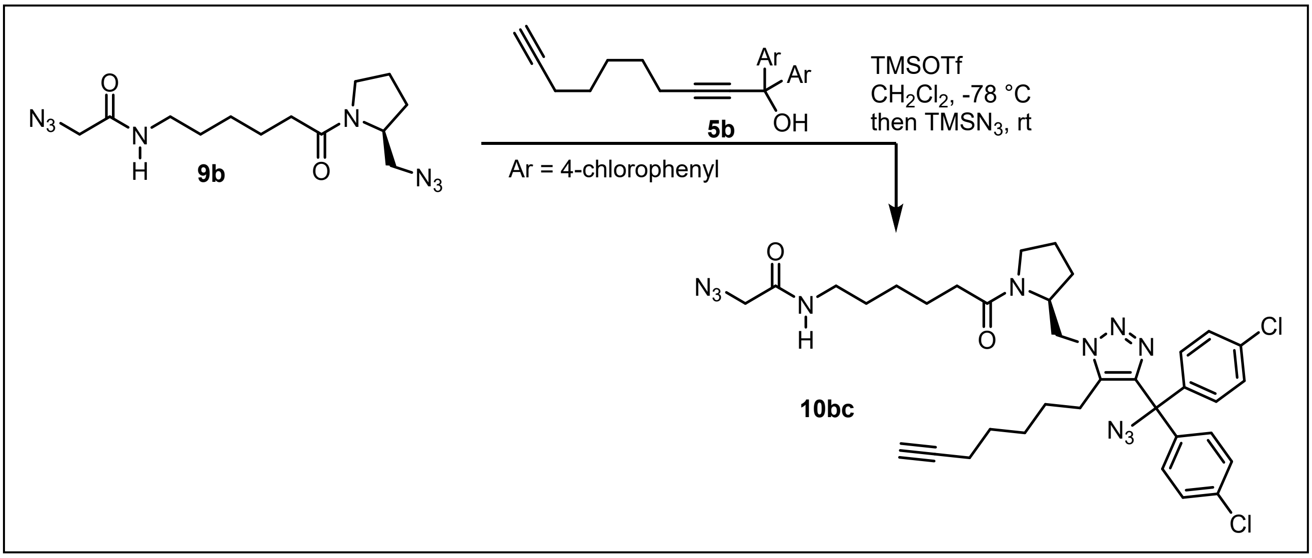
(*S*)-*N*^{4}-Butyl-*N*^{1}-((1-(6-(2-(4-(butylcarbamoyl)-2-(diphenylphosphoryl)benzamido)acetamido)hexanoyl)pyrrolidin-2-yl)methyl)-2-(diphenylphosphoryl)terephthalamide (10bb)



10bb

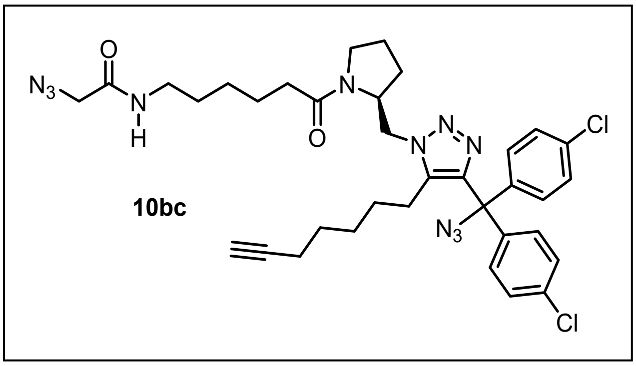
white solid; R$_f$ value 0.23 (dichloromethane / methanol = 10 / 1); $[\alpha]_D^{25}$ −1.95 (c = 1.0, CHCl$_3$); m.p. 149.7–150.6 °C; IR (KBr, neat) ν_{max} 3271, 3061, 2956, 2930, 2871, 1645, 1542, 1438, 1310, 1254, 1184, 1119, 1103 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.45 (s, 2H), 8.01–7.96 (m, 2H), 7.74–7.42 (m, 22H), 3.97–3.70 (m, 3H), 3.43–3.17 (m, 8H), 2.87 (s, 2H), 2.50 (br-s, 3H), 2.25–2.20 (m, 2H), 1.84–1.26 (m, 18H), 0.90–0.85 (m, 6H); ^{13}C NMR (126 MHz, DMSO-d6) δ 171.0, 168.1, 166.6, 164.7, 164.6, 164.5, 134.8, 132.5, 131.9, 131.8, 131.7, 131.4, 131.3, 129.9, 128.5, 128.3 (d, *J* = 10.8 Hz), 127.9 (d, *J* = 12.1 Hz), 55.5, 46.2, 42.9, 41.2, 38.7, 38.4, 33.7, 30.82, 30.80, 28.5, 27.1, 25.9, 23.8, 23.2, 19.3, 13.3; ^{31}P NMR (202 MHz, DMSO-d6) δ 30.2, 29.9; HRMS (ESI) calcd for $C_{61}H_{70}N_6O_8NaP_2$ [M+Na]$^+$ 1099.4628, found 1099.4620.

Selective conjugation onto the unfunctionalized alkyl azide position of 9b with 5b



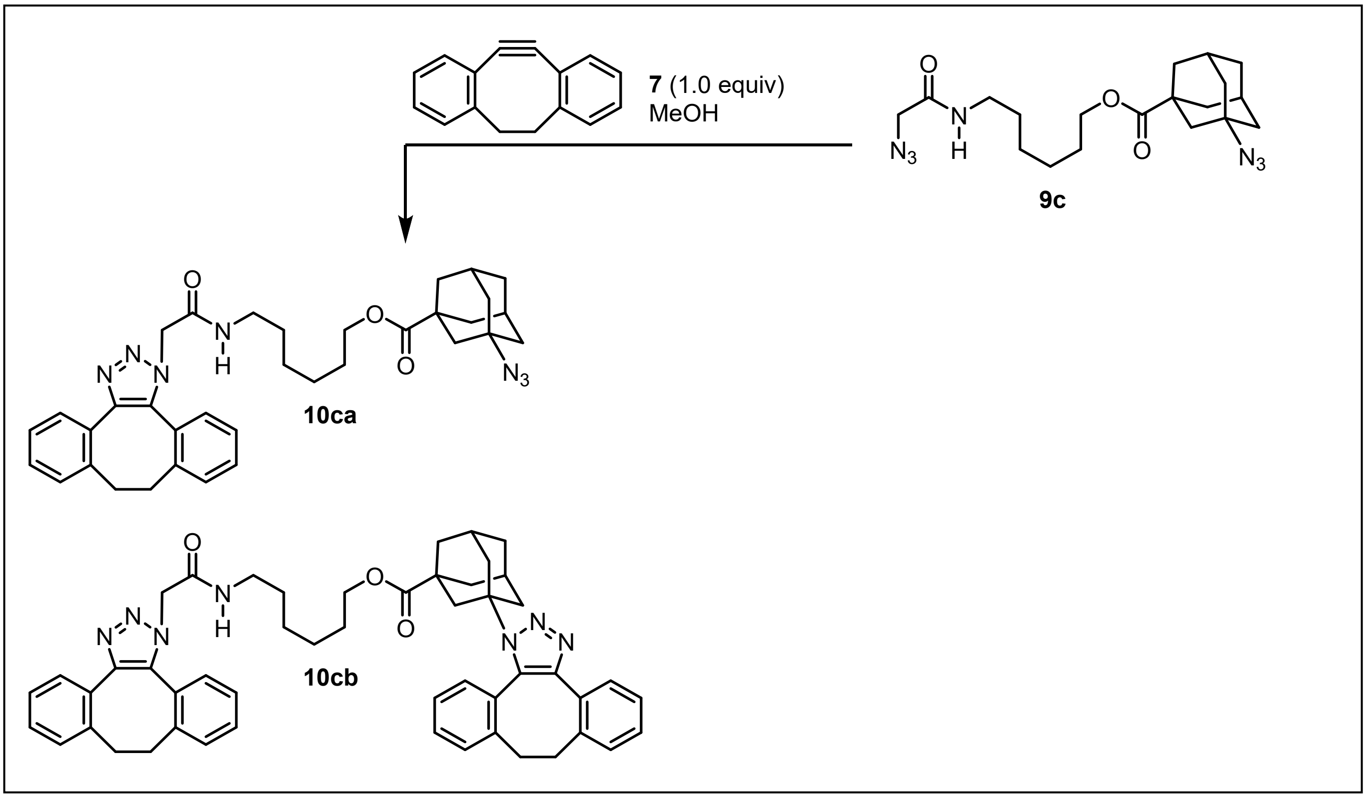
To a stirred solution of (*S*)-2-azido-*N*-(6-(2-(azidomethyl)pyrrolidin-1-yl)-6-oxohexyl)acetamide **9b** (32.5 mg, 0.1 mmol) and 1,1-bis(4-chlorophenyl)deca-2,9-diyn-1-ol **5b** (37.2 mg, 0.1 mmol) in dichloromethane (1 mL) under N_2 gas atmosphere, TMSOTf (45 µL, 0.25 mmol) was added at −78 °C and stirred for 5 min. Then, trimethylsilyl azide ($TMSN_3$, 39.3 µL, 0.3 mmol) was added to the mixture, and the mixture was warmed up to room temperature. After 30 min, the reaction was quenched by saturated $NaHCO_3$ aq. The organic components were extracted with dichloromethane and was washed with brine. The combined organic layer was dried over sodium sulfate. The concentration of the collected organic layer *in vacuo* followed by silica gel column chromatography (from hexane elution to 50% -> 60% -> 67% -> 100% ethyl acetate in hexane) gave **10bc** (14.4 mg, 20%) as a light yellow oil and the recovered starting material **9b** (19.1 mg, 59%).

(*S*)-2-Azido-*N*-(6-(2-((4-(azidobis(4-chlorophenyl)methyl)-5-(hept-6-yn-1-yl)-1*H*-1,2,3-triazol-1-yl)methyl)pyrrolidin-1-yl)-6-oxohexyl)acetamide (10bc)



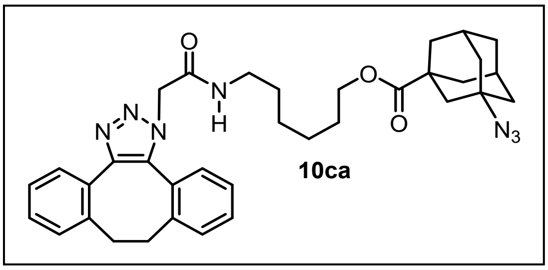
Light yellow oil; R_f value 0.58 (ethyl acetate); $[\alpha]_D^{23}$ −3.1 (c = 0.25, $CHCl_3$); IR (NaCl, neat) ν_{max} 3303, 2937, 2862, 2105, 1641, 1542, 1490, 1422, 1251, 1093 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35–7.31 (m, 4H), 7.28–7.24 (m, 4H), 6.51 (br-s, 1H), 4.46 (dd, 1H, *J* = 4.0, 9.0 Hz), 4.38–4.35 (m, 1H), 4.27 (dd, 1H, *J* = 7.5, 5.5 Hz), 3.95 (d, 2H, *J* = 1.5 Hz), 3.49–3.24 (m, 5H), 2.66–2.60 (m, 1H), 2.45–2.39 (m, 1H), 2.27 (t, 2H, *J* = 7.5 Hz), 2.14–2.08 (m, 2H), 1.98–1.84 (m, 4H), 1.70–1.62 (m, 2H), 1.57–1.50 (m, 2H), 1.41–1.33 (m, 4H), 1.27–1.18 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.4, 166.6, 144.8, 140.2, 140.1, 136.5, 134.2, 129.49, 129.45, 128.58, 128.47, 84.2, 71.2, 68.4, 56.5, 52.6, 49.0, 47.1, 39.1, 34.5, 29.1, 28.4, 28.3, 27.8, 27.5, 26.5, 24.0, 23.7, 22.6, 18.1; HRMS (ESI) calcd for $C_{35}H_{41}{}^{35}Cl_2N_{11}O_2Na$ $[M+Na]^+$ 740.2719, found 740.2715.

Selective conjugation onto the α-AzSA position of 9c with 7



To a stirred solution of 6-(2-azidoacetamido)hexyl 3-azidoadamantane-1-carboxylate **9c** (10.1 mg, 0.025 mmol) in methanol (0.25 mL) under N_2 gas atmosphere, dibenzocyclooctyne **7** (5.1 mg, 0.025 mmol) was added at room temperature. After 3 h, the reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (33% to 40% to 50% ethyl acetate in hexane) to give **10ca** (12.6 mg, 83 %) as a colorless oil and an overreaction product **10cb** (1.7 mg, 8 % based on the starting material diazide **9c**) as a colorless oil.

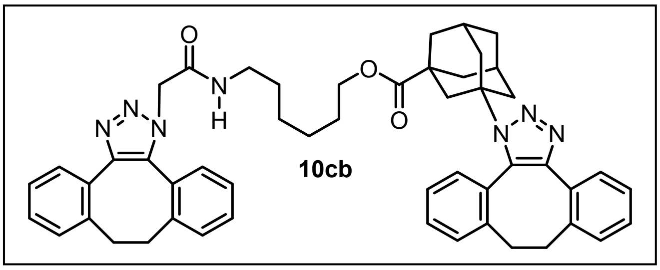
6-(2-(8,9-Dihydro-1*H*-dibenzo[3,4:7,8]cycloocta[1,2-d][1,2,3]triazol-1-yl)acetamido)hexyl 3-azidoadamantane-1-carboxylate (10ca)



10ca

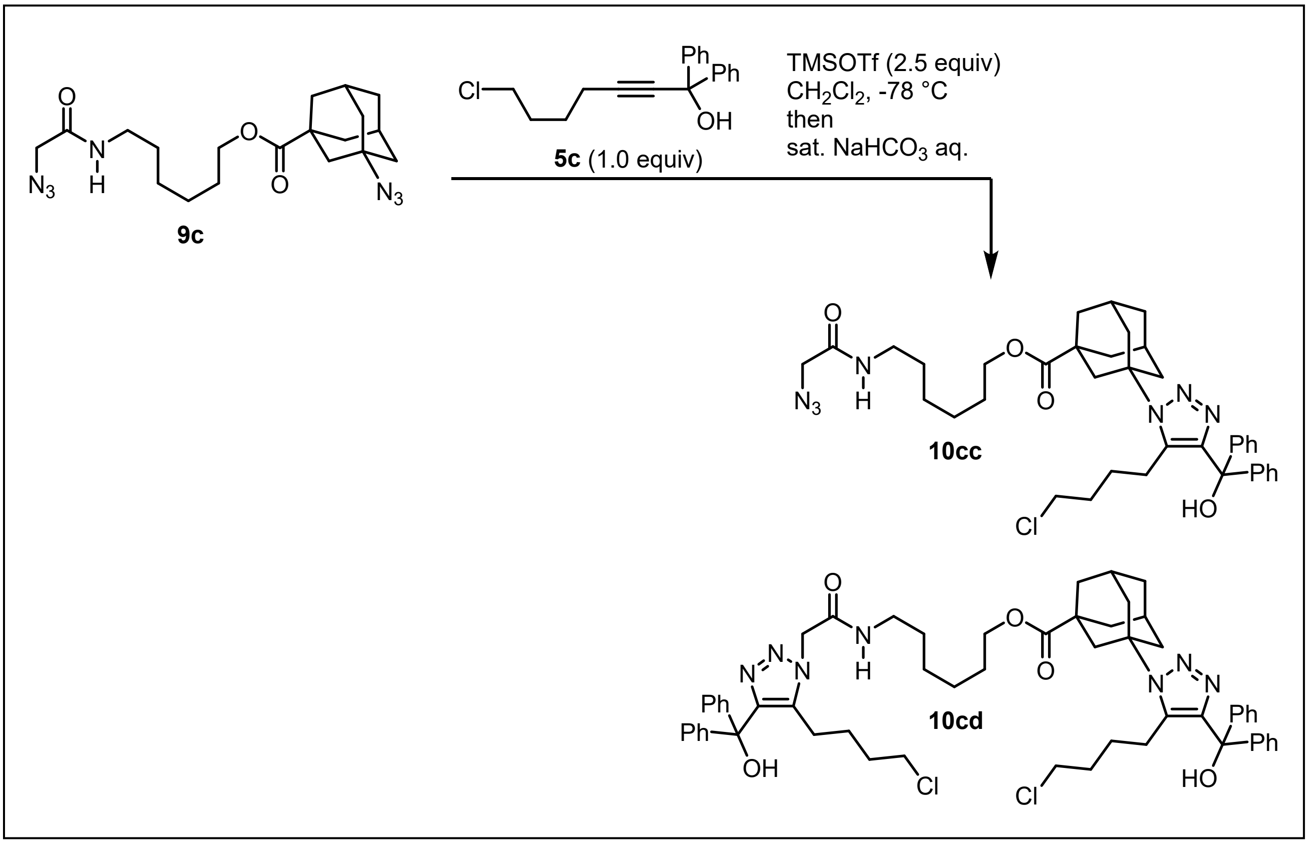
Colorless oil; R_f value 0.37 (hexane / ethyl acetate = 1 / 2); IR (NaCl, neat) ν_{max} 3309, 3065, 2933, 2858, 2089, 1724, 1692, 1669, 1555, 1454, 1247, 1089 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.53–7.51 (m, 1H), 7.37 (d, 2H, *J* = 4.0 Hz), 7.29–7.18 (m, 4H), 7.14 (d, 1H, *J* = 7.5 Hz), 6.39 (br-s, 1H), 5.09 (d, 1H, *J* = 16.5 Hz), 4.94 (d, 1H, *J* = 16.0 Hz), 4.05 (t, 2H, *J* = 6.5 Hz), 3.42–3.39 (m, 1H), 3.32–3.25 (m, 2H), 3.15–3.13 (m, 2H), 2.96–2.93 (m, 1H), 2.27 (t, 2H, *J* = 3.0 Hz), 1.91 (s, 2H), 1.85–1.72 (m, 8H), 1.64–1.58 (m, 4H), 1.51–1.49 (m, 2H), 1.35–1.30 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 176.0, 165.4, 146.9, 141.6, 137.8, 135.1, 131.7, 131.0, 130.4, 130.2, 129.1, 129.0, 128.4, 126.8, 126.1, 125.1, 64.3, 58.8, 51.3, 43.0, 42.5, 40.5, 39.7, 37.5, 36.4, 34.8, 33.0, 29.3, 29.2, 28.4, 26.3, 25.4; HRMS (ESI) calcd for $C_{35}H_{40}N_7O_3$ [M-H]$^-$ 606.3198, found 606.3197.

6-(2-(8,9-Dihydro-1*H*-dibenzo[3,4:7,8]cycloocta[1,2-d][1,2,3]triazol-1-yl)acetamido)hexyl 3-(8,9-dihydro-1*H*-dibenzo[3,4:7,8]cycloocta[1,2-d][1,2,3]triazol-1-yl)adamantane-1-carboxylate (10cb)



10cb

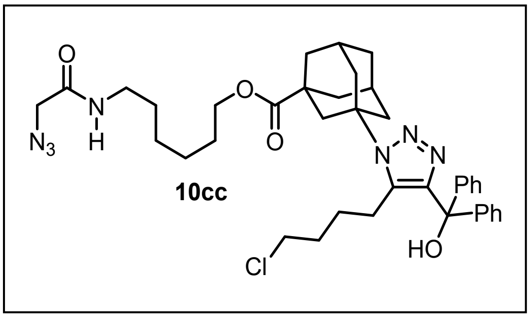
Colorless oil; R$_f$ value 0.28 (hexane / ethyl acetate = 1 / 2); IR (NaCl, neat) ν_{max} 3241, 3063, 2933, 2859, 2089, 1723, 1689, 1551, 1453, 1245, 1079 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.53–7.52 (m, 1H), 7.39–7.14 (m , 14H), 7.05–7.04 (m, 1H), 6.69 (br-s, 1H), 5.07–5.05 (m, 1H), 4.95–4.92 (m, 1H), 4.06 (t, 2H, *J* = 6.0 Hz), 3.43–3.40 (m, 1H), 3.31–3.26 (m, 2H), 3.17–3.13 (m, 2H), 3.01–2.89 (m, 3H), 2.66 (d, 1H, *J* = 11 Hz), 2.43 (d, 1H, *J* = 12 Hz), 2.32–2.15 (m, 6H), 1.91–1.55 (m, 12H), 1.35–1.25 (m, 4H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 175.8, 165.5, 146.8, 145.3, 141.7, 138.1, 137.8, 135.2, 133.8, 131.7, 131.3, 131.0, 130.9, 130.32, 130.27, 130.1, 129.7, 129.3, 129.1, 128.3, 126.7, 126.1, 126.0, 125.7, 125.3, 64.4, 44.1, 43.0, 42.3, 41.5, 39.8, 37.4, 36.4, 34.7, 33.1, 32.8, 29.4, 29.3, 29.2, 28.3, 26.3, 25.7; HRMS (ESI) calcd for $C_{51}H_{52}N_7O_3$ [M-H]$^-$ 810.4137, found 810.4131.



Selective conjugation onto the *tert*-alkyl azide position of 9c with 5b

To a stirred solution of 6-(2-azidoacetamido)hexyl 3-azidoadamantane-1-carboxylate **9c** (10.3 mg, 0.025 mmol) and 7-chloro-1,1-diphenylhept-2-yn-1-ol **5c** (7.7 mg, 0.025 mmol) in dichloromethane (0.25 mL) under N_2 gas atmosphere, TMSOTf (11.3 μL, 0.0625 mmol) was added at –78 °C. After 5 min, the reaction was quenched by saturated $NaHCO_3$ aq. The organic components were extracted with dichloromethane and washed with brine. The combined organic layer was dried over sodium sulfate. The concentration of the collected organic layer *in vacuo*, followed by purification by silica gel column chromatography (33% to 40% to 50% ethyl acetate in hexane), gave **10cc** (8.3 mg, 47%) as a colorless oil, an overreaction product **10cd** (1.9 mg, 7% based on the starting material diazide **9c**) as a colorless oil, and the recovered starting material **9c** (4.5 mg, 45%).

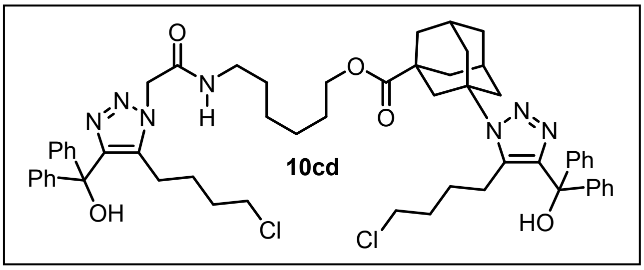
6-(2-Azidoacetamido)hexyl 3-(5-(4-chlorobutyl)-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)adamantane-1-carboxylate (10cc)



10cc

Colorless oil; R_f value 0.38 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3302, 2933, 2859, 2103, 1721, 1664, 1542, 1491, 1448, 1246, 1096, 1076 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34–7.28 (m, 10H), 6.47 (br-s, 1H), 4.26 (br-s, 1H), 4.08 (t, 2H, *J* = 7.0 Hz), 3.89 (s, 2H), 3.32–3.25 (m, 4H), 2.51 (s, 2H), 2.43–2.33 (m, 8H), 1.96–1.91 (m, 4H), 1.78–1.75 (m, 2H), 1.65–1.61 (m, 2H), 1.58–1.53 (m, 2H), 1.47–1.36 (m, 6H), 1.22–1.19 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 175.8, 166.5, 149.5, 145.4, 134.5, 127.94, 127.89, 127.6, 78.0, 64.5, 63.1, 52.6, 44.0, 43.1, 43.0, 41.3, 39.3, 37.5, 34.8, 32.2, 29.3, 28.3, 26.9, 26.3, 25.6, 24.0; HRMS (ESI) calcd for $C_{38}H_{47}{}^{35}ClN_7O_4$ [M-H]$^-$ 700.3384, found 700.3372.

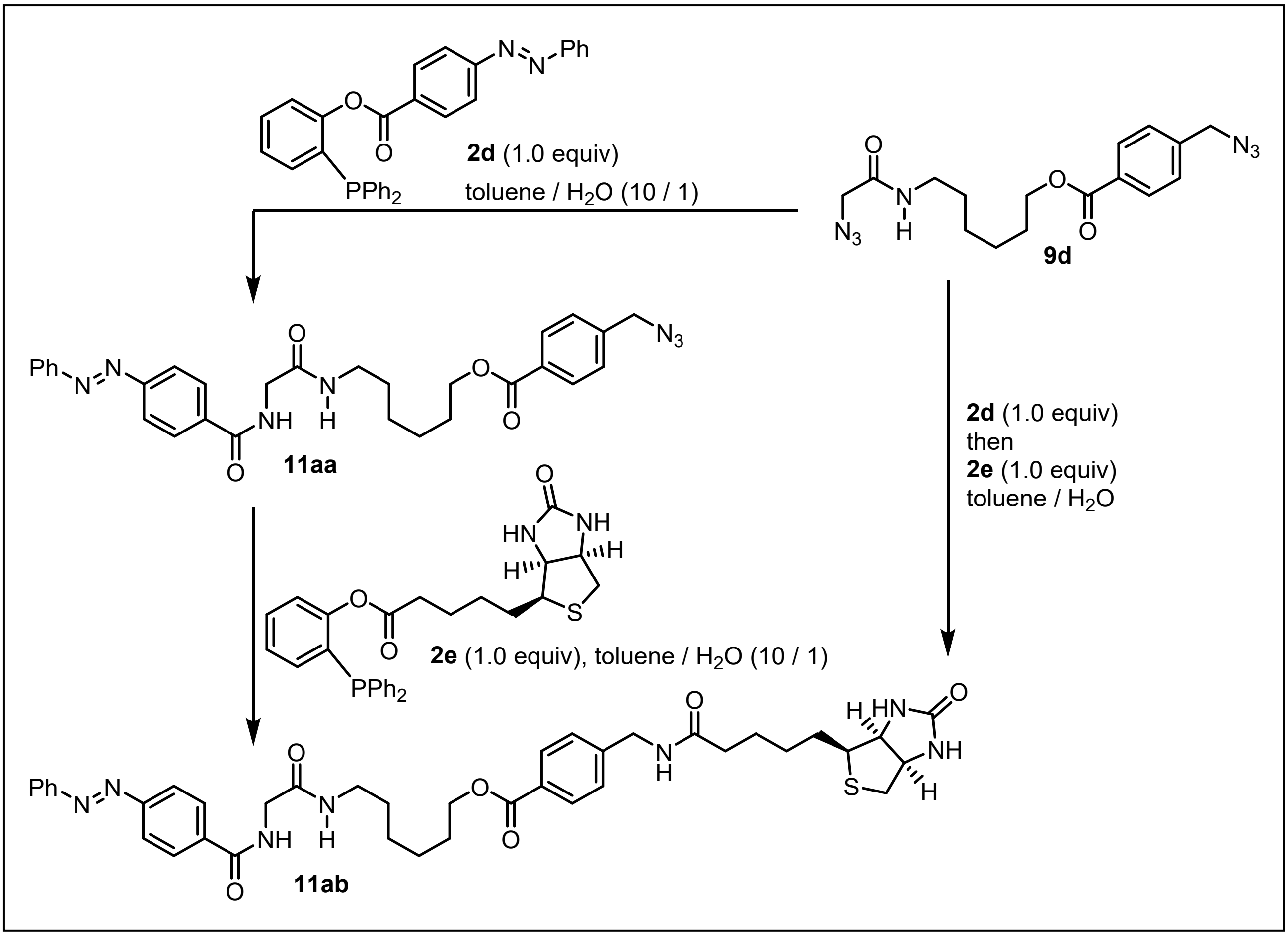
6-(2-(5-(4-Chlorobutyl)-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)acetamido)hexyl 3-(5-(4-chlorobutyl)-4-(hydroxydiphenylmethyl)-1*H*-1,2,3-triazol-1-yl)adamantane-1-carboxylate (10cd)

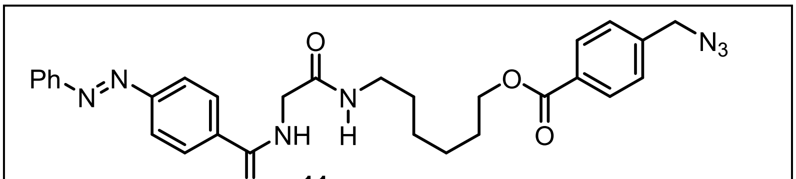


10cd

Colorless oil; R$_f$ value 0.13 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3307, 2928, 2858, 2091, 1719, 1671, 1538, 1448, 1246 cm^{-1}; ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.31–7.27 (m, 20H), 4.73 (br-s, 1H), 4.09–4.05 (m, 3H), 3.31–3.23 (m, 7H), 2.56 (s, 2H), 2.38–2.28 (m, 8H), 2.18–2.13 (m, 2H), 1.98–1.92 (m, 4H), 1.84–1.14 (m, 20H); ^{13}C NMR (126 MHz, CDCl$_3$) δ 175.8, 165.2, 149.4, 149.1, 145.2, 145.1, 135.5, 135.1, 128.1, 128.0, 127.9, 127.8, 127.74, 127.66, 77.9, 77.8, 64.5, 64.3, 44.2, 44.1, 43.3, 43.0, 41.3, 40.5, 39.7, 37.49, 37.45, 34.8, 32.2, 29.3, 29.2, 28.2, 27.0, 26.1, 25.8, 25.6, 24.0, 22.2; HRMS (ESI) calcd for $C_{57}H_{66}{}^{35}Cl_2N_7O_5$ [M-H]$^-$ 998.4508, found 998.4516.

Selective conjugation of diazide 9d by prior use of α-AzSA position





11aa

(*E*)-6-(2-(4-(Phenyldiazenyl)benzamido)acetamido)hexyl 4-(azidomethyl)benzoate (11aa)

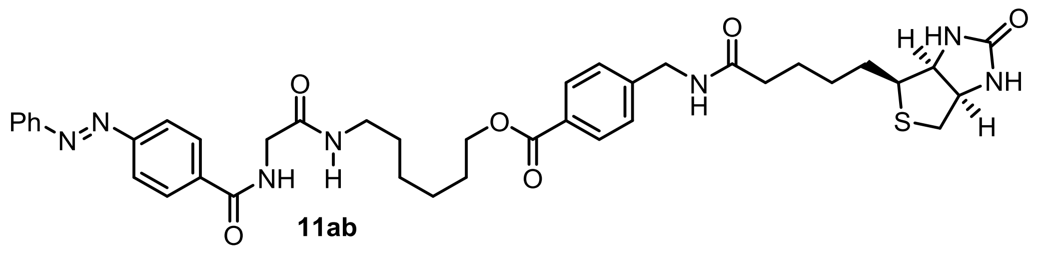
0.2 mmol scale reaction: To a stirred solution of 6-(2-azidoacetamido)hexyl 4-(azidomethyl)benzoate **9d** (71.9 mg, 0.2 mmol) in toluene (2 mL) and water (0.2 mL) under N_2 gas atmosphere, 2-(diphenylphosphaneyl)phenyl (*E*)-4-(phenyldiazenyl)benzoate **2d** (97.3 mg, 0.2 mmol) was added at room temperature. After 29 h at the same temperature, the reaction mixture was concentrated *in vacuo*. The obtained material was purified by silica gel column chromatography (9% to 25% to 40% to 50% to 60% ethyl acetate in hexane to ethyl acetate elution) to give **11aa** (84.6 mg, 78%) as an orange solid.

1 mmol scale reaction: A reaction with **9d** (359 mg, 1 mmol) and **2d** (486.7 mg, 1 mmol) in toluene (10 mL) and water (1 mL) in 29 h gave **11aa** (455 mg, 84%) as an orange solid.

Orange solid; R_f value 0.18 (hexane / ethyl acetate = 1 / 2); m.p. 140–141 °C; IR (KBr, neat) ν_{max} 3307, 3066, 2932, 2854, 2102, 1715, 1650, 1633, 1541, 1283, 1247, 1106 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.05 (d, 2H, *J* = 8.0 Hz), 7.99–7.95 (m, 6H), 7.55–7.52 (m, 3H), 7.40 (d, 2H, *J* = 8.0 Hz), 7.07–7.05 (m, 1H), 6.05 (br-s, 1H), 4.42 (s, 2H), 4.33 (t, 2H, *J* = 6.5 Hz), 4.15 (d, 2H, *J* = 4.5 Hz), 3.34 (dt, 2H, *J* = 6.5, 6.5 Hz), 1.80–1.77 (m, 2H), 1.60–1.58 (m, 2H), 1.48–1.42 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.7, 167.0, 166.2, 154.4, 152.4, 140.3, 135.1, 131.7, 130.2, 130.1, 129.2, 128.1, 127.9, 123.1, 122.9, 64.9, 54.2, 43.8, 39.5, 29.3, 28.5, 26.4, 25.6; HRMS (ESI) calcd for

$C_{29}H_{31}N_7NaO_4$ [M+Na]$^+$ 564.2335, found 564.2331. UV-vis ($CHCl_3$) $\lambda_{max}(\varepsilon)$ 326 (16000), 449 (453) nm.

6-(2-(4-((*E*)-phenyldiazenyl)benzamido)acetamido)hexyl 4-((5-((4*S*)-2-oxohexahydro-1*H*-thieno[3,4-d]imidazol-4-yl)pentanamido)methyl)benzoate (11ab)



11ab

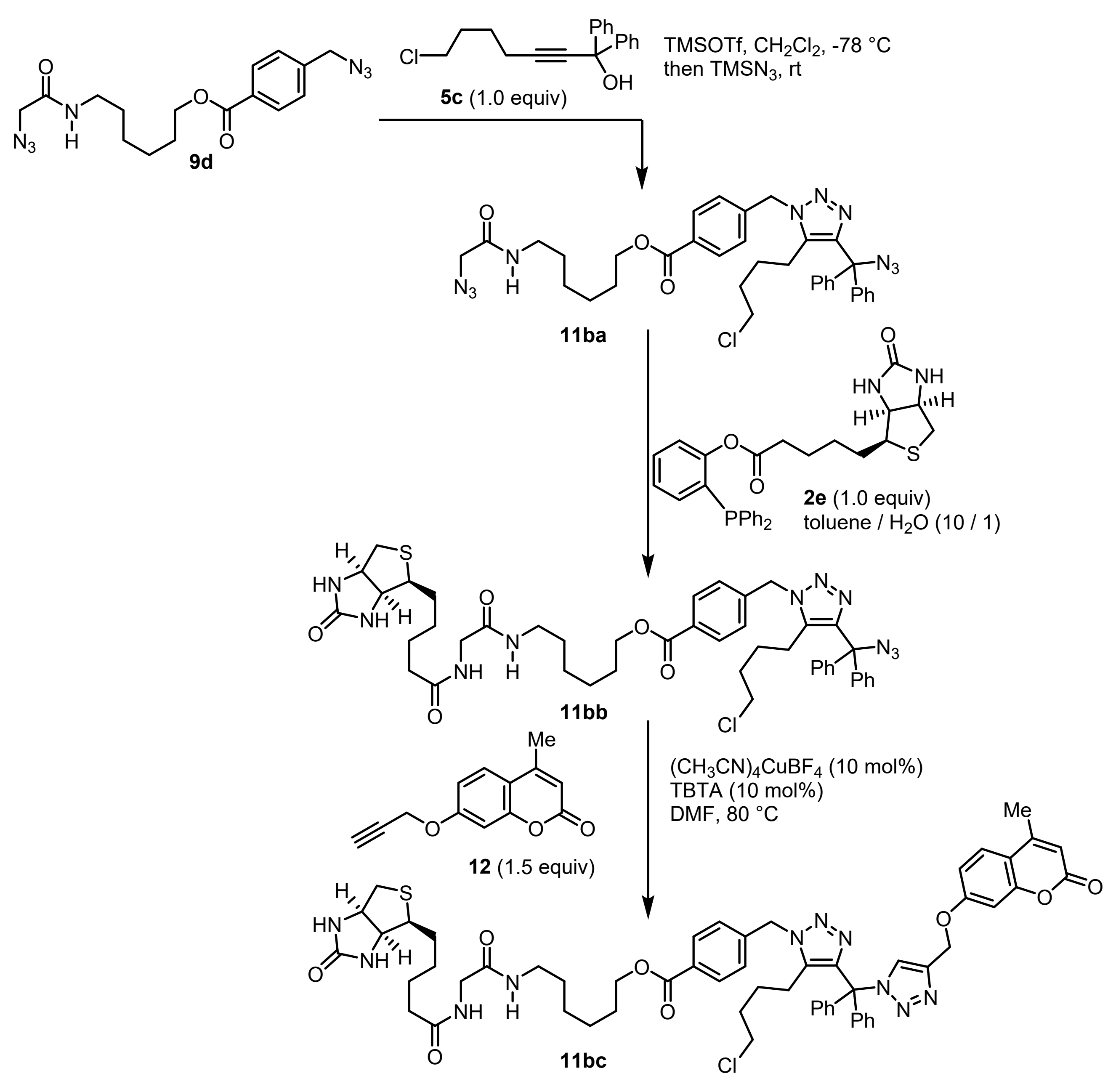
To a stirred solution of (*E*)-6-(2-(4-(phenyldiazenyl)benzamido)acetamido)hexyl 4-(azidomethyl)benzoate **11aa** (13.5 mg, 0.025 mmol) in toluene (0.25 mL) and water (0.025 mL) under N_2 gas atmosphere, 2-(diphenylphosphaneyl)phenyl 5-((4*R*)-2-oxohexahydro-1*H*-thieno[3,4-*d*]imidazol-4-yl)pentanoate **2e** (12.8 mg, 0.025 mmol) was added at room temperature. After 24 h at the same temperature, the reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (2% to 5% to 9% to 17% methanol in dichloromethane) to give **11ab** (9.3 mg, 50%) as an orange solid.

Orange solid; R_f value 0.20 (dichloromethane / methanol = 10 / 1); m.p. 202.5–203.2 °C; $[\alpha]_D^{29}$ +14.5 (c = 0.1, DMSO); IR (KBr, neat) ν_{max} 3286, 3070, 2931, 2856, 1700, 1674, 1645, 1543, 1465, 1416, 1387, 1280, 1177, 1154, 1106 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.97 (t, 1H, *J* = 6.0 Hz), 8.44 (t, 1H, *J* = 6.5 Hz), 8.11–8.09 (m, 2H), 8.00–7.90 (m, 7H), 7.65–7.61 (m, 3H), 7.37 (d, 2H, *J* = 8.5 Hz), 6.47 (br-s, 1H), 6.39 (br-s, 1H), 4.32–4.24 (m, 5H), 4.13–4.10 (m, 1H), 3.86 (d, 2H, *J* = 5.5 Hz), 3.10–3.06 (m, 3H), 2.81 (dd, *J* = 5.0, 7.0 Hz), 2.71 (d, 1H, *J* = 12.0 Hz), 2.15 (t, 2H, *J* = 7.5 Hz), 1.71–1.68 (m, 2H), 1.61–1.23 (m, 12H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.2, 168.5, 165.6, 163.8, 162.7, 153.3, 151.9, 145.4, 136.2, 132.0, 129.6, 129.2, 128.7, 128.3, 128.1, 127.3, 122.7, 122.3, 64.5, 61.0, 59.2, 55.4, 42.7, 41.8, 40.0, 38.5, 35.1, 29.0, 28.2, 28.1, 28.0, 26.0, 25.3, 25.2; HRMS (ESI) calcd for $C_{39}H_{47}N_7O_6NaS$ [M+Na]$^+$ 764.3206, found 764.3216. UV-vis (DMSO) $\lambda_{max}(\varepsilon)$ 329 (43500), 449 (1340) nm.

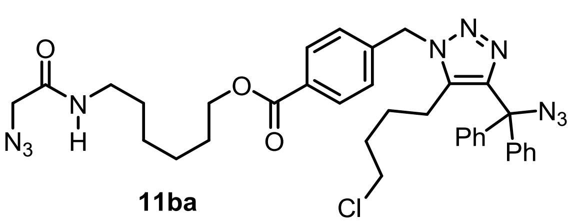
One-pot sequential traceless Staudinger-Bertozzi ligation from diazide 9c to three-component coupling product 11ab

To a stirred solution of diazide **9d** (28.4 mg, 0.079 mmol) in toluene (0.8 mL) and water (0.08 mL) under N_2 gas atmosphere, **2d** (38.3 mg, 0.079 mmol) was added at room temperature and stirred for 30 h. Then, **2e** (39.9 mg, 0.079 mmol) was added at the same temperature. After an additional stir for 30 h, the reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (5% to 9% to 17% methanol in dichloromethane) to give **11ab** (27.9 mg, 48%) as an orange solid through the one-pot reaction.

Selective conjugation of diazide 9d by prior use of benzylic position



6-(2-azidoacetamido)hexyl 4-((4-(azidodiphenylmethyl)-5-(4-chlorobutyl)-1*H*-1,2,3-triazol-1-yl)methyl)benzoate (11ba)


11ba

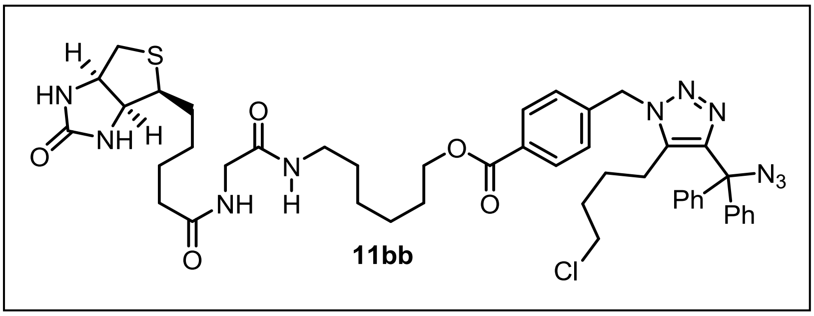
0.1 mmol scale reaction: To a stirred solution of 6-(2-azidoacetamido)hexyl 4-(azidomethyl)benzoate **9d** (36.1 mg, 0.1 mmol) and 7-chloro-1,1-diphenylhept-2-yn-1-ol **5c** (30.1 mg, 0.1 mmol) in dichloromethane (1 mL) under N_2 gas atmosphere, TMSOTf (45 µL, 0.25 mmol) was added at –78 °C. After 5 min at the same temperature, $TMSN_3$ (39 µL, 0.3 mmol) was added to the mixture, and then the stirred mixture was warmed up to room temperature. After 30 min, the reaction was quenched by saturated sodium bicarbonate aqueous solution. The organic components were extracted with dichloromethane. The organic layer was washed with brine and was dried over sodium sulfate. The concentration of the collected organic layer *in vacuo* followed by silica gel column chromatography (9% to 17% to 25% to 33% to 40% to 50% ethyl acetate in hexane) gave **11ba** (51.7 mg, 76%) as a colorless oil and recovered starting material **9d**

(2.7 mg, 7.5%).

1 mmol scale reaction: A reaction with **9d** (359 mg, 1 mmol), **5c** (298.9 mg, 1 mmol), TMSOTf (0.45 mL, 2.5 mmol), and $TMSN_3$ (0.4 mL, 3 mmol) in dichloromethane (10 mL) gave **11ba** (507 mg, 74%) and recovered starting material **9d** (65.3 mg, 18%).

Colorless oil; R_f value 0.23 (hexane / ethyl acetate = 1 / 1); IR (NaCl, neat) ν_{max} 3306, 2937, 2858, 2359, 2103, 1716, 1673, 1546, 1447, 1276, 1180, 1109 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.02 (d, 2H, *J* = 8.5 Hz), 7.38–7.30 (m, 10H), 7.23 (d, 2H, *J* = 8.0 Hz), 6.34 (br-s, 1H), 5.57 (s, 2H), 4.32 (t, 2H, *J* = 6.0 Hz), 4.00 (s, 2H), 3.32–3.25 (m, 4H), 2.21–2.18 (m, 2H), 1.79–1.76 (m, 2H), 1.60–1.56 (m, 2H), 1.49–1.38 (m, 6H), 1.11–1.08 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.4, 166.0, 146.7, 141.6, 139.8, 135.3, 130.5, 130.3, 128.3, 128.15, 128.12, 126.8, 72.1, 65.0, 52.7, 51.6, 43.9, 39.3, 31.8, 29.3, 28.5, 26.4, 25.6, 25.3, 22.2; HRMS (ESI) calcd for $C_{35}H_{39}ClN_{10}O_3Na$ $[M+Na]^+$ 705.2793, found 705.2791.

6-(2-(5-((4*S*)-2-oxohexahydro-1*H*-thieno[3,4-d]imidazol-4-yl)pentanamido)acetamido)hexyl 4-((4-(azidodiphenylmethyl)-5-(4-chlorobutyl)-1*H*-1,2,3-triazol-1-yl)methyl)benzoate (11bb)

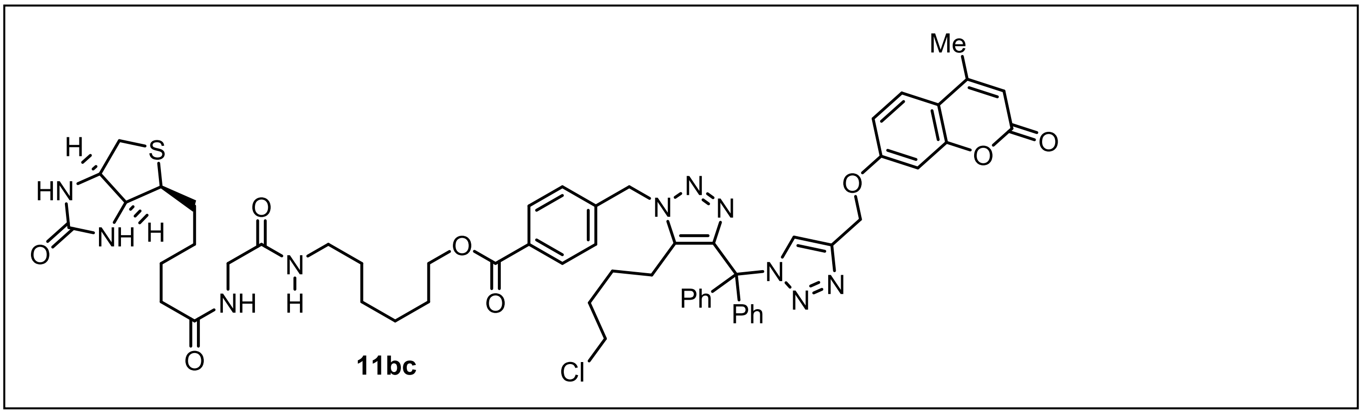


11bb

To a stirred solution of 6-(2-azidoacetamido)hexyl 4-((4-(azidodiphenylmethyl)-5-(4-chlorobutyl)-1*H*-1,2,3-triazol-1-yl)methyl)benzoate **11ba** (34.0 mg, 0.05 mmol) in toluene (0.5 mL) and water (0.05 mL) under N_2 gas atmosphere, 2-(diphenylphosphaneyl)phenyl 5-((4*R*)-2-oxohexahydro-1*H*-thieno[3,4-*d*]imidazol-4-yl)pentanoate **2e** (25.2 mg, 0.05 mmol) was added at room temperature. After 24 h at the same temperature, the reaction mixture was concentrated *in vacuo* and was purified by silica gel column chromatography (2% to 5% to 9% methanol in dichloromethane) to give **11bb** (33.1 mg, 75%) as a light yellow oil.

Light yellow oil; R_f value 0.23 (dichloromethane / methanol = 10 / 1); $[\alpha]_D^{23}$ +10.3 (c = 0.5, $CHCl_3$); IR (NaCl, neat) ν_{max} 3289, 3068, 2934, 2861, 2246, 2104, 1697, 1644, 1555, 1463, 1278, 1112 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.01 (d, 3H, *J* = 8.0 Hz), 7.37–7.21 (m, 11H), 7.05 (br-s, 1H), 6.44 (br-s, 1H), 5.56 (s, 2H), 4.50 (s, 1H), 4.31–4.28 (m, 3H), 3.88 (s, 2H), 3.27–3.12 (m, 5H), 2.88 (d, 1H, *J* = 8.5 Hz), 2.72 (d, 1H, *J* = 12.5 Hz), 2.26–2.16 (m, 4H), 1.76–1.25 (m, 16H), 1.13–1.09 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 174.2, 170.0, 166.0, 164.6, 141.6, 139.8, 135.3, 130.4, 130.2, 128.2, 128.1, 127.9, 127.6, 127.5, 126.8, 72.0, 65.1, 61.7, 60.2, 55.8, 51.5, 44.0, 43.9, 43.2, 40.6, 39.4, 35.3, 31.7, 29.1, 28.5, 28.1, 28.0, 26.4, 25.6, 25.3, 22.1; HRMS (ESI) calcd for $C_{45}H_{55}{}^{35}ClN_{10}O_5NaS$ $[M+Na]^+$ 905.3664, found 905.3665.

6-(2-(5-((4*S*)-2-oxohexahydro-1*H*-thieno[3,4-d]imidazol-4-yl)pentanamido)acetamido)hexyl 4-((5-(4-chlorobutyl)-4-((4-(((4-methyl-2-oxo-2H-chromen-7-yl)oxy)methyl)-1*H*-1,2,3-triazol-1-yl)diphenylmethyl)-1H-1,2,3-triazol-1-yl)methyl)benzoate (11bc)



11bc

To a stirred solution of 6-(2-(5-((4*S*)-2-oxohexahydro-1*H*-thieno[3,4-d]imidazol-4-yl)pentanamido)acetamido)hexyl 4-((4-(azidodiphenylmethyl)-5-(4-chlorobutyl)-1*H*-1,2,3-triazol-1-yl)methyl)benzoate **11bc** (22.1 mg, 0.025 mol) in *N*,*N*-dimethyl formamide (0.42 mL) under N_2 gas atmosphere, 4-methyl-7-(prop-2-yn-1-yloxy)-2*H*-chromen-2-one **12** (8.2 mg, 0.0375 mmol), tris[(1-benzyl-1*H*-1,2,3-triazol-4-yl)methyl]amine (TBTA, 1.4 mg, 0.0025 mmol), and tetrakis(acetonitrile)copper(I) tetrafluoroborate ($(MeCN)_4CuBF_4$, 0.8 mg, 0.0025 mmol) were added at room temperature, successively. Then, the reaction mixture was heated at 80 °C. After 7 h, the mixture was diluted with water, extracted with dichloromethane, and washed with brine. The collected organic layer was dried over sodium sulfate. The concentration of the collected organic components *in vacuo* followed by silica gel column chromatography (0 % to 3 % to 9% methanol in dichloromethane) gave **11bc** (50% yield on ^{1}H NMR). For further purification, GPC was taken to give the pure **11bc** (11.8 mg, 43%) as a yellow oil.

Yellow oil; R_f value 0.25 (dichloromethane / methanol = 10 / 1); $[\alpha]^{17}_{D}$ +16.3 (c = 0.29, $CHCl_3$); IR (NaCl, neat) ν_{max} 3280, 3071, 2932, 2866, 1700, 1613, 1561, 1542, 1457, 1387, 1277, 1143, 1108 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d6) δ 8.31 (s, 2H), 7.96 (s, 3H), 7.75–7.66 (m, 2H), 7.39–7.22 (m, 9H), 7.14 (s, 1H), 7.05–6.97 (m, 3H), 6.41 (s, 1H), 6.34 (s, 1H), 6.23 (s, 1H), 5.72 (s, 1H), 5.65 (s, 1H), 5.30 (d, 2H, *J* = 13.0 Hz), 4.30–4.25 (m, 3H), 4.12 (s, 1H), 3.62 (d, 2H, *J* = 4.5 Hz), 3.51 (s, 1H), 3.22–3.21 (m, 1H), 3.09–3.04 (m, 3H), 2.82–2.80 (m, 1H), 2.57 (d, 1H, *J* = 12.5 Hz), 2.40 (s, 3H), 2.12 (s, 2H), 1.68–1.03 (m, 18H), 0.85–0.77 (m, 2H); ^{13}C NMR (126 MHz, DMSO-d6) δ 172.4, 168.7, 165.4, 162.7, 160.1, 154.6, 153.4, 149.4, 147.0, 141.5, 140.6, 135.0, 129.6, 129.0, 128.4, 128.1, 127.4, 127.3, 127.2, 126.6, 113.4, 112.7, 112.6, 111.3, 101.6, 79.2, 77.0, 69.8, 64.7, 61.0, 59.2, 55.4, 50.1, 44.6, 44.3, 42.0, 40.3, 40.0, 38.4, 35.0, 31.6, 29.0, 28.2, 28.1, 28.0, 26.0, 25.15, 25.10, 21.8, 18.1; HRMS (ESI) calcd for $C_{58}H_{65}{}^{35}ClN_{10}O_8SNa$ $[M+Na]^+$ 1119.4293, found 1119.4296. UV-vis ($CHCl_3$) $\lambda_{max}(\varepsilon)$ 291 (9930), 320 (17950) nm.

[7] UV-vis Spectra of the Conjugated Compounds

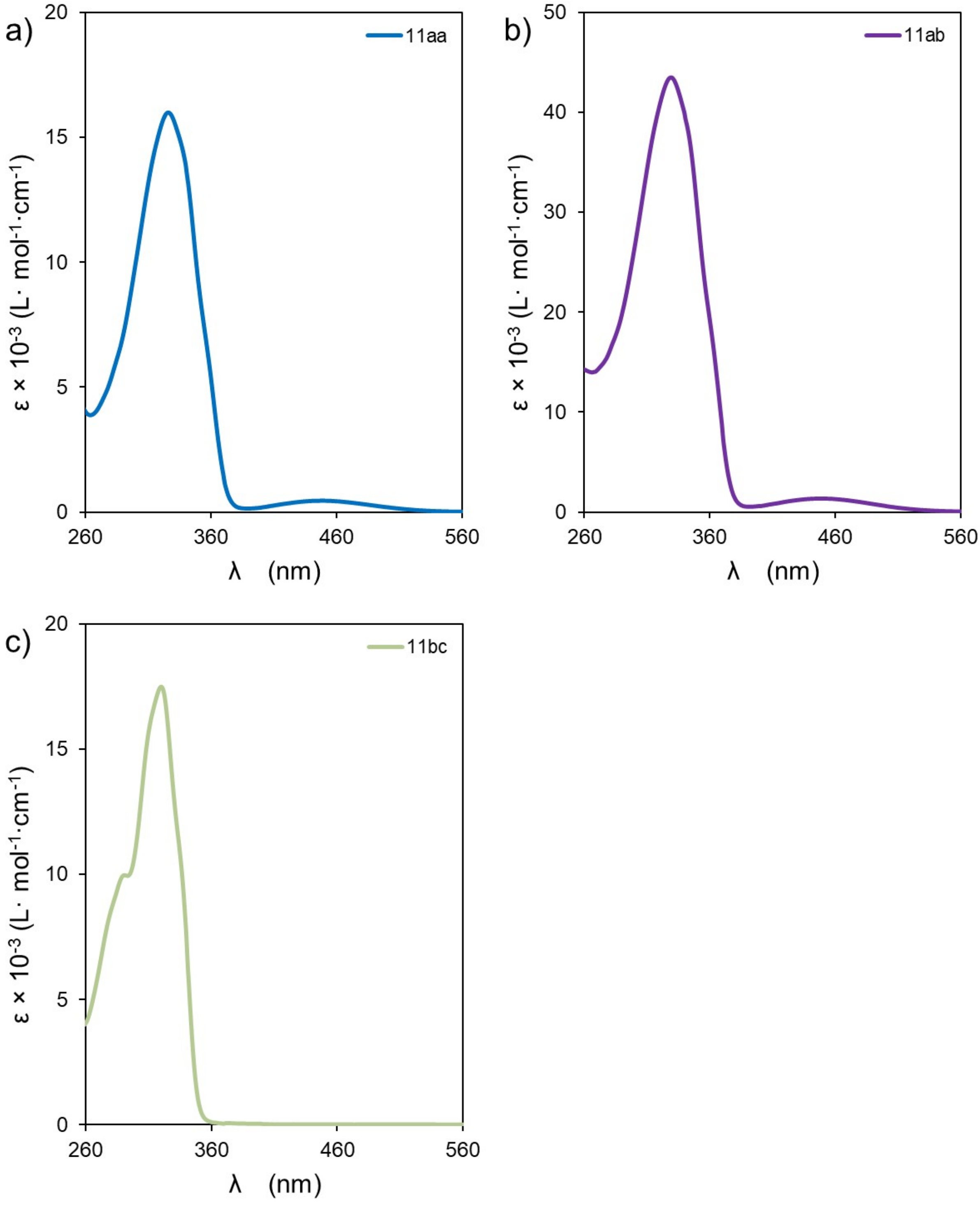
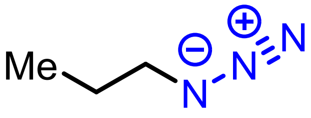


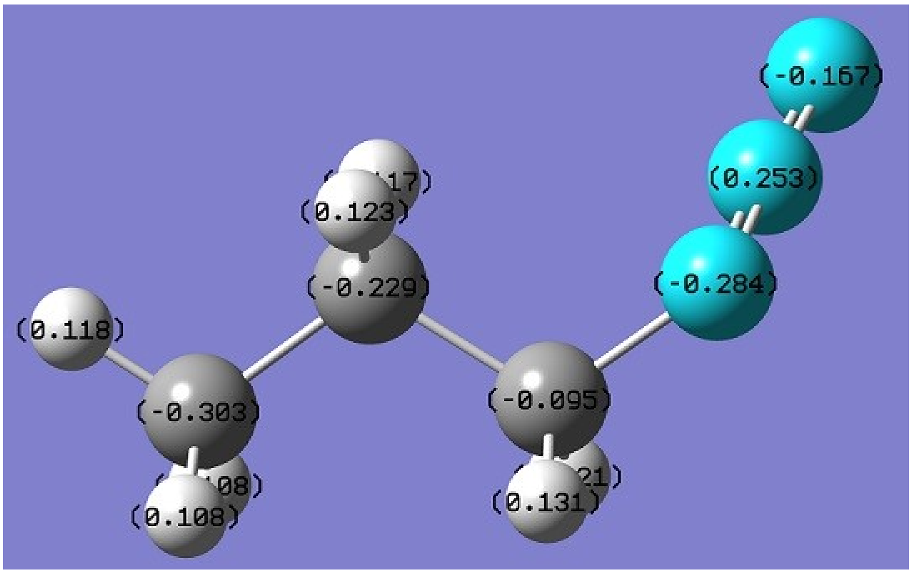
Figure S1. UV-vis absorption spectra: (a) **11aa** (chloroform, 0.046 mmol/L). (b) **11ab** (DMSO, 0.018 mmol/L). (c) **11bc** (chloroform, 0.0341 mmol/L).

[8] DFT Calculation Results (Gaussian09 dispersion-corrected B3LYP-D3/6-311**)[3]

(1) Propylazide 1a



1a



E(RB3LYP-D3) = -282.808229550 (a.u.)

Standard orientation:

Center	Element	Atomic	Coordinates (Angstroms)		
Number		Type	X	Y	Z
1	C	0	1.204079	0.327364	-0.396996
2	C	0	0.367384	-0.769456	0.266814
3	C	0	2.627960	0.377712	0.163277
4	N	0	-1.002426	-0.873537	-0.289439
5	N	0	-1.763554	0.051250	-0.011990
6	N	0	-2.556542	0.841233	0.180859
7	H	0	0.710444	1.294345	-0.247881
8	H	0	1.224109	0.146922	-1.476062
9	H	0	0.321926	-0.611515	1.352261
10	H	0	0.817837	-1.747796	0.095487
11	H	0	3.213815	1.160711	-0.323617
12	H	0	3.147894	-0.572430	0.007217
13	H	0	2.625098	0.583419	1.238013

Mulliken charges:

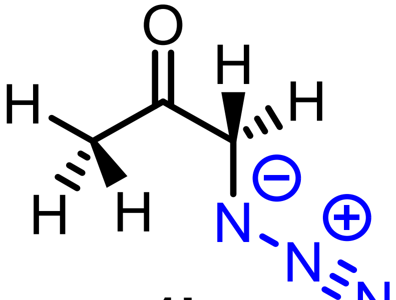
1	C	-0.228722
2	C	-0.094796
3	C	-0.303450
4	N	-0.283588
5	N	0.253225
6	N	-0.167132
7	H	0.116602
8	H	0.122583
9	H	0.121144
10	H	0.130504
11	H	0.117617
12	H	0.108335
13	H	0.107676

Sum of Mulliken charges = -0.00000

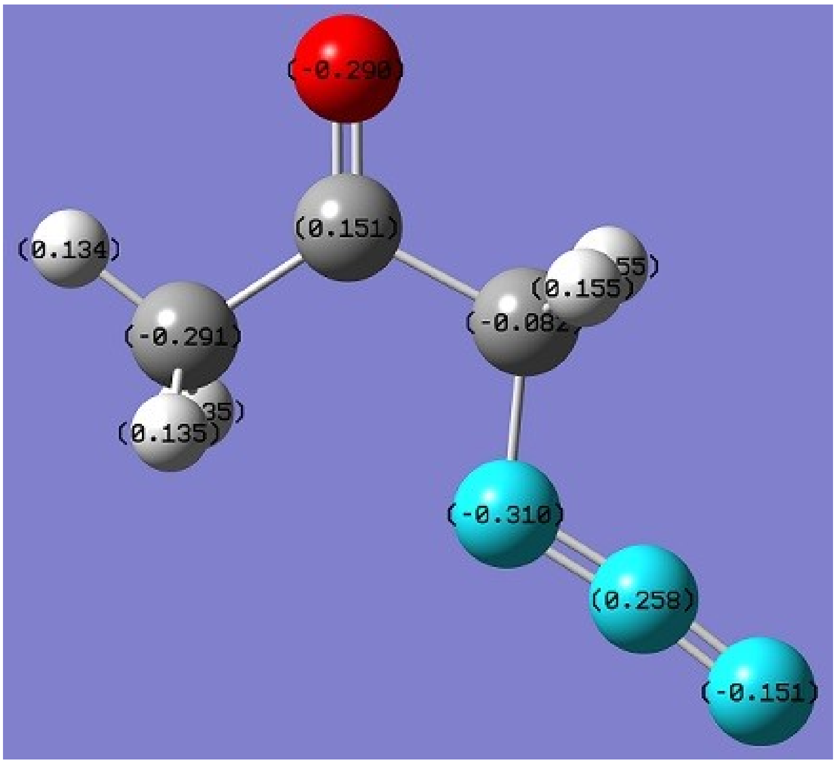
Mulliken charges with hydrogens summed into heavy atoms:

1	C	0.010463
2	C	0.156853
3	C	0.030178
4	N	-0.283588
5	N	0.253225
6	N	-0.167132

(2) Azidoacetone 1b



1b



E(RB3LYP-D3) = -356.835785534 (a.u.)

Standard orientation:

Center Number	Element	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	C	0	-1.493541	-0.175109	-0.000017
2	C	0	-0.049123	-0.687599	0.000145
3	O	0	-2.381779	-0.993335	-0.000106
4	C	0	-1.731959	1.313654	-0.000014
5	N	0	0.927255	0.416380	0.000082
6	N	0	2.111971	0.086222	-0.000008
7	N	0	3.231202	-0.096029	-0.000117
8	H	0	0.066111	-1.325090	0.884950
9	H	0	0.066241	-1.325330	-0.884469
10	H	0	-1.259836	1.770841	0.874186
11	H	0	-1.259624	1.770897	-0.874070
12	H	0	-2.803915	1.503684	-0.000132

Mulliken charges:

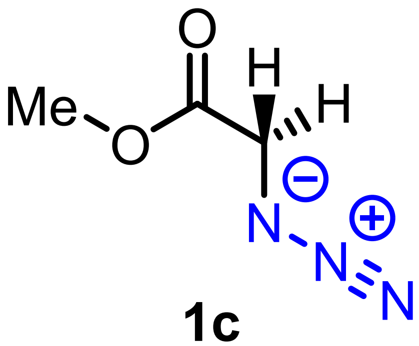
1	C	0.151295
2	C	-0.082047
3	O	-0.290145
4	C	-0.291031
5	N	-0.309691
6	N	0.258097
7	N	-0.151325
8	H	0.155321
9	H	0.155317
10	H	0.134917
11	H	0.134920
12	H	0.134371

Sum of Mulliken charges = -0.00000

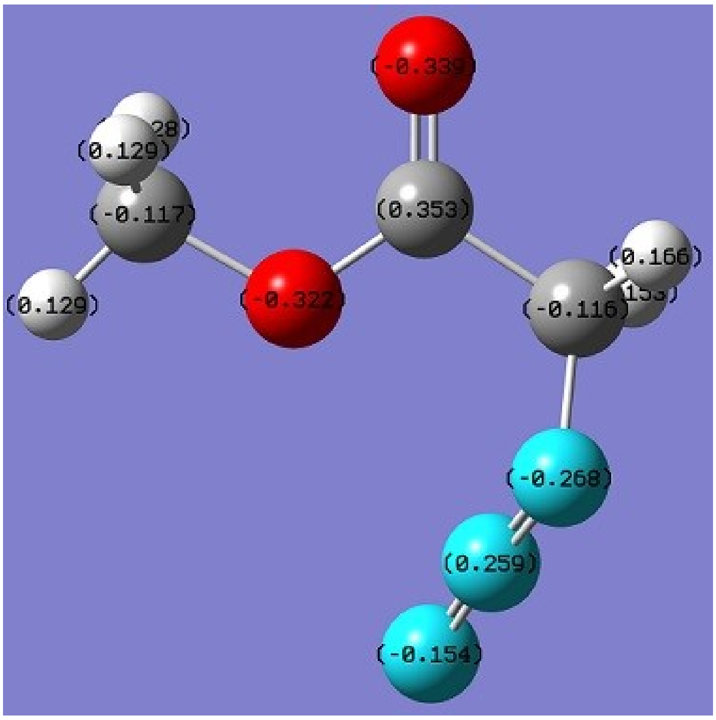
Mulliken charges with hydrogens summed into heavy atoms:

1	C	0.151295
2	C	0.228591
3	O	-0.290145
4	C	0.113177
5	N	-0.309691
6	N	0.258097
7	N	-0.151325

(3) Methyl azidoacetate 1c



1c



E(RB3LYP-D3) = -432.089851743 (a.u.)

Standard orientation:

Center Number	Element	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	O	0	0.731562	-0.716209	-0.114505
2	C	0	0.930257	0.597435	0.060434
3	C	0	-0.381866	1.380410	0.086926
4	O	0	2.003133	1.117136	0.222548
5	N	0	-1.532064	0.752744	-0.569103
6	N	0	-2.004180	-0.243694	-0.018380
7	N	0	-2.533887	-1.161369	0.381524
8	C	0	1.919376	-1.536398	-0.112843
9	H	0	-0.201312	2.322732	-0.425709
10	H	0	-0.589831	1.615292	1.139272
11	H	0	1.566802	-2.555559	-0.249440
12	H	0	2.581114	-1.241353	-0.928481
13	H	0	2.449974	-1.430982	0.834617

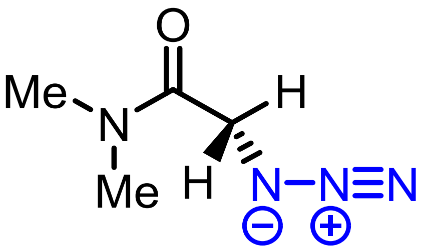
Mulliken charges:

```
1     O   -0.321795
2     C    0.352743
3     C   -0.115900
4     O   -0.339198
5     N   -0.268462
6     N    0.258684
7     N   -0.153810
8     C   -0.117164
9     H    0.165847
10    H    0.153024
11    H    0.129359
12    H    0.128791
13    H    0.127883
Sum of Mulliken charges = -0.00000
```

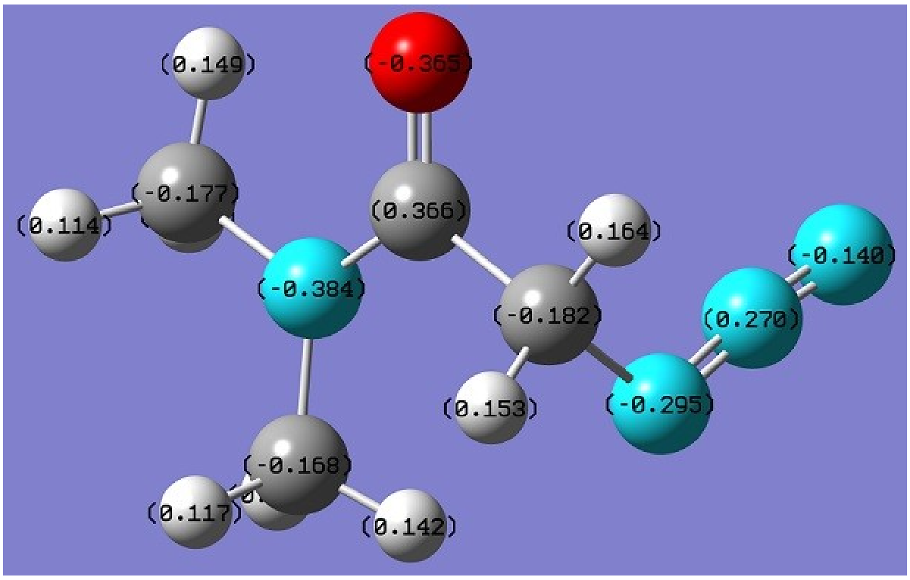
Mulliken charges with hydrogens summed into heavy atoms:

```
1     O   -0.321795
2     C    0.352743
3     C    0.202970
4     O   -0.339198
5     N   -0.268462
6     N    0.258684
7     N   -0.153810
8     C    0.268868
```

(4) *N*,*N*-Dimethyl azidoacetamide 1d



1d



E(RB3LYP-D3) = -451.541011205 (a.u.)

Standard orientation:

Center Number	Element	Atomic Type	Coordinates (Angstroms)		
			X	Y	Z
1	N	0	-1.360099	-0.232295	-0.123346
2	C	0	-0.497210	0.667723	0.435019
3	C	0	0.683520	0.115314	1.258333
4	O	0	-0.608207	1.877233	0.305205
5	C	0	-2.506392	0.264663	-0.875912
6	N	0	1.613145	-0.746190	0.495528
7	N	0	2.244397	-0.189504	-0.406646
8	N	0	2.886245	0.197954	-1.256281
9	C	0	-1.337489	-1.670228	0.111832
10	H	0	0.333141	-0.498463	2.088567
11	H	0	1.196643	0.989992	1.661920
12	H	0	-2.535314	-0.201404	-1.865617
13	H	0	-3.440370	0.029864	-0.352498
14	H	0	-2.417286	1.342632	-0.981664
15	H	0	-2.097633	-1.962852	0.846908
16	H	0	-1.555187	-2.189552	-0.825762
17	H	0	-0.358736	-2.002666	0.446076

Mulliken charges:

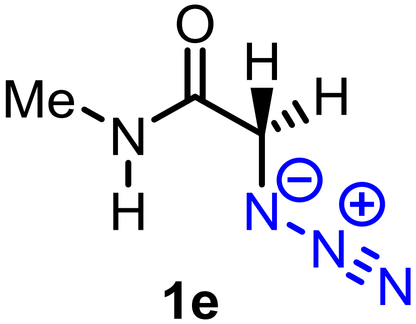
1	N	-0.383985
2	C	0.365974
3	C	-0.182310
4	O	-0.365149
5	C	-0.176587
6	N	-0.295384
7	N	0.270416
8	N	-0.140051
9	C	-0.167602
10	H	0.152888
11	H	0.163777
12	H	0.117678
13	H	0.114197
14	H	0.148773
15	H	0.116860
16	H	0.118839
17	H	0.141664

Sum of Mulliken charges = -0.00000

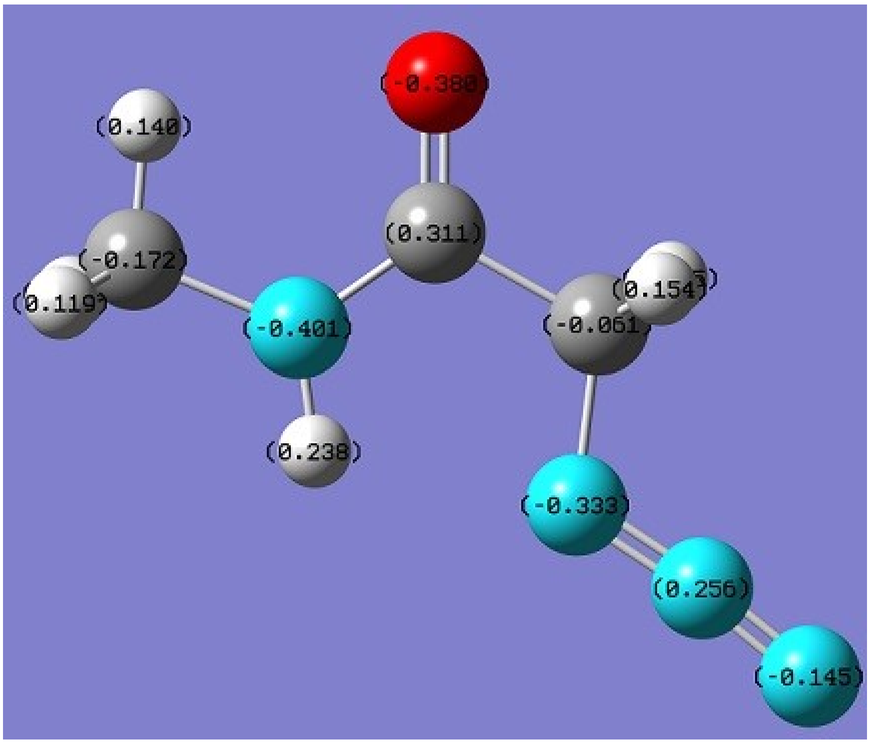
Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.383985
2	C	0.365974
3	C	0.134355
4	O	-0.365149
5	C	0.204061
6	N	-0.295384
7	N	0.270416
8	N	-0.140051
9	C	0.209761

(5) *N*-Methyl azidoacetamide 1e (optimized conformation)



1e



E(RB3LYP-D3) = -412.227363700 (a.u.)

Standard orientation:

```
---------------------------------------------------------------------
Center     Element      Atomic              Coordinates (Angstroms)
Number                   Type              X           Y           Z
---------------------------------------------------------------------
    1          N           0        1.382210   -0.710071   -0.000330
    2          C           0        1.001913    0.588432   -0.000021
    3          C           0       -0.506005    0.843815    0.005550
    4          O           0        1.756690    1.545823   -0.004769
    5          C           0        2.777172   -1.116037   -0.004217
    6          N           0       -1.281450   -0.414779    0.019994
    7          N           0       -2.505172   -0.299559    0.000548
    8          N           0       -3.638684   -0.307389   -0.015025
    9          H           0        0.654340   -1.408967    0.005740
   10          H           0       -0.732978    1.440512   -0.883928
   11          H           0       -0.723889    1.454020    0.888032
   12          H           0        3.008576   -1.710645   -0.892431
   13          H           0        3.387305   -0.214014   -0.011075
   14          H           0        3.016308   -1.702162    0.887625
---------------------------------------------------------------------
```

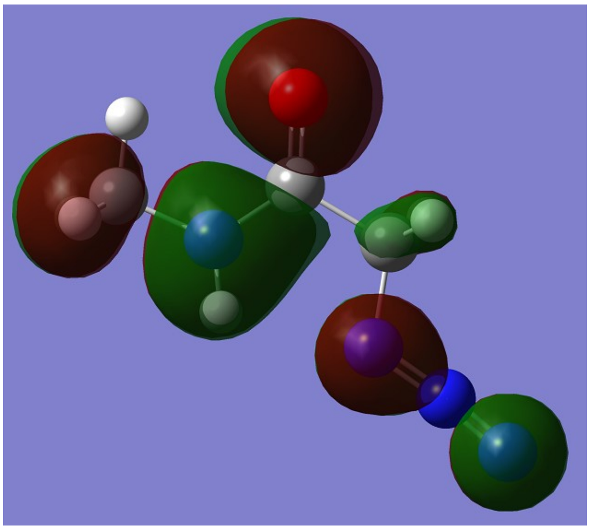
Mulliken charges:

1	N	-0.401376
2	C	0.310985
3	C	-0.061213
4	O	-0.380483
5	C	-0.171704
6	N	-0.332525
7	N	0.256202
8	N	-0.145459
9	H	0.238245
10	H	0.154370
11	H	0.155101
12	H	0.118934
13	H	0.139828
14	H	0.119096

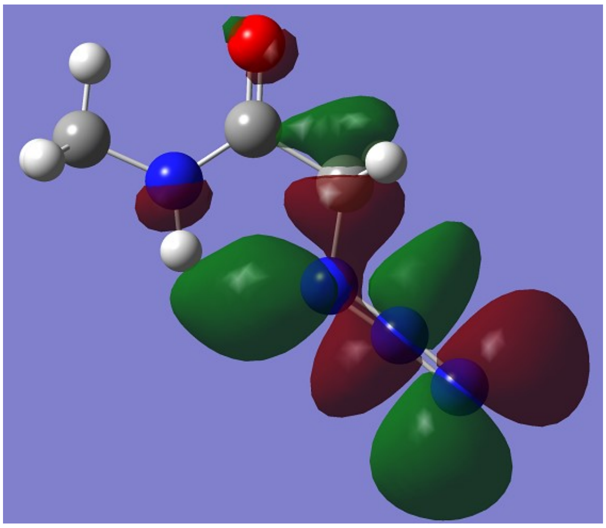
Sum of Mulliken charges = -0.00000

Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.163132
2	C	0.310985
3	C	0.248258
4	O	-0.380483
5	C	0.206154
6	N	-0.332525
7	N	0.256202
8	N	-0.145459

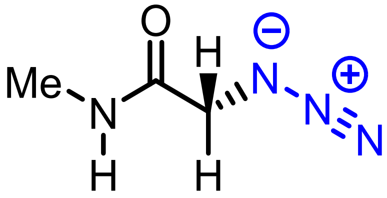


HOMO

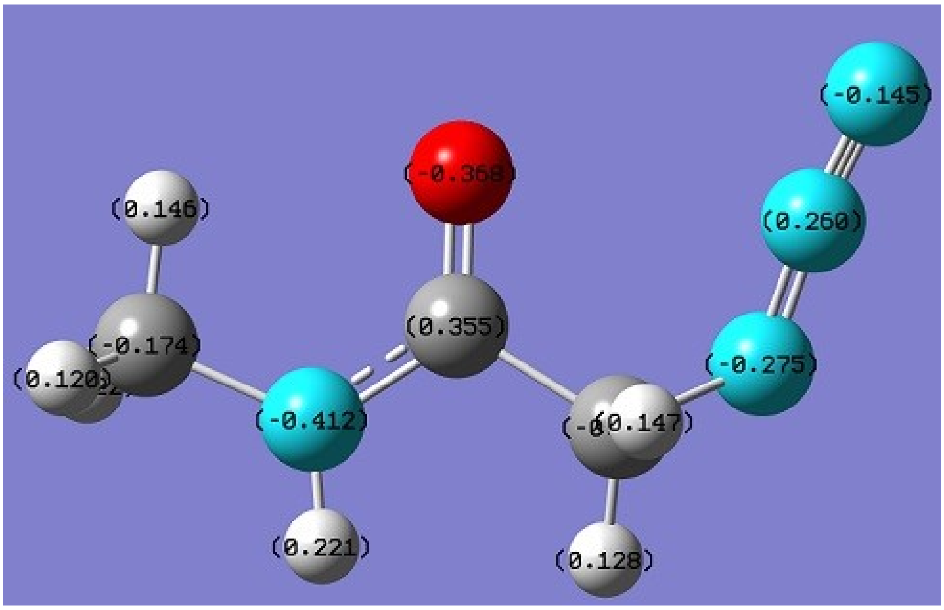


LUMO

(6) Conformational isomer of *N*-methyl azidoacetamide 1e’ (fixed to Gauche conformation)



1e'



E(RB3LYP-D3) = -412.223399883 (a.u.)

Standard orientation:

```
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 Center     Element      Atomic              Coordinates (Angstroms)
 Number                   Type              X           Y           Z
 ---------------------------------------------------------------------
      1          N           0        1.955277    0.461726    0.013121
      2          C           0        0.668488    0.026335    0.088868
      3          C           0       -0.378044    1.136281    0.287463
      4          O           0        0.334957   -1.142799    0.053021
      5          C           0        3.085214   -0.447954   -0.108438
      6          N           0       -1.610602    0.878202   -0.457019
      7          N           0       -2.276119   -0.099251   -0.097722
      8          N           0       -3.007604   -0.933404    0.125156
      9          H           0        2.132569    1.452957   -0.005152
     10          H           0       -0.019128    2.105321   -0.060719
     11          H           0       -0.568158    1.216197    1.366640
     12          H           0        3.798268   -0.295183    0.706097
     13          H           0        2.697305   -1.463964   -0.058836
     14          H           0        3.598871   -0.311808   -1.064303
 ---------------------------------------------------------------------
```

Mulliken charges:

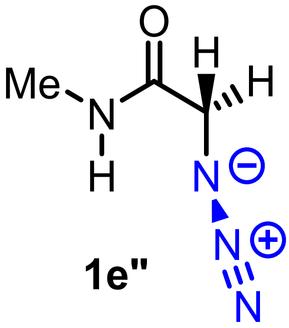
1	N	-0.411578
2	C	0.354797
3	C	-0.125877
4	O	-0.367688
5	C	-0.173943
6	N	-0.274978
7	N	0.259510
8	N	-0.145233
9	H	0.221030
10	H	0.128473
11	H	0.147311
12	H	0.119641
13	H	0.146117
14	H	0.122418

Sum of Mulliken charges = -0.00000

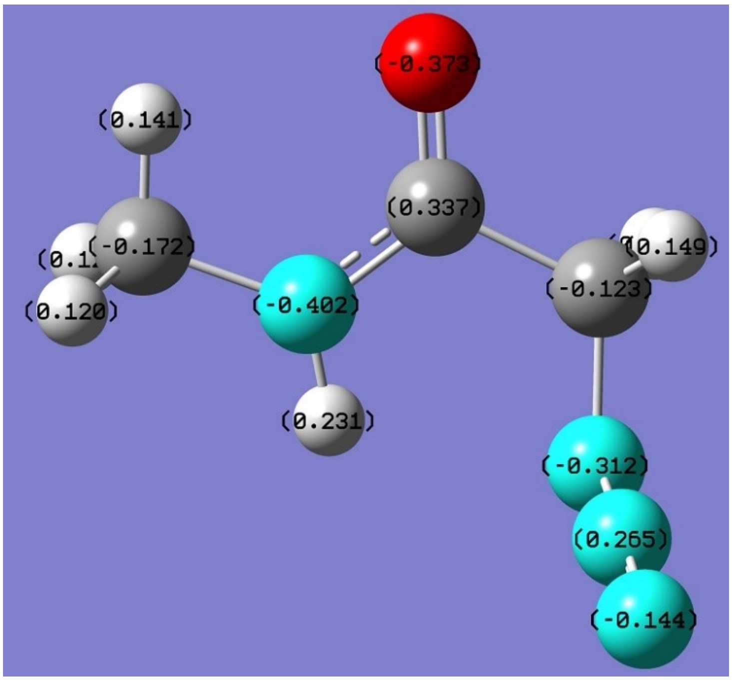
Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.190549
2	C	0.354797
3	C	0.149907
4	O	-0.367688
5	C	0.214233
6	N	-0.274978
7	N	0.259510
8	N	-0.145233

(7) Conformational isomer of *N*-methyl azidoacetamide 1e” (azido group almost perpendicular to the amide plain)



1e"



E(RB3LYP-D3) = -412.227143941 (a.u.)

Standard orientation:

Center Number	Element	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	N	0	1.163933	-0.683321	0.233042
2	C	0	0.918019	0.617150	-0.054198
3	C	0	-0.476642	1.132129	0.339331
4	O	0	1.707814	1.387099	-0.570813
5	C	0	2.446971	-1.314333	-0.027736
6	N	0	-1.421768	0.092441	0.800123
7	N	0	-2.228769	-0.313958	-0.038854
8	N	0	-3.022960	-0.757481	-0.714727
9	H	0	0.438177	-1.199298	0.707511
10	H	0	-0.863018	1.698207	-0.511868
11	H	0	-0.337600	1.827406	1.168462
12	H	0	2.323468	-2.199547	-0.657088
13	H	0	3.074188	-0.590998	-0.546617
14	H	0	2.939138	-1.605998	0.904637

Mulliken charges:

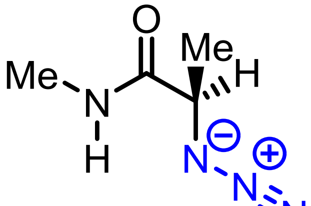
1	N	-0.402143
2	C	0.336602
3	C	-0.122938
4	O	-0.373030
5	C	-0.172169
6	N	-0.312178
7	N	0.264854
8	N	-0.144259
9	H	0.230982
10	H	0.149273
11	H	0.163716
12	H	0.119619
13	H	0.140884
14	H	0.120786

Sum of Mulliken charges = -0.00000

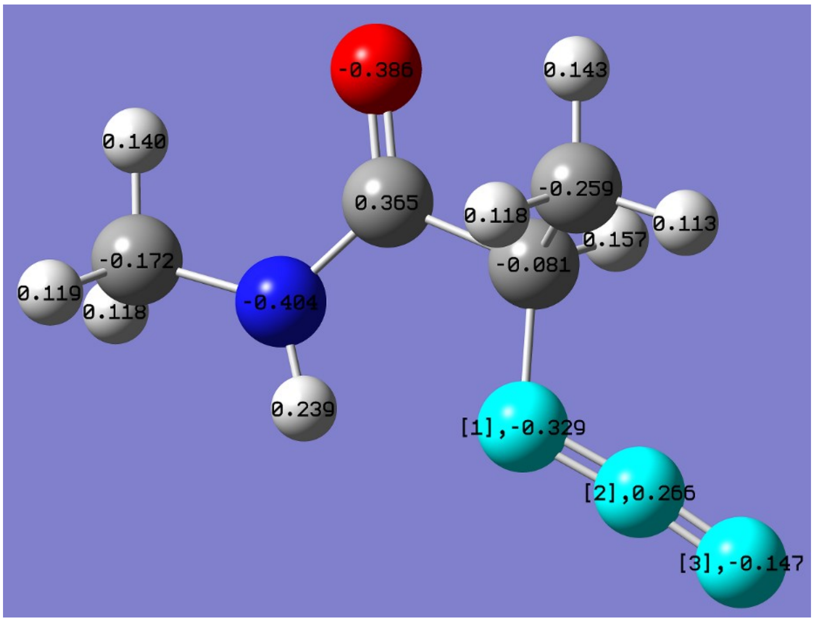
Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.171161
2	C	0.336602
3	C	0.190051
4	O	-0.373030
5	C	0.209120
6	N	-0.312178
7	N	0.264854
8	N	-0.144259

(8) 2-Azido *N*-methylpropamide 1f



1f



E(RB3LYP-D3) = -451.560077666 (a.u.)

Standard orientation:

```
---------------------------------------------------------------------
 Center     Element     Atomic              Coordinates (Angstroms)
 Number                  Type              X           Y           Z
---------------------------------------------------------------------
      1        N           0         -1.514565   -0.843017    0.128817
      2        C           0         -1.079064    0.387106   -0.227204
      3        C           0          0.445179    0.583142   -0.264672
      4        O           0         -1.799795    1.328487   -0.517968
      5        C           0         -2.925010   -1.181407    0.208977
      6        C           0          0.849283    1.779205    0.600071
      7        N           0          1.129559   -0.670198    0.161426
      8        N           0          2.337302   -0.723204   -0.059251
      9        N           0          3.450719   -0.868342   -0.218088
     10        H           0         -0.815288   -1.534947    0.353284
     11        H           0          0.689085    0.787659   -1.314157
     12        H           0         -3.497474   -0.295837   -0.062902
     13        H           0         -3.172153   -1.992655   -0.481631
     14        H           0         -3.196514   -1.484867    1.224034
     15        H           0          1.916080    1.991035    0.494812
     16        H           0          0.278027    2.652649    0.285943
     17        H           0          0.633164    1.574120    1.651001
---------------------------------------------------------------------
```

Mulliken charges:

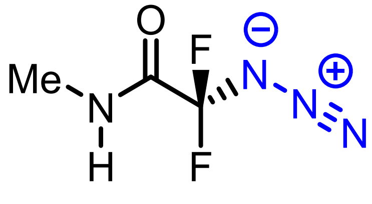
1	N	-0.403594
2	C	0.365395
3	C	-0.080533
4	O	-0.386476
5	C	-0.172143
6	C	-0.259151
7	N	-0.329143
8	N	0.266068
9	N	-0.146975
10	H	0.238583
11	H	0.157422
12	H	0.139750
13	H	0.118123
14	H	0.118554
15	H	0.113357
16	H	0.143165
17	H	0.117599

Sum of Mulliken charges = -0.00000

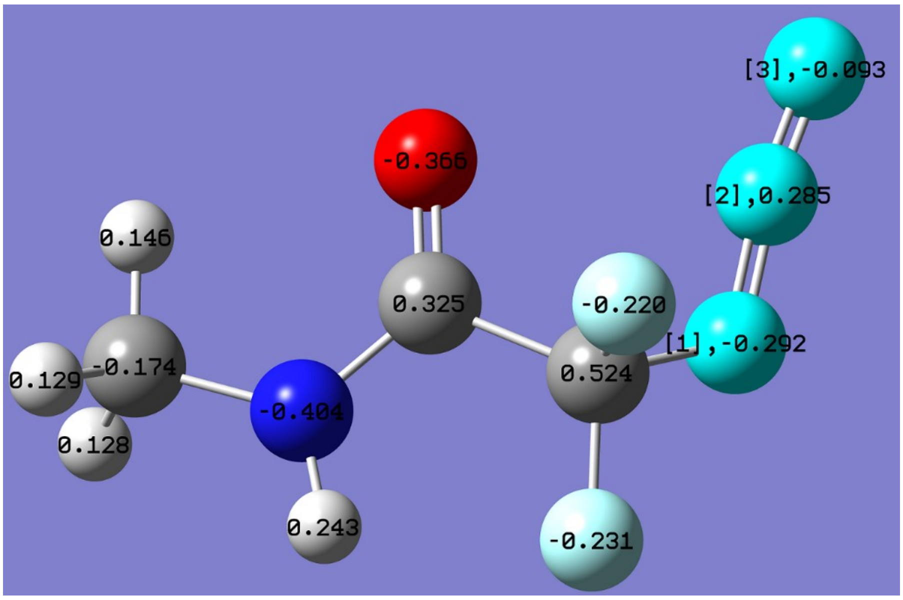
Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.165011
2	C	0.365395
3	C	0.076889
4	O	-0.386476
5	C	0.204283
6	C	0.114970
7	N	-0.329143
8	N	0.266068
9	N	-0.146975

(9) 2-Azido-2,2-difluoro *N*-methylacetamide 1g (optimized conformation)



1g



E(RB3LYP-D3) = -610.76404 (a.u.)

Standard orientation:

Center Number	Element	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	N	0	1.980561	-0.095043	0.176958
2	C	0	0.732296	0.331751	-0.095765
3	C	0	-0.361506	-0.769242	-0.033863
4	O	0	0.398520	1.462869	-0.391459
5	F	0	0.108351	-1.914705	0.534541
6	F	0	-0.699540	-1.080203	-1.326095
7	C	0	3.134617	0.792219	0.140083
8	N	0	-1.507461	-0.393675	0.731823
9	N	0	-2.126923	0.607764	0.332593
10	N	0	-2.813158	1.468300	0.098740
11	H	0	2.107394	-1.062647	0.428814
12	H	0	2.786732	1.783367	-0.145564
13	H	0	3.609880	0.847879	1.122561
14	H	0	3.864962	0.442831	-0.593681

Mulliken charges:

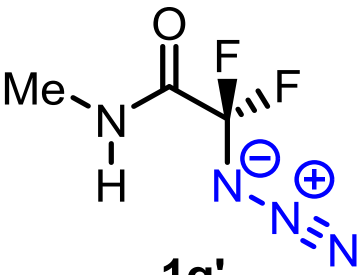
1	N	-0.403768
2	C	0.325133
3	C	0.524357
4	O	-0.366258
5	F	-0.231426
6	F	-0.220298
7	C	-0.173929
8	N	-0.291953
9	N	0.284758
10	N	-0.092743
11	H	0.242561
12	H	0.146076
13	H	0.128333
14	H	0.129156

Sum of Mulliken charges = 0.00000

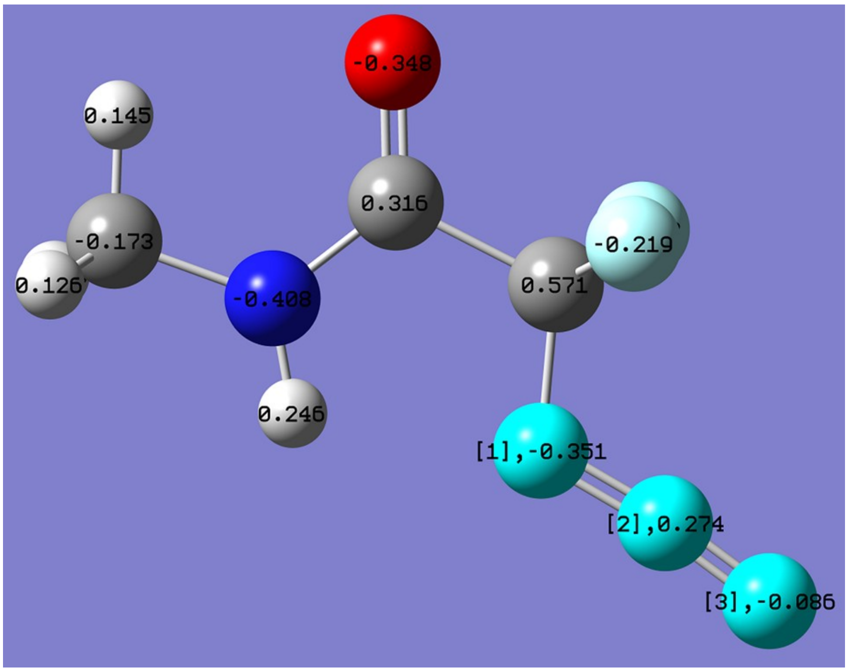
Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.161206
2	C	0.325133
3	C	0.524357
4	O	-0.366258
5	F	-0.231426
6	F	-0.220298
7	C	0.229636
8	N	-0.291953
9	N	0.284758
10	N	-0.092743

(10) Conformational isomer of 2-azido-2,2-difluoro *N*-methylacetamide 1g' (fixed to lead interaction between NH and N_3)



1g'



E(RB3LYP-D3) = -610.75971 (a.u.)

Standard orientation:

Center	Element	Atomic	Coordinates (Angstroms)		
Number		Type	X	Y	Z
1	N	0	1.654664	-0.901739	-0.000077
2	C	0	1.163875	0.356749	0.002702
3	C	0	-0.386516	0.456772	-0.000343
4	O	0	1.806870	1.383708	0.004732
5	F	0	-0.780340	1.164494	-1.097987
6	F	0	-0.784380	1.187311	1.080002
7	C	0	3.083241	-1.175524	-0.000546
8	N	0	-1.011334	-0.844487	0.011824
9	N	0	-2.253275	-0.832715	0.004740
10	N	0	-3.372645	-0.948678	-0.000035
11	H	0	0.997130	-1.666661	-0.000093
12	H	0	3.607599	-0.221401	0.002418
13	H	0	3.368426	-1.743920	0.888462
14	H	0	3.368901	-1.738565	-0.892819

Mulliken charges:

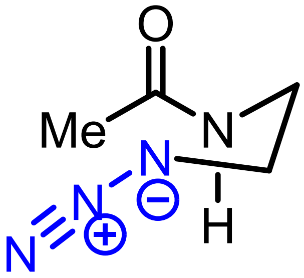
1	N	-0.408178
2	C	0.315926
3	C	0.570990
4	O	-0.348221
5	F	-0.218502
6	F	-0.217783
7	C	-0.173091
8	N	-0.351112
9	N	0.273902
10	N	-0.086137
11	H	0.245628
12	H	0.144784
13	H	0.125899
14	H	0.125894

Sum of Mulliken charges = -0.00000

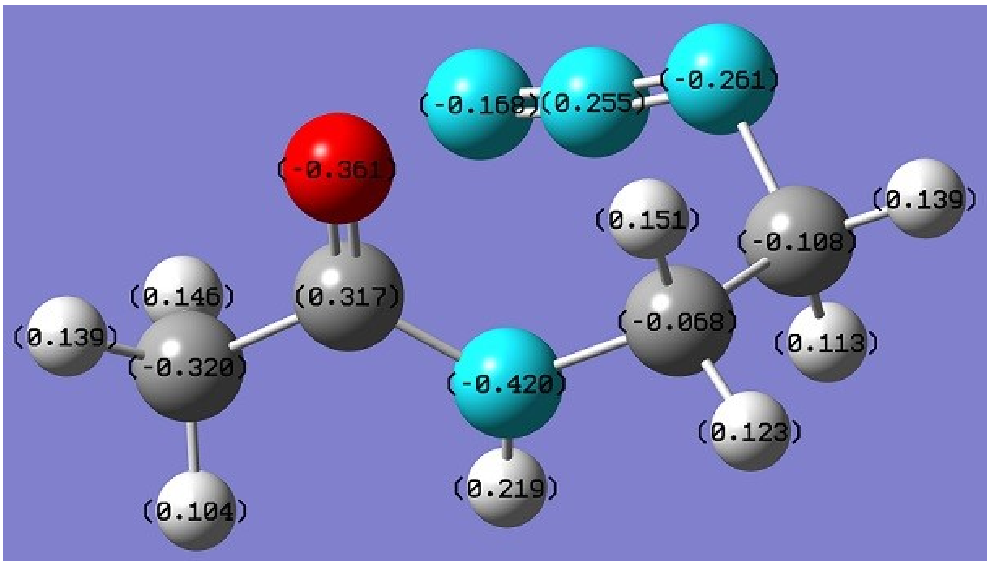
Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.162550
2	C	0.315926
3	C	0.570990
4	O	-0.348221
5	F	-0.218502
6	F	-0.217783
7	C	0.223486
8	N	-0.351112
9	N	0.273902
10	N	-0.086137

(11) *N*-(2-azidoethyl)acetamide 1h (optimized conformation)



1h



E(RB3LYP-D3) = -451.558118216 (a.u.)

Standard orientation:

```
---------------------------------------------------------------------
Center     Element     Atomic              Coordinates (Angstroms)
Number                 Type             X            Y            Z
---------------------------------------------------------------------
    1         N           0          0.570641    -0.831785     0.671086
    2         C           0         -0.522772    -1.642278     0.168041
    3         C           0         -1.876533    -0.928191     0.280638
    4         C           0          1.509649    -0.255869    -0.155333
    5         O           0          1.546056    -0.466174    -1.351977
    6         N           0         -1.949109     0.293836    -0.541501
    7         N           0         -1.332979     1.273702    -0.128675
    8         N           0         -0.830634     2.254773     0.145548
    9         O           0          2.458892     0.703713     0.537739
   10         H           0          0.594520    -0.612982     1.654662
   11         H           0         -0.300969    -1.853341    -0.878155
   12         H           0         -0.575165    -2.592647     0.711132
   13         H           0         -2.101001    -0.696871     1.330702
   14         H           0         -2.666011    -1.581516    -0.091947
   15         H           0          2.672253     0.422754     1.572164
   16         H           0          3.386513     0.748760    -0.030157
   17         H           0          2.000574     1.697303     0.535700
---------------------------------------------------------------------
```

Mulliken charges:

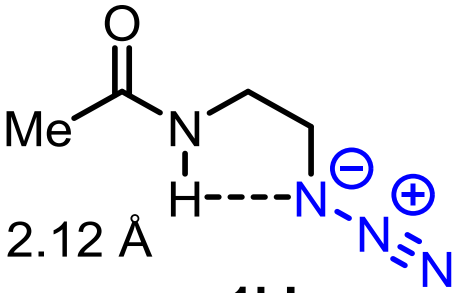
1	N	-0.419504
2	C	-0.068329
3	C	-0.108390
4	C	0.316632
5	O	-0.360688
6	N	-0.261424
7	N	0.254732
8	N	-0.168322
9	C	-0.320387
10	H	0.218842
11	H	0.151094
12	H	0.123321
13	H	0.113209
14	H	0.139235
15	H	0.104218
16	H	0.139266
17	H	0.146496

Sum of Mulliken charges = -0.00000

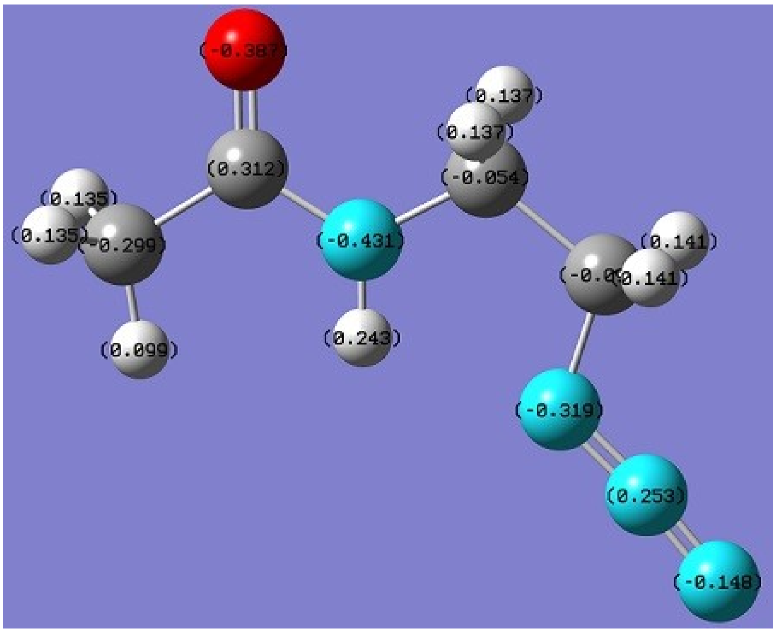
Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.200662
2	C	0.206086
3	C	0.144055
4	C	0.316632
5	O	-0.360688
6	N	-0.261424
7	N	0.254732
8	N	-0.168322
9	C	0.069593

(12) Conformational isomer of *N*-(2-azidoethyl)acetamide 1h’ (fixed to lead interaction between NH and N_3)



1h'



E(RB3LYP-D3) = -451.548767671 (a.u.)

Standard orientation:

Center	Element	Atomic	Coordinates (Angstroms)		
Number		Type	X	Y	Z
1	N	0	-0.892004	0.054926	0.000096
2	C	0	-0.240623	-1.242965	0.000048
3	C	0	1.305763	-1.133718	0.000088
4	C	0	-2.250086	0.141655	-0.000065
5	O	0	-2.963103	-0.849556	-0.000194
6	N	0	1.732190	0.286490	0.000167
7	N	0	2.944386	0.485863	-0.000036
8	N	0	4.039321	0.781154	-0.000191
9	C	0	-2.823340	1.549285	0.000047
10	H	0	-0.308376	0.876632	0.000149
11	H	0	-0.573440	-1.810840	0.873517
12	H	0	-0.573413	-1.810748	-0.873489
13	H	0	1.714324	-1.632691	-0.884174
14	H	0	1.714280	-1.632764	0.884330
15	H	0	-2.067348	2.337498	-0.000157
16	H	0	-3.459596	1.662362	-0.879892
17	H	0	-3.459147	1.662416	0.880310

Mulliken charges:

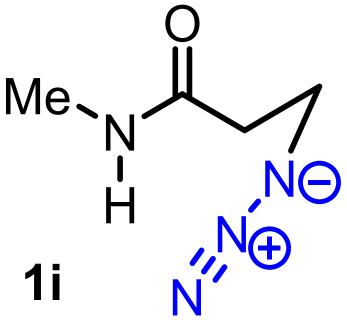
1	N	-0.430809
2	C	-0.053845
3	C	-0.096329
4	C	0.312439
5	O	-0.387175
6	N	-0.319305
7	N	0.253402
8	N	-0.148239
9	C	-0.299115
10	H	0.243015
11	H	0.137316
12	H	0.137319
13	H	0.141200
14	H	0.141207
15	H	0.099215
16	H	0.134851
17	H	0.134854

Sum of Mulliken charges = -0.00000

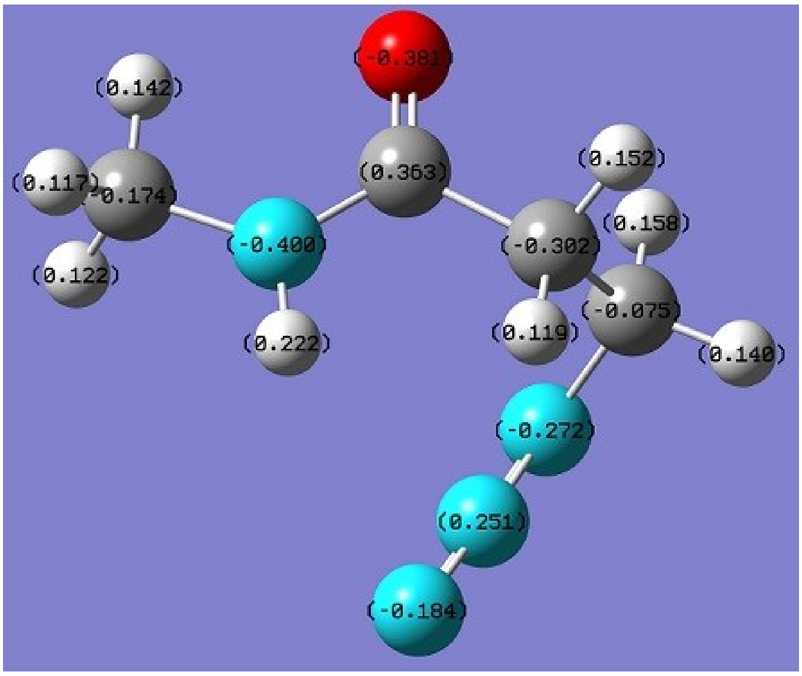
Mulliken charges with hydrogens summed into heavy atoms:

1	N	-0.187794
2	C	0.220790
3	C	0.186077
4	C	0.312439
5	O	-0.387175
6	N	-0.319305
7	N	0.253402
8	N	-0.148239
9	C	0.069804

(13) *N*-Methyl 3-azidopropionamide 1i (β-AzSA)



1i
(β-ASA)



E(RB3LYP-D3) = -451.555615219 (a.u.)

Standard orientation:

Center Number	Element	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	N	0	1.352840	0.673275	0.410275
2	C	0	1.025479	-0.632764	0.202650
3	C	0	-0.238018	-1.113058	0.916357
4	O	0	1.658907	-1.387792	-0.514905
5	C	0	-1.351380	-1.382792	-0.100780
6	C	0	2.469033	1.315637	-0.265960
7	N	0	-1.766693	-0.173528	-0.859334
8	N	0	-1.875986	0.862147	-0.214445
9	N	0	-1.982426	1.879340	0.284057
10	H	0	0.729042	1.249001	0.953338
11	H	0	0.008609	-2.052620	1.415486
12	H	0	-0.580386	-0.410064	1.682714
13	H	0	-0.996475	-2.083950	-0.853998
14	H	0	-2.228068	-1.815662	0.393043
15	H	0	3.128622	1.804833	0.455264
16	H	0	3.024348	0.542619	-0.794344
17	H	0	2.118220	2.057410	-0.989738

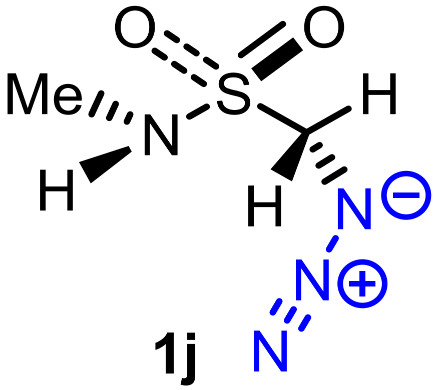
Mulliken charges:

```
1     N   -0.399742
2     C    0.363399
3     C   -0.301574
4     O   -0.381247
5     C   -0.075407
6     C   -0.173634
7     N   -0.271622
8     N    0.250537
9     N   -0.183940
10    H    0.221568
11    H    0.152213
12    H    0.119446
13    H    0.158420
14    H    0.140003
15    H    0.117178
16    H    0.142183
17    H    0.122218
Sum of Mulliken charges = -0.00000
```

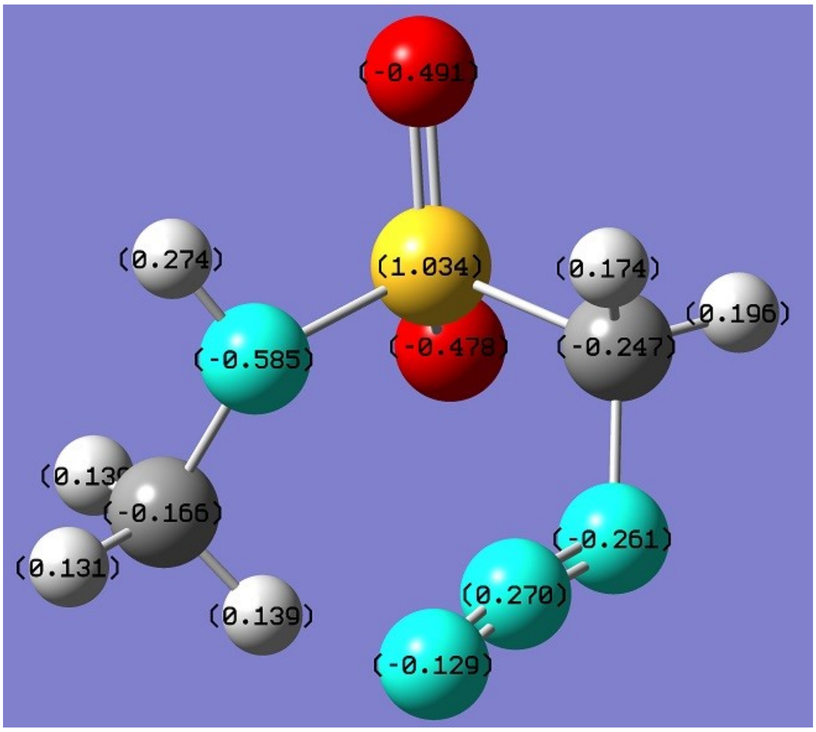
Mulliken charges with hydrogens summed into heavy atoms:

```
1     N   -0.178174
2     C    0.363399
3     C   -0.029915
4     O   -0.381247
5     C    0.223017
6     C    0.207945
7     N   -0.271622
8     N    0.250537
9     N   -0.183940
```

(14) 1-azido-*N*-methylmethanesulfonamide 1j



1j



E(RB3LYP) = -847.486928571 (a.u.)

Standard orientation:

```
 ---------------------------------------------------------------------
 Center     Element      Atomic              Coordinates (Angstroms)
 Number                  Type              X           Y           Z
 ---------------------------------------------------------------------
      1        N           0        -0.270891    1.091473   -0.652715
      2        S           0        -1.113182   -0.228220   -0.024672
      3        C           0         0.229088   -1.498574    0.005086
      4        O           0        -1.509044    0.050540    1.349967
      5        O           0        -2.068825   -0.656826   -1.042663
      6        C           0         0.062032    2.202285    0.255915
      7        N           0         1.418288   -1.031751    0.684502
      8        N           0         2.210913   -0.364296    0.007256
      9        N           0         3.027385    0.245715   -0.481207
     10        H           0        -0.720547    1.373076   -1.517084
     11        H           0        -0.179779   -2.333685    0.570698
     12        H           0         0.387460   -1.780057   -1.038662
     13        H           0         0.587259    1.807875    1.124463
     14        H           0         0.731790    2.877452   -0.277751
     15        H           0        -0.818903    2.746909    0.603798
 ---------------------------------------------------------------------
```

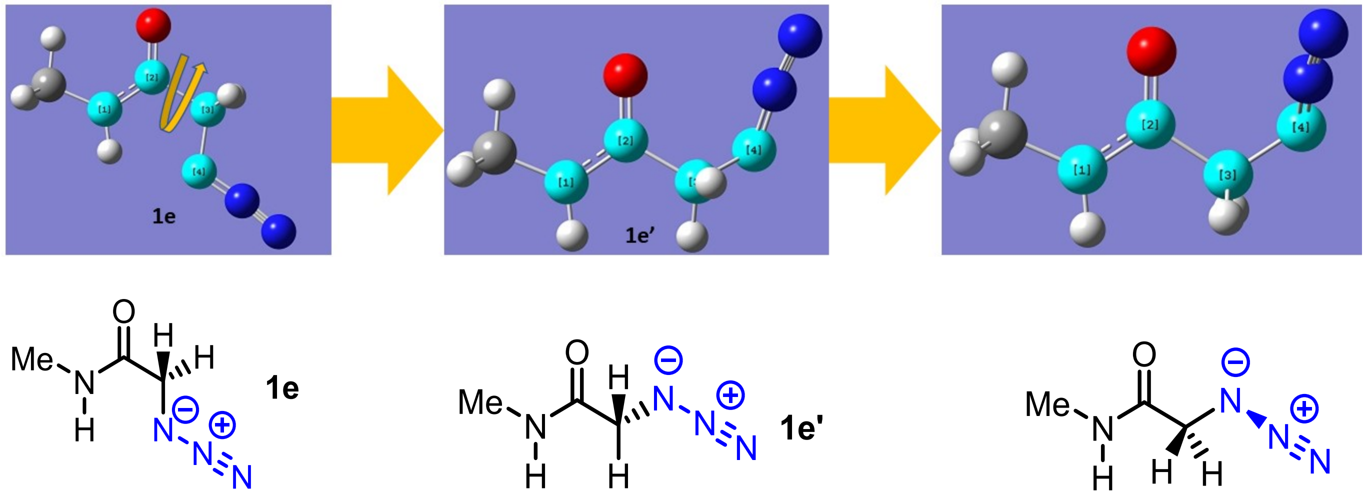
Mulliken charges:

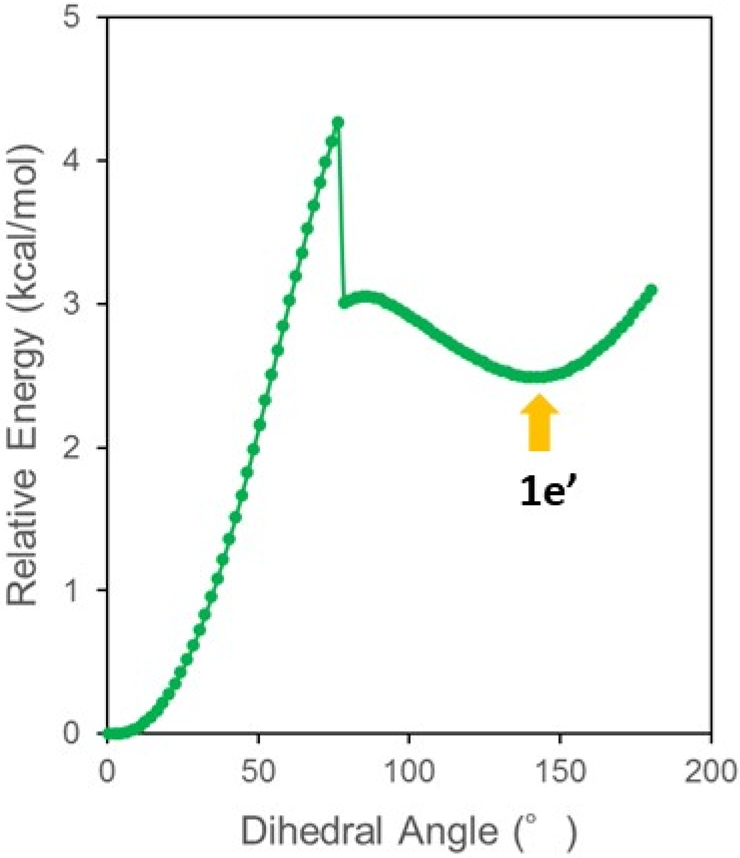
```
1    N   -0.585144
2    S    1.033638
3    C   -0.247313
4    O   -0.477892
5    O   -0.490824
6    C   -0.165559
7    N   -0.261169
8    N    0.270355
9    N   -0.128921
10   H    0.273891
11   H    0.195875
12   H    0.173922
13   H    0.139326
14   H    0.130979
15   H    0.138836
Sum of Mulliken charges =   -0.00000
```

Mulliken charges with hydrogens summed into heavy atoms:

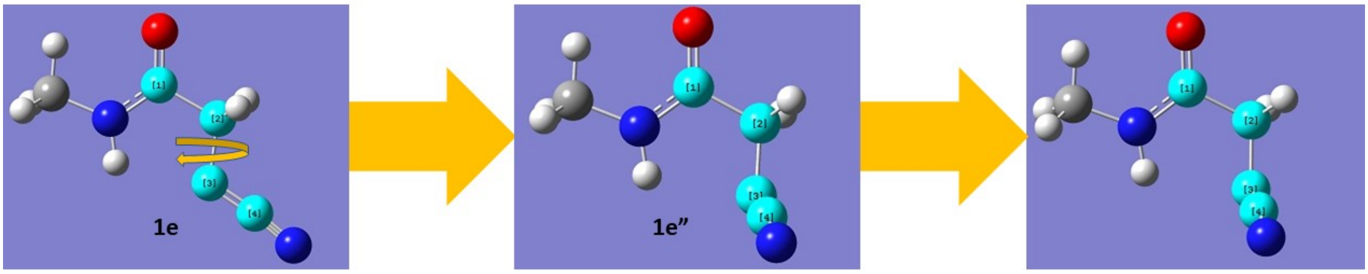
```
1    N   -0.311254
2    S    1.033638
3    C    0.122485
4    O   -0.477892
5    O   -0.490824
6    C    0.243582
7    N   -0.261169
8    N    0.270355
9    N   -0.128921
```

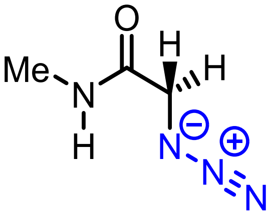
(15) Relative energy profile of 1e by changing the dihedral angles of C-C bond



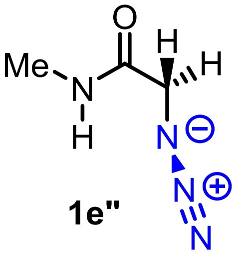


(16) Relative energy profile of 1e by changing the dihedral angles of azido moiety

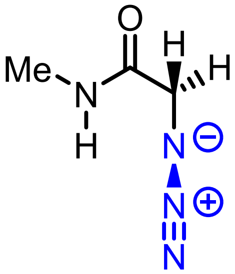


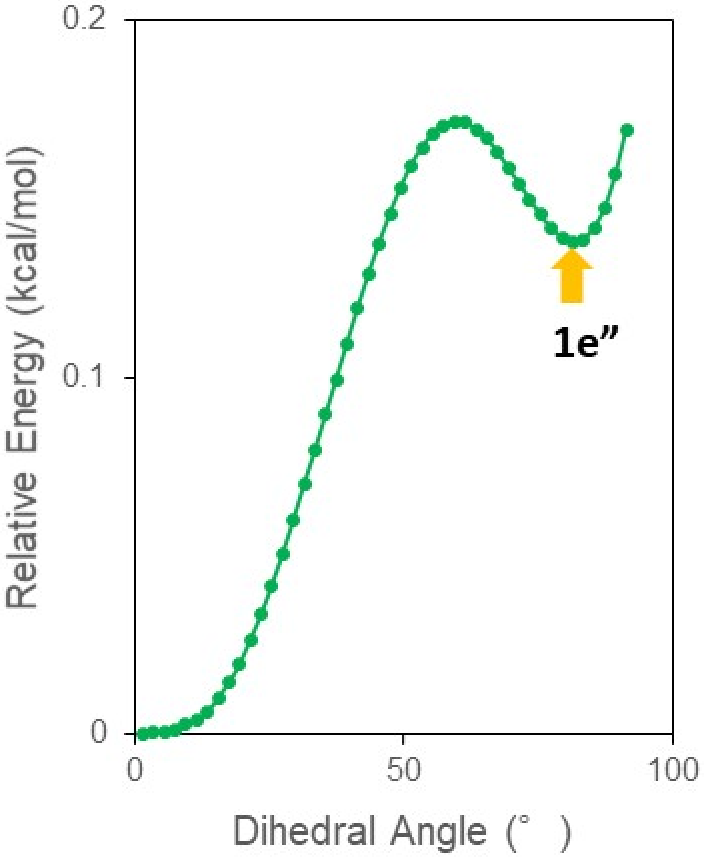


1e

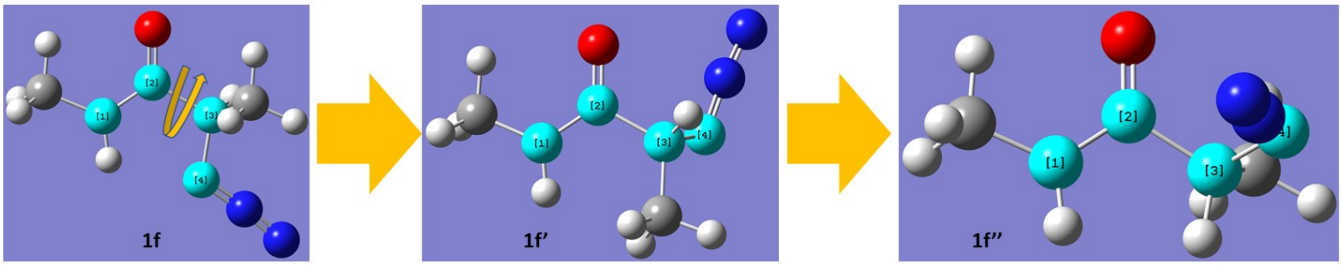


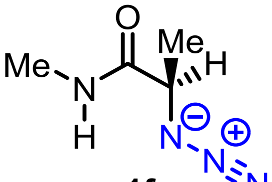
1e"



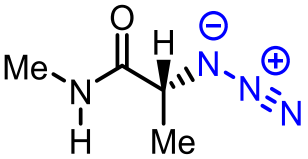


(17) Relative energy profile of 1f by changing the dihedral angles of C-C bond

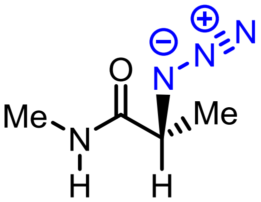




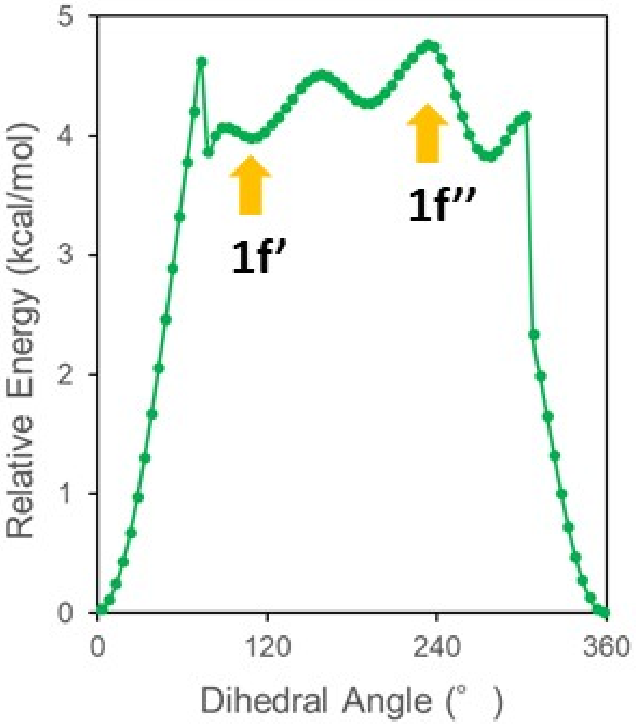
1f



1f'

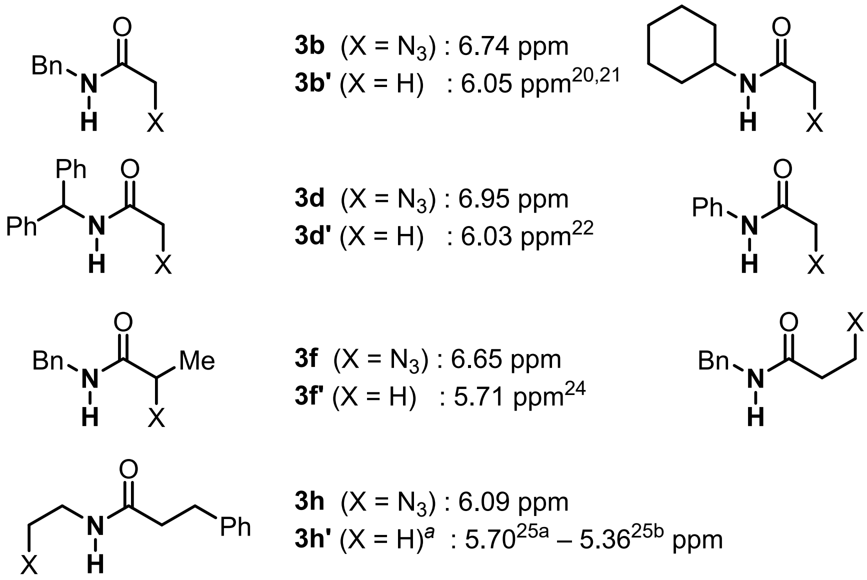


1f''



[9] Comparison of Chemical Shifts of NH in the Secondary Amides

Scheme S1. Comparison of Chemical Shifts of amide N-H protons in ^{1}H NMR spectra ($CDCl_3$, ambient temperature)



3b (X = N_3) : 6.74 ppm
3b' (X = H) : 6.05 ppm[20,21]

3c (X = N_3) : 6.16 ppm
3c' (X = H) : 5.60 ppm[21]

3d (X = N_3) : 6.95 ppm
3d' (X = H) : 6.03 ppm[22]

3e (X = N_3) : 7.99 ppm
3e' (X = H)[a] : 8.22[23a] – 7.15[23b] ppm

3f (X = N_3) : 6.65 ppm
3f' (X = H) : 5.71 ppm[24]

3g (X = N_3) : 5.87 ppm
3f' (X = H) : 5.71 ppm[24]

3h (X = N_3) : 6.09 ppm
3h' (X = H)[a] : 5.70[25a] – 5.36[25b] ppm

[a] Chemical shifts of amide N-H are variable. Among them, those of **3e'** and **3h'** would not be suitable for estimation of the hydrogen bonding because of the wide range of the observed signals.

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[11] ^{1}H, ^{13}C and ^{31}P NMR Spectra

See next pages.