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Synthesis of Optically Active Deuterated Primary Amines via Reduction of *N-tert*-Butanesulfinyl Aldimines

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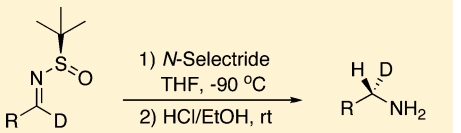
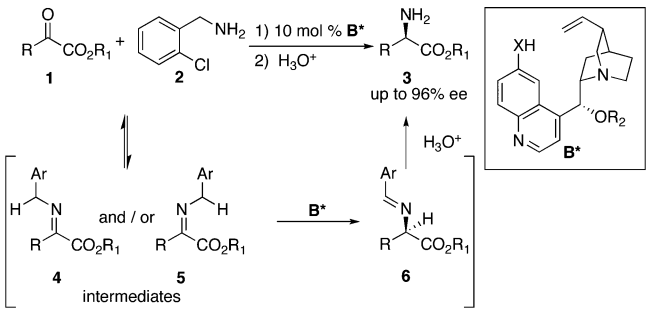
Supporting Information

ABSTRACT: Optically active deuterated primary amines have been obtained with 78−98% ee's from chiral *N-tert*-butanesulfinyl aldimines via reduction with *N*-Selectride and subsequent alcoholysis.



Recently, we have reported an efficient biomimetic transamination of α-keto esters to optically active α-amino esters with high ee's with a quinine-derived chiral base as catalyst and *o*-ClPhCH$_2$NH$_2$ as nitrogen source (Scheme 1).[1]

Scheme 1



In this transamination process, the enantioselectivity is determined by the [1,3]-proton shift from ketimine **4** and/or **5** to aldimine **6**. To further understand the influencing factors for the enantioselectivity, optically active deuterated primary amine *o*-ClPhCHDNH$_2$ would provide a useful probe for the study. During such efforts, we have found that *o*-ClPhCHDNH$_2$ can be efficiently synthesized from the corresponding chiral *N-tert*-butanesulfinyl aldimines[2] via reduction with *N*-Selectride and subsequent alcoholysis (Scheme 2).[3] Considering the potential usefulness of deuterated chiral primary amines for the study of other reaction mechanisms,[4−9] we further investigated the reaction scope of this process. Herein, we wish to report our studies on this subject.

N-tert-Butanesulfinyl aldimine **7a**, prepared from deuterated 2-chlorobenzaldehyde and (*R*)-(+)-*tert*-butanesulfinamide,[10] was used as a test substrate for initial studies (Table 1). Among various hydrides examined, LiAlH$_4$, LiBEt$_3$H, and *N*-Selectride were found to be highly effective for the reduction,

Scheme 2

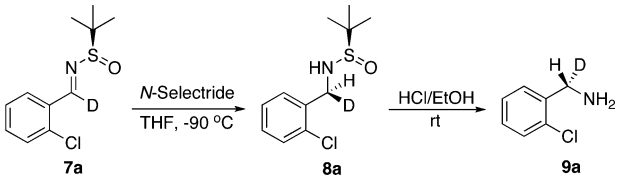
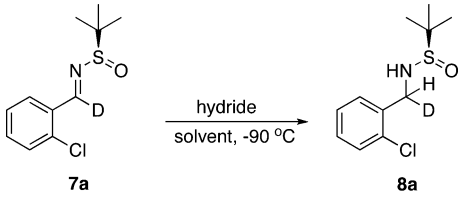


Table 1. Studies on Reaction Conditions[a]



entry	hydride	solvent	yield[b] (%)	de[c] (%)
1	DIBAL	THF	88	40 (R_S, R)
2	$NaBH_4$	THF	87	44 (R_S, R)
3	$LiAlH_4$	THF	93	90 (R_S, S)
4	$LiBEt_3H$	THF	94	95 (R_S, S)
5	*N*-Selectride	THF	98	98 (R_S, S)
6	*N*-Selectride	CH_2Cl_2	90	63 (R_S, S)
7	*N*-Selectride	Et_2O	92	95 (R_S, S)
8	*N*-Selectride	toluene	94	86 (R_S, S)

[a]The reactions were carried out with **7a** (0.50 mmol) and hydride (0.75 mmol) in solvent (5 mL) at −90 °C under N_2 for 3 h. [b]Isolated yield based on **7a**. [c]The de's were determined by ^{1}H NMR.

and up to 98% de was obtained with *N*-Selectride in THF at −90 °C (Table 1, entry 5). As shown in Table 2, the reaction

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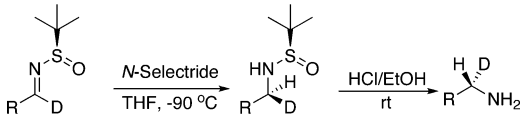
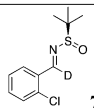
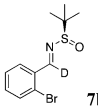
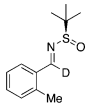
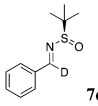
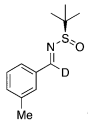
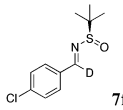
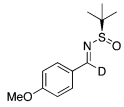
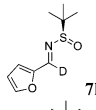
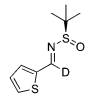
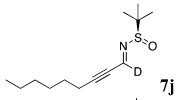
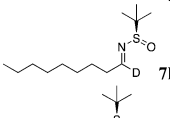
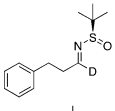
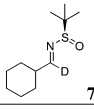
Table 2. Reduction of Deuterated *N*-*tert*-Butanesulfinyl Aldimines[a,b]

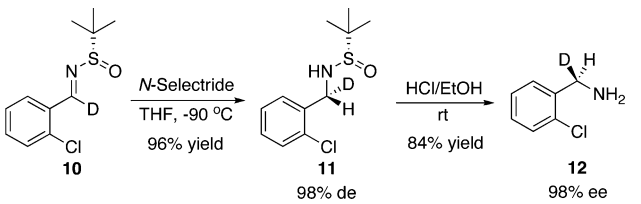


entry	aldimine (7)	8 yield[c] (%)	8 de[d] (%)	9 yield[c] (%)	9 ee[e,f] (%)
1	 **7a**	97	98	85	98
2	 **7b**	93	97	89	97
3	 **7c**	94	95	83	95
4	 **7d**	94	96	81	96
5	 **7e**	94	94	81	94
6	 **7f**	92	95	84	95
7	 **7g**	94	94	81	94
8	 **7h**	93	94	65	94
9	 **7i**	90	94	78	94
10	 **7j**	93	93	83	93
11	 **7k**	94	85	86	85
12	 **7l**	97	86	87	86
13	 **7m**	92	78	81	78

[a]All reductions were carried out with **7** (1.50 mmol) and *N*-Selectride (2.25 mmol) in THF (15 mL) at −90 °C under N_2 for 3 h unless otherwise stated. For entry 7, the reaction was carried out with *N*-Selectride (4.50 mmol) for 48 h. For entries 8 and 9, the reactions were carried out with *N*-Selectride (4.50 mmol) for 24 h. [b]The alcoholysis was carried out with *tert*-butanesulfinamides (**8**) (1.25 mmol) and 33% HCl/EtOH (3 mL) in EtOH (6 mL) at rt for 3 h. [c]Isolated yield of **8** based on **7**, and isolated yield of **9** based on **8**. [d]The de's were determined by ^{1}H NMR. [e]The ee's were determined by ^{1}H NMR after the primary amines were converted to the corresponding (*R*)-M*α*NP amides unless otherwise stated. For entry 13, the ee was determined by ^{1}H NMR after the primary amine was converted to the corresponding (*S*)-Mosher amide. [f]For entry 4, the absolute configuration (*S*) of **9d** was determined by comparing the ^{1}H NMR of the corresponding (*R*)-M*α*NP amide and (*S*)-Mosher amide with the reported ones (refs 9b and 4o,) as well as supported by comparing its optical rotation with the reported one (ref 4d). The absolute configurations of remaining amines were tentatively proposed by analogy.

can be applied to a variety of deuterated *N*-*tert*-butanesulfinyl aromatic aldimines **7** to give the corresponding *tert*-butanesulfinamides (**8**) in 90−97% yields and 94−98% de's (Table 2, entries 1−9). The substituents on the phenyl group appear to have little effect on diastereoselectivity in the cases examined. An alkynyl aldimine was also an effective substrate, giving the reduction product in 93% yield and 93% de (Table 2, entry 10). Slightly lower diastereoselectivities (78−86% de's) were obtained with aliphatic aldimines (Table 2, entries 11−13). The *tert*-butanesulfinamides can be readily converted to the corresponding chiral deuterated primary amines in 65−89% yields and 78−98% ee's with HCl/EtOH at rt. No racemization was observed during the alcoholysis. The ee was determined by the ^{1}H NMR analysis of the corresponding (*R*)-2-methoxy-2-(1-naphthyl)propionic amides [(*R*)-M*α*NP amides][9b,11] or (*S*)-Mosher amide.[12] The (*R*)-deuterated primary amine (**12**) was obtained with 98% ee from (*S*)-(−)-*tert*-butanesulfinamide (Scheme 3).

Scheme 3



In conclusion, we have developed an efficient method for the synthesis of deuterated primary amines with high ee's via reduction of deuterated *N*-*tert*-butanesulfinyl aldimines with *N*-Selectride and subsequent alcoholysis. The current process provides ready access to various optically active deuterated primary amines, which could be useful for studies of reaction mechanisms in the future.

EXPERIMENTAL SECTION

General Methods. All commercially available reagents were used without further purification unless otherwise noted. All solvents were freshly distilled under nitrogen from appropriate drying agents before use. Tetrahydrofuran, toluene, and ethyl ether were distilled from sodium-benzophenone. Dichloromethane was distilled from CaH_2. Column chromatography was performed on silica gel (200−300 mesh). ^{1}H NMR spectra were recorded on a 400 MHz NMR spectrometer, and ^{13}C NMR spectra were recorded on a 100 MHz NMR spectrometer. High-resolution mass spectra (HRMS) were obtained using an ESI-FTICR or ESI-LTQ-Orbitrap mass spectrometer. IR spectra were recorded on an FT-IR spectrometer. Melting points were uncorrected. Deuterated aldehydes were prepared from the corresponding esters by reduction with $LiAlD_4$[13] and subsequent

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oxidation with PCC.[14] *N*-*tert*-Butanesulfinyl aldimines were prepared from the deuterated aldehydes according to the reported procedure.[10]

Representative Procedure for Diastereoselective Reduction of *N*-*tert*-Butanesulfinyl Aldimines (Table 2, Entry 1). To a stirred solution of **7a** (0.367 g, 1.50 mmol) in THF (15 mL) at −90 °C was added *N*-Selectride (1.0 M in THF) (2.25 mL, 2.25 mmol) dropwise under N_2.[3c] The reaction mixture was stirred at −90 °C for 3 h, quenched with saturated aqueous NH_4Cl, extracted with EtOAc (3 × 30 mL), washed with brine, dried over $MgSO_4$, filtered, concentrated, and purified by flash chromatography (silica gel, petroleum ether/ethyl acetate = 4/3) to give *tert*-butanesulfinamide **8a** as a white solid (0.358 g, 97% yield, 98% de).

Representative Procedure for Alcoholysis (Table 2, Entry 1). To a solution of *tert*-butanesulfinamide **8a** (0.308 g, 1.25 mmol) in EtOH (6 mL) was added HCl (33% in EtOH) (3 mL) at rt.[3d] Upon stirring at rt for 3 h, the reaction mixture was diluted with water (30 mL), concentrated to remove EtOH, washed with Et_2O (4 × 15 mL), brought to pH > 13 with 4 N NaOH, extracted with Et_2O (3 × 30 mL), washed with brine, dried over $MgSO_4$, filtered, and concentrated to give deuterated amine **9a** as a light yellow oil (0.152 g, 85% yield, 98% ee).

Representative Procedure for the Determination of the Optical Purity of Chiral Amines. To a solution of DCC (0.031 g, 0.15 mmol) and (*R*)-(−)-2-methoxy-2-(1-naphthyl)propionic acid (0.035 g, 0.15 mmol) in CH_2Cl_2 (5 mL) at rt was added amine **9a** (0.014 g, 0.10 mmol).[9b] The reaction mixture was stirred at rt for 3 h and filtrated. The filtrate was concentrated and purified by flash chromatography (silica gel, petroleum ether/ethyl acetate = 4/1) to give the corresponding (*R*)-M*α*NP amide **13a** as a colorless oil (0.025 g, 71%). The enantiomeric excess was determined by ^{1}H NMR analysis of the resulting (*R*)-M*α*NP amide.

(*R*)-*N*-[(*S*)-(2-Chlorophenyl)methyl-*d*]-2-methylpropane-2-sulfinamide (8a). White solid (0.358 g, 97% yield, 98% de); mp. 107−108 °C; IR (film) 3205, 1464, 1439, 1057 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.45−7.34 (m, 2H), 7.30−7.21 (m, 2H), 4.33 (d, *J* = 8.0 Hz, 1H), 3.57 (d, *J* = 7.6 Hz, 1H), 1.23 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 136.3, 134.0, 130.2, 129.8, 129.2, 127.2, 56.2, 47.3 (t, $J_{C\text{-}D}$ = 21.0 Hz), 22.8; HRMS Calcd for $C_{11}H_{16}ClDNOS$ (M + H): 247.0777; Found: 247.0775.

(*S*)-(2-Chlorophenyl)methan-*d*-amine (9a). Yellow oil (0.152 g, 85% yield, 98% ee); IR (film) 3368, 3312, 1620, 1471 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.43−7.30 (m, 2H), 7.29−7.15 (m, 2H), 3.91 (t, *J* = 2.0 Hz, 1H), 1.51 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 140.8, 133.5, 129.6, 129.1, 128.3, 127.2, 44.4 (t, $J_{C\text{-}D}$ = 21.0 Hz); HRMS Calcd for C_7H_8ClDN (M + H): 143.0481; Found: 143.0479.

(*S*)-*N*-[(*R*)-(2-Chlorophenyl)methyl-*d*]-2-methylpropane-2-sulfinamide (11). White solid (0.355 g, 96% yield, 98% de); mp. 108−109 °C; IR (film) 3211, 1466, 1440, 1047 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.43−7.34 (m, 2H), 7.28−7.21 (m, 2H), 4.33 (d, *J* = 7.6 Hz, 1H), 3.57 (d, *J* = 7.2 Hz, 1H), 1.23 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 136.3, 133.7, 130.1, 129.7, 129.1, 127.1, 56.1, 47.1 (t, $J_{C\text{-}D}$ = 22.0 Hz), 22.7.

(*R*)-(2-Chlorophenyl)methan-*d*-amine (12). Yellow oil (0.149 g, 84% yield, 98% ee); IR (film) 3373, 3297, 1593, 1471 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.42−7.30 (m, 2H), 7.29−7.13 (m, 2H), 3.90 (br s, 1H), 1.57 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 140.8, 133.5, 129.7, 129.1, 128.4, 127.2, 44.5 (t, $J_{C\text{-}D}$ = 22.0 Hz).

(*R*)-*N*-[(*S*)-(2-Bromophenyl)methyl-*d*]-2-methylpropane-2-sulfinamide (8b). White solid (0.407 g, 93% yield, 97% de); mp. 114−115 °C; IR (film) 3213, 1470, 1459, 1058 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.56 (d, *J* = 8.0 Hz, 1H), 7.41 (dd, *J* = 7.6, 1.2 Hz, 1H), 7.30 (t, *J* = 7.6 Hz, 1H), 7.16 (td, *J* = 8.0, 1.6 Hz, 1H), 4.31 (d, *J* = 7.6 Hz, 1H), 3.61 (d, *J* = 7.6 Hz, 1H), 1.23 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 137.8, 132.7, 130.0, 129.1, 127.5, 123.6, 55.9, 49.2 (t, $J_{C\text{-}D}$ = 21.0 Hz), 22.6; HRMS Calcd for $C_{11}H_{16}BrDNOS$ (M + H): 291.0272; Found: 291.0275.

(*S*)-(2-Bromophenyl)methan-*d*-amine (9b). Yellow oil (0.208 g, 89% yield, 97% ee); IR (film) 3372, 3287, 1590, 1466, 1437 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.54 (d, *J* = 8.0 Hz, 1H), 7.37 (d, *J* = 7.6 Hz, 1H), 7.29 (t, *J* = 7.6 Hz, 1H), 7.16−7.05 (m, 1H), 3.89 (t, *J* = 2.0 Hz, 1H), 1.51 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 142.5, 133.0, 129.3, 128.7, 127.9, 123.7, 46.9 (t, $J_{C\text{-}D}$ = 21.0 Hz); HRMS Calcd for C_7H_8BrDN (M + H): 186.9976; Found: 186.9970.

(*R*)-2-Methyl-*N*-[(*S*)-*o*-tolylmethyl-*d*]propane-2-sulfinamide (8c). White solid (0.321 g, 94% yield, 95% de); mp. 75−76 °C; IR (film) 3217, 1483, 1456, 1056 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.34−7.28 (m, 1H), 7.25−7.15 (m, 3H), 4.21 (d, *J* = 8.8 Hz, 1H), 3.31 (d, *J* = 8.8 Hz, 1H), 2.36 (s, 3H), 1.24 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 136.9, 136.2, 130.6, 129.0, 128.0, 126.2, 55.9, 47.1 (t, $J_{C\text{-}D}$ = 22.0 Hz), 22.8, 19.1; HRMS Calcd for $C_{12}H_{19}DNOS$ (M + H): 227.1323; Found: 227.1323.

(*S*)-*o*-Tolylmethan-*d*-amine (9c). Yellow oil (0.127 g, 83% yield, 95% ee); IR (film) 3371, 3299, 1605, 1460 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.31 (d, *J* = 6.8 Hz, 1H), 7.24−7.13 (m, 3H), 3.85 (t, *J* = 2.0 Hz, 1H), 2.35 (s, 3H), 1.36 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 141.3, 135.6, 130.4, 127.2, 127.0, 126.3, 44.0 (t, $J_{C\text{-}D}$ = 21.0 Hz), 19.0; HRMS Calcd for $C_8H_{11}DN$ (M + H): 123.1027; Found: 123.1025.

(*R*)-2-Methyl-*N*-[(*S*)-phenylmethyl-*d*]propane-2-sulfinamide (8d). White solid (0.300 g, 94% yield, 96% de); mp. 66−68 °C; IR (film) 3184, 1494, 1451, 1046 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.38−7.32 (m, 4H), 7.32−7.26 (m, 1H), 4.24 (d, *J* = 8.0 Hz, 1H), 3.51 (d, *J* = 7.6 Hz, 1H), 1.24 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 138.5, 128.4, 127.9, 127.4, 55.7, 48.8 (t, $J_{C\text{-}D}$ = 21.0 Hz), 22.6; HRMS Calcd for $C_{11}H_{17}DNOS$ (M + H): 213.1166; Found: 213.1164.

(*S*)-Phenylmethan-*d*-amine (9d).[9b] Yellow oil (0.110 g, 81% yield, 96% ee); IR (film) 3362, 3286, 1604, 1450 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.37−7.28 (m, 4H), 7.28−7.21 (m, 1H), 3.85 (t, *J* = 2.0 Hz, 1H), 1.44 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 143.4, 128.6, 127.2, 126.9, 46.3 (t, $J_{C\text{-}D}$ = 21.0 Hz).

(*R*)-2-Methyl-*N*-[(*S*)-*m*-tolylmethyl-*d*]propane-2-sulfinamide (8e). White solid (0.319 g, 94% yield, 94% de); mp. 74−75 °C; IR (film) 3181, 1608, 1040 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.24 (t, *J* = 8.0 Hz, 1H), 7.17−7.08 (m, 3H), 4.20 (d, *J* = 8.0 Hz, 1H), 3.43 (d, *J* = 8.0 Hz, 1H), 2.35 (s, 3H), 1.25 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 138.5, 138.4, 129.0, 128.6, 128.5, 125.3, 56.0, 49.2 (t, $J_{C\text{-}D}$ = 21.0 Hz), 22.8, 21.5; HRMS Calcd for $C_{12}H_{19}DNOS$ (M + H): 227.1323; Found: 227.1324.

(*S*)-*m*-Tolylmethan-*d*-amine (9e). Yellow oil (0.124 g, 81% yield, 94% ee); IR (film) 3371, 3287, 1608, 1488 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.23 (t, *J* = 7.6 Hz, 1H), 7.18−7.03 (m, 3H), 3.82 (br s, 1H), 2.36 (s, 3H), 1.44 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 143.5, 138.4, 128.6, 128.0, 127.7, 124.3, 46.4 (t, $J_{C\text{-}D}$ = 20.0 Hz), 21.6; HRMS Calcd for $C_8H_{11}DN$ (M + H): 123.1027; Found: 123.1026.

(*R*)-*N*-[(*S*)-(4-Chlorophenyl)methyl-*d*]-2-methylpropane-2-sulfinamide (8f). White solid (0.342 g, 92% yield, 95% de); mp. 106−107 °C; IR (film) 3172, 1491, 1471, 1039 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.35−7.25 (m, 4H), 4.22 (d, *J* = 7.6 Hz, 1H), 3.45 (d, *J* = 7.6 Hz, 1H), 1.24 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 137.1, 133.6, 129.6, 128.9, 56.1, 48.6 (t, $J_{C\text{-}D}$ = 22.0 Hz), 22.8; HRMS Calcd for $C_{11}H_{16}ClDNOS$ (M + H): 247.0777; Found: 247.0777.

(*S*)-(4-Chlorophenyl)methan-*d*-amine (9f).[9b] Yellow oil (0.150 g, 84% yield, 95% ee); IR (film) 3372, 3298, 1595, 1491 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.34−7.21 (m, 4H), 3.83 (t, *J* = 2.0 Hz, 1H), 1.43 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 141.8, 132.6, 128.8, 128.6, 45.6 (t, $J_{C\text{-}D}$ = 21.0 Hz).

(*R*)-*N*-[(*S*)-(4-Methoxyphenyl)methyl-*d*]-2-methylpropane-2-sulfinamide (8g). White solid (0.341 g, 94% yield, 94% de); mp. 62−64 °C; IR (film) 3206, 1612, 1514, 1055 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.29−7.23 (m, 2H), 6.90−6.85 (m, 2H), 4.17 (d, *J* = 8.0 Hz, 1H), 3.81 (s, 3H), 3.38 (d, *J* = 8.0 Hz, 1H), 1.24 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 159.4, 130.7, 129.6, 114.2, 56.0, 55.5, 48.8 (t, $J_{C\text{-}D}$ = 21.0 Hz), 22.9; HRMS Calcd for $C_{12}H_{19}DNO_2S$ (M + H): 243.1272; Found: 243.1276.

(*S*)-(4-Methoxyphenyl)methan-*d*-amine (9g).[9b] Yellow oil (0.139 g, 81% yield, 94% ee); IR (film) 3366, 3281, 1611, 1514 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.22 (d, *J* = 8.4 Hz, 2H), 6.87 (d, *J* = 8.4 Hz, 2H), 3.79 (s, 3H), 3.78 (t, *J* = 2.0 Hz, 1H), 1.39 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 158.6, 135.8, 128.4, 114.1, 55.4, 45.7 (t, $J_{C\text{-}D}$ = 21.0 Hz).

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(*R*)-*N*-[(*S*)-Furan-2-ylmethyl-*d*]-2-methylpropane-2-sulfinamide (8h). Colorless oil (0.283 g, 93% yield, 94% de); IR (film) 3209, 1475, 1364, 1057 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40−7.36 (m, 1H), 6.33 (dd, J = 3.2, 2.0 Hz, 1H), 6.27 (d, J = 3.2 Hz, 1H), 4.26−4.18 (m, 1H), 3.44 (d, J = 6.8 Hz, 1H), 1.22 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.0, 142.6, 110.5, 108.0, 56.2, 42.1 (t, $J_{C\text{-}D}$ = 21.0 Hz), 22.7; HRMS Calcd for $C_9H_{15}DNO_2S$ (M + H): 203.0959; Found: 203.0959.

(*S*)-Furan-2-ylmethan-*d*-amine (9h). Yellow oil (0.080 g, 65% yield, 94% ee); IR (film) 3361, 3291, 1660, 1505, 1147 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.33 (d, J = 1.2 Hz, 1H), 6.29 (dd, J = 3.2, 2.0 Hz, 1H), 6.12 (d, J = 3.2 Hz, 1H), 3.79 (t, J = 2.4 Hz, 1H), 1.49 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.9, 141.7, 110.3, 105.2, 39.2 (t, $J_{C\text{-}D}$ = 21.0 Hz); HRMS Calcd for C_5H_7DNO (M + H): 99.0663; Found: 99.0666.

(*R*)-2-Methyl-*N*-[(*S*)-thiophen-2-ylmethyl-*d*]propane-2-sulfinamide (8i). White solid (0.294 g, 90% yield, 94% de); mp. 79−81 °C; IR (film) 3171, 1473, 1459, 1048 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.25 (d, J = 4.8 Hz, 1H), 7.00 (d, J = 3.6 Hz, 1H), 6.96 (dd, J = 4.8, 3.6 Hz, 1H), 4.41 (d, J = 7.6 Hz, 1H), 3.57 (d, J = 7.2 Hz, 1H), 1.25 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.0, 126.9, 125.9, 125.5, 56.1, 44.1 (t, $J_{C\text{-}D}$ = 22.0 Hz), 22.7; HRMS Calcd for $C_9H_{15}DNOS_2$ (M + H): 219.0731; Found: 219.0730.

(*S*)-Thiophen-2-ylmethan-*d*-amine (9i). Yellow oil (0.111 g, 78% yield, 94% ee); IR (film) 3364, 3295, 1592, 1439 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.20 (d, J = 5.2 Hz, 1H), 6.95 (dd, J = 5.2, 3.2 Hz, 1H), 6.92 (d, J = 3.2 Hz, 1H), 4.04 (t, J = 2.0 Hz, 1H), 1.63 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.5, 126.9, 124.1, 123.8, 41.2 (t, $J_{C\text{-}D}$ = 21.0 Hz); HRMS Calcd for C_5H_7DNS (M + H): 115.0435; Found: 115.0436.

(*R*)-2-Methyl-*N*-[(*S*)-non-2-yn-1-yl-1-*d*]propane-2-sulfinamide (8j). Yellow oil (0.341 g, 93% yield, 93% de); IR (film) 3204, 2242, 1057 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.81 (dt, J = 6.8, 2.0 Hz, 1H), 3.25 (d, J = 6.4 Hz, 1H), 2.18 (td, J = 6.8, 2.0 Hz, 2H), 1.54−1.43 (m, 2H), 1.42−1.24 (m, 6H), 1.23 (s, 9H), 0.88 (t, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 85.5, 76.2, 56.1, 35.0 (t, $J_{C\text{-}D}$ = 22.0 Hz), 31.5, 28.69, 28.67, 22.7, 18.9, 14.2; HRMS Calcd for $C_{13}H_{25}DNOS$ (M + H): 245.1792; Found: 245.1795.

(*S*)-Non-2-yn-1-*d*-1-amine (9j). Yellow oil (0.146 g, 83% yield, 93% ee); IR (film) 3373, 3284, 2221, 1602 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.38 (br s, 1H), 2.16 (t, J = 6.4 Hz, 2H), 1.55−1.43 (m, 2H), 1.42−1.18 (m, 8H), 0.88 (t, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 82.8, 81.0, 31.6 (t, $J_{C\text{-}D}$ = 21.0 Hz), 31.5, 29.0, 28.7, 22.7, 18.8, 14.2; HRMS Calcd for $C_9H_{17}DN$ (M + H): 141.1497; Found: 141.1495.

(*R*)-2-Methyl-*N*-[(*S*)-nonyl-1-*d*]propane-2-sulfinamide (8k). Colorless oil (0.351 g, 94% yield, 85% de); IR (film) 3203, 1053 cm^{-1}; ^1H NMR (400 MHz, MeOD) δ 3.02 (t, J = 7.2 Hz, 1H), 1.61−1.51 (m, 2H), 1.42−1.26 (m, 12H), 1.22 (s, 9H), 0.90 (t, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, MeOD) δ 56.8, 46.5 (t, $J_{C\text{-}D}$ = 21.0 Hz), 33.0, 32.1, 30.7, 30.4, 27.8, 23.7, 23.1, 14.4; HRMS Calcd for $C_{13}H_{29}DNOS$ (M + H): 249.2105; Found: 249.2109.

(*S*)-Nonan-1-*d*-1-amine (9k). Yellow oil (0.155 g, 86% yield, 85% ee); IR (film) 3330, 1467 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 2.65 (t, J = 6.8 Hz, 1H), 1.46−1.37 (m, 2H), 1.36−1.14 (m, 14H), 0.87 (t, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 42.1 (t, $J_{C\text{-}D}$ = 20.0 Hz), 34.0, 32.1, 29.8, 29.7, 29.5, 27.1, 22.9, 14.3; HRMS Calcd for $C_9H_{21}DN$ (M + H): 145.1810; Found: 145.1808.

(*R*)-2-Methyl-*N*-[(*S*)-3-phenylpropyl-1-*d*]propane-2-sulfinamide (8l). Colorless oil (0.349 g, 97% yield, 86% de); IR (film) 3215, 1603, 1455, 1051 cm^{-1}; ^1H NMR (400 MHz, MeOD) δ 7.30−7.22 (m, 2H), 7.22−7.12 (m, 3H), 3.04 (t, J = 7.2 Hz, 1H), 2.75−2.60 (m, 2H), 1.94−1.82 (m, 2H), 1.23 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.6, 128.7, 128.6, 126.2, 55.7, 45.0 (t, $J_{C\text{-}D}$ = 21.0 Hz), 33.2, 32.7, 22.8; HRMS Calcd for $C_{13}H_{21}DNOS$ (M + H): 241.1479; Found: 241.1476.

(*S*)-3-Phenylpropan-1-*d*-1-amine (9l). Colorless oil (0.148 g, 87% yield, 86% ee); IR (film) 3364, 3296, 1602, 1496, 1454 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.32−7.24 (m, 2H), 7.22−7.15 (m, 3H), 2.71 (t, J = 7.2 Hz, 1H), 2.65 (t, J = 7.6 Hz, 2H), 1.77 (q, J = 7.2 Hz, 2H), 1.35 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.3, 128.51, 128.48, 125.9, 41.5 (t, $J_{C\text{-}D}$ = 21.0 Hz), 35.4, 33.4; HRMS Calcd for $C_9H_{13}DN$ (M + H): 137.1184; Found: 137.1181.

(*R*)-*N*-[(*S*)-Cyclohexylmethyl-*d*]-2-methylpropane-2-sulfinamide (8m). White solid (0.302 g, 92% yield, 78% de); mp. 85−86 °C; IR (film) 3208, 1470, 1444, 1052 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.13 (d, J = 7.2 Hz, 1H), 2.85 (t, J = 7.6 Hz, 1H), 1.83−1.61 (m, 5H), 1.51−1.39 (m, 1H), 1.29−1.11 (m, 12H), 0.98−0.84 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 55.7, 51.8 (t, $J_{C\text{-}D}$ = 21.0 Hz), 39.0, 30.9, 30.8, 26.5, 25.90, 25.88, 22.7; HRMS Calcd for $C_{11}H_{23}DNOS$ (M + H): 219.1636; Found: 219.1634.

(*S*)-Cyclohexylmethan-*d*-amine (9m). Yellow oil (0.115 g, 81% yield, 78% ee); IR (film) 3360, 3289, 1574, 1448 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 2.47 (d, J = 5.2 Hz, 1H), 1.79−1.60 (m, 5H), 1.47 (br s, 2H), 1.31−1.09 (m, 4H), 0.95−0.79 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 48.6 (t, $J_{C\text{-}D}$ = 20.0 Hz), 41.3, 30.9, 26.8, 26.2; HRMS Calcd for $C_7H_{15}DN$ (M + H): 115.1340; Found: 115.1339.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

^1H NMR and ^{13}C NMR spectra. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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