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1,8-Diazabicyclo[5.4.0]undec-7-ene-mediated formation of *N*-sulfinyl imines

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Abstract

A facile and efficient method was developed for the preparation of a variety of aryl, heteroaryl, and alkyl *N*-sulfinyl imines using 1,8-diazabicyclo[5.4.0]undec-7-ene. In addition to *tert*-butanesulfinamide, the condensation is also effective with *p*-toluenesulfinamide. The reaction was performed at room temperature and produces the corresponding *N*-sulfinyl imines in excellent yields in the absence of acids, metals, and additives. This methodology is also useful for the preparation of *N*-sulfinyl imines on gram scale. A one-pot synthesis was developed using aryl and heteroaryl alcohols with both *tert*-butanesulfinamide and *p*-toluenesulfinamide at room temperature, resulting in the corresponding *N*-sulfinyl imines with good yields.

Keywords

condensation, 1,8-diazabicyclo[5.4.0]undec-7-ene, *N*-sulfinyl imines, one-pot synthesis, sulfinamide

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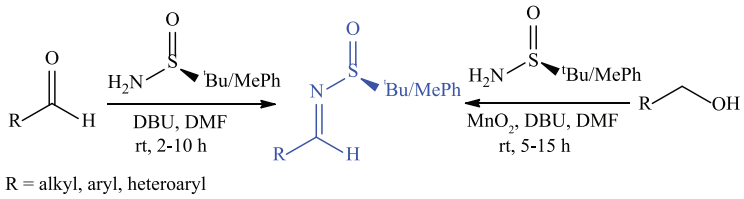

R = alkyl, aryl, heteroaryl

- Metal-free reaction
- One-pot synthesis
- Mild reaction conditions
- Scalable

Introduction

Imine bond formation by the condensation of carbonyl compounds and primary amine groups is important in organic synthesis due to the significance of imines in the fields of chemistry and biology.[1] Chiral sulfinamides function as amine counterparts and have been employed as useful chiral auxiliaries in asymmetric synthesis.[2–4] They represent key building blocks for the synthesis of a number of biologically active molecules, chiral amines,[4–8] and aziridines[9–12] and also are constituents of pharmaceuticals, agro-chemicals, and compounds with industrial interest.[13] There are several reports for the synthesis of aldimines, and these are mainly based on the condensation of aldehydes with sulfinamides in the presence of reagents containing metals. Earlier reports were focused on the application of either activating or dehydrating agents such as copper(II) sulfate,[14] magnesium sulfate–pyridinium *p*-toluenesulfonate,[14] titanium(IV) alkoxides,[14–16] cesium carbonate,[17] ytterbium(III) triflate,[18] potassium hydrogen sulfate,[19] and so on, to accomplish this conversion. These methods suffer from certain disadvantages like long reaction times, heating, low yields, formation of by-products, and usage of large excess reagents. Nevertheless, several reagents can achieve this transformation; indeed, there is a scope for the development of mild and efficient methods to address the drawbacks of the existing methodologies.

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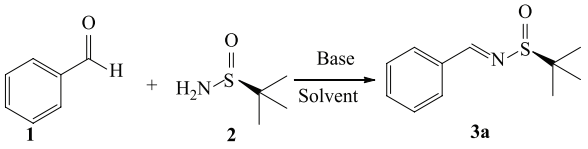
Table 1. Optimization of the reaction conditions.



Entry	Base (equiv.)	Solvent	Time (h)	Temp (°C)	Isolated yield (%)[a]
1	NMM (1.5)	THF	0.5	RT	np[b]
2	DABCO (1.5)	THF	0.5	RT	np[b]
3	DBU (1.5)	THF	0.5	RT	35
4	DBU (1.5)	THF	1	RT	62
5	DBU (1.5)	THF	2	RT	85
6	DBU (1.5)	1,4-Dioxane	2	RT	72
7	DBU (1.5)	DME	2	RT	75
8	**DBU** (1.5)	**DMF**	**2**	**RT**	**87**
9	DBU (1.5)	Solvent free	2	RT	np[b]
10	DBU (1.0)	DMF	2	RT	72
11	DBU (2.0)	DMF	2	RT	87
12	DBU (1.5)	DMF	0.5	50	30
13	DBU (1.5)	DMF	1	50	45
14	DBU (1.5)	DMF	2	50	55

NMM: *N*-methylmorpholine; THF: tetrahydrofuran; DABCO: 1,4-diazabicyclo[2.2.2]octane; DBU: 1,8-diazabicyclo[5.4.0]undec-7-ene; DME: dimethoxyethane; DMF: dimethyl formamide; RT: room temperature.

[a]Isolated yield after chromatographic purification.

[b]np: No product formation was observed.

The bold values in Table 1, indicate the best condition among screened conditions this is to attract readers attention to find the best among screened conditions.

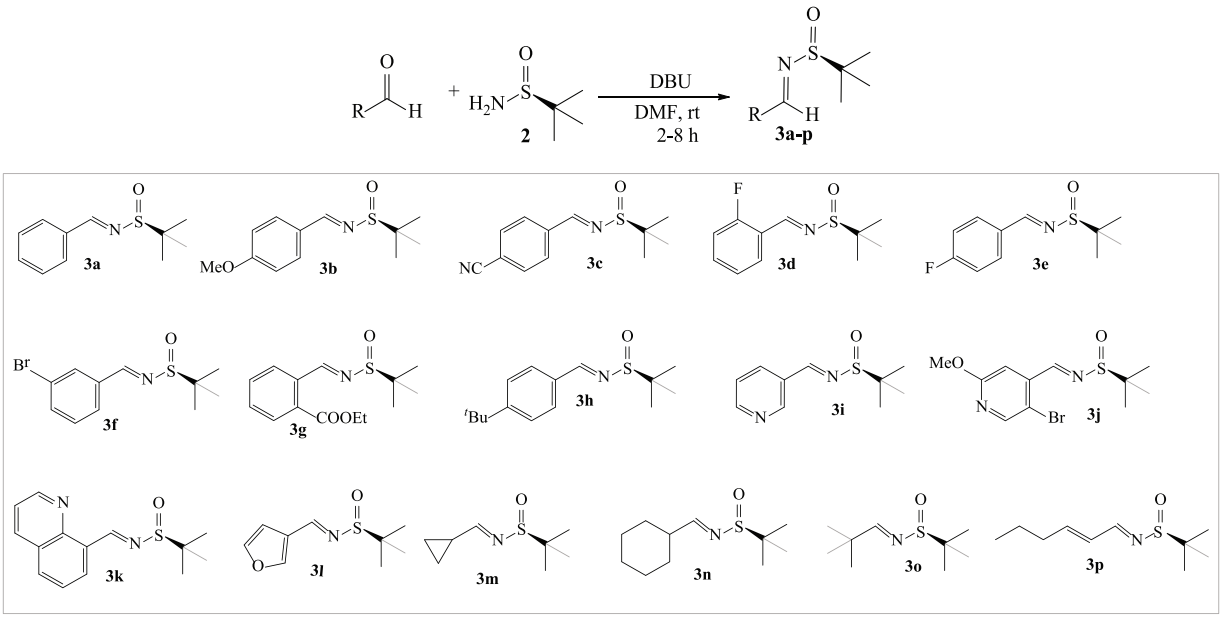
1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU) is a sterically hindered amidine, which is used as a non-nucleophilic base in organic synthesis to achieve various transformations.[20] It is cheap, readily available, and easy to remove from reaction mixtures. To the best of our knowledge, methods for the synthesis of *N*-sulfinyl imines using DBU have not been reported yet. Herein, we aimed to develop a simple, mild, highly efficient, economic, and metal-free protocol for the formation of sulfinyl imines from sulfinamides and aldehydes in the presence of DBU. This method offers various advantages such as high yields and simple work-up, is scalable, and employs mild reaction condition.

Results and discussion

We initially optimized the method by using benzaldehyde (1; Table 1) and (*S*)-*tert*-butanesulfinamide (**2**) as starting materials. In our preliminary experiments, benzaldehyde (**1**) (1.0 equiv.) was subjected to reaction with (*S*)-*tert*-butanesulfinamide (**2**) (1.5 equiv.) in the presence of different bases such as *N*-methylmorpholine (NMM), 1,4-diazabicyclo[2.2.2]octane (DABCO), and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in tetrahydrofuran (THF) at room temperature to obtain the corresponding sulfinyl imine. After 0.5 h, there was no product formation in case of NMM and DABCO, whereas formation of the desired product **3a** was observed with DBU (Table 1, entries 1–3), which was analyzed by thin-layer chromatography (TLC) and confirmed by 1H nuclear magnetic resonance (NMR). To determine the optimum reaction conditions, we further investigated the influence of solvents, time, stoichiometry, and temperature, and the results are summarized in Table 1. The results indicated that the solvents THF, 1,4-dioxane, dimethoxyethane (DME), and dimethyl formamide (DMF) were suitable for the reaction (Table 1, entries 5–8). It was established that DMF was the best among the screened solvents. No product formation was observed in the case of the solvent-free reaction after 2 h (Table 1, entry 9). In summary, this reaction is best performed with **1** (1.0 mmol) and **2** (1.5 mmol) in the presence of DBU (1.5 mmol) in DMF at room temperature (Table 1, entry 8). The scope of this condensation is amenable not only for *N*-(*tert*-butylsulfinyl)imines but also for *N*-*p*-toluenesulfinyl imines. Alternatively, a one-pot synthesis was carried out with alcohols and sulfinamides by employing manganese dioxide and DBU at room temperature to obtain good product yields.

With optimized reaction conditions in hand, the scope of the reaction was subsequently examined with respect to various aldehydes (Table 2). The parent benzaldehyde (Table 2, entry 1) was smoothly reacted with **2**, and the corresponding sulfinyl imine **3a** was obtained in 87% yield. Condensation of an electron-donating benzaldehyde (Table 2, entry 2) with **2** provided the sulfinyl imine in lower yield when compared to an electron-withdrawing benzaldehyde (Table 2, entry 3). The reaction was explored with substrates bearing *ortho, para*, and *meta* substitutents (Table 2, entries 4–8) which were also converted into the corresponding sulfinyl imines in good to excellent yields. Simple and substituted pyridine carboxaldehydes (Table 2, entries 9 and 10) reacted efficiently with **2** to provide imines **3i** and **3j** in similar yields. The bicyclic quinoline-8-carbaldehyde (Table 2, entry 11) provided the corresponding imine **3k** in 85% yield.

Table 2. Synthesis of *N*-(*tert*-butylsulfinyl)imines **3a–p**[a].



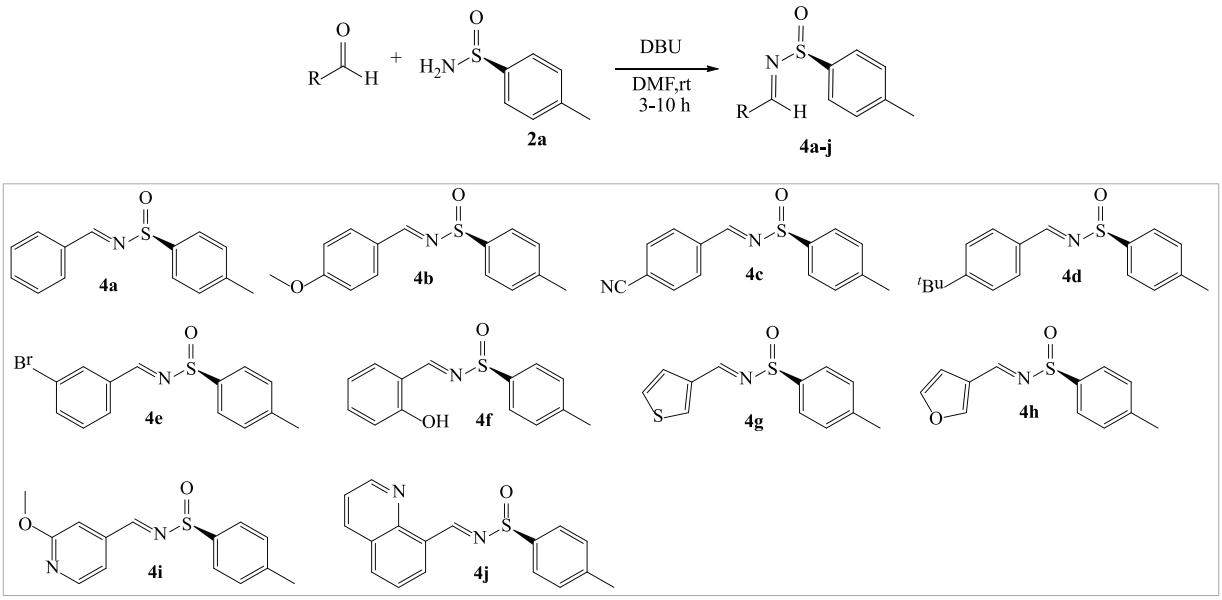
Entry	R	Time(h)	Product	Isolated yield (%)[b]
1	C_6H_5	2	**3a**	87
2	4-$MeOC_6H_4$	8	**3b**	81
3	4-NCC_6H_4	3	**3c**	92
4	2-FC_6H_4	4	**3d**	83
5	4-FC_6H_4	4	**3e**	87
6	3-BrC_6H_4	2	**3f**	92
7	2-$EtOOCC_6H_4$	8	**3g**	90
8	4-$^tBuC_6H_4$	7	**3h**	80
9	3-Pyridyl	2	**3i**	94
10	5-Br-2-MeO-4-Pyridyl	2	**3j**	96
11	8-Quinolinyl	5	**3k**	85
12	3-Furyl	3	**3l**	91
13	Cyclopropyl	5	**3m**	90
14	Cyclohexyl	5	**3n**	88
15	*tert*-butyl	6	**3o**	91
16	(*E*)-2-hexenyl	6	**3p**	83

DBU: 1,8-diazabicyclo[5.4.0]undec-7-ene; DMF: dimethyl formamide; RT: room temperature.
[a]Reaction conditions: aldehyde (1.0 mmol) and **2** (1.5 mmol) in DMF (1 mL) in the presence of DBU (1.5 mmol) at RT for 2–8 h.
[b]Isolated yield after chromatographic purification.

Similarly, furan-3-carbaldehyde (Table 2, entry 12) gave the desired product **3l** in high yield. On the other hand, aliphatic secondary, tertiary, and unsaturated aldehydes (Table 2, entries 13–16) were converted into the corresponding imines **3m–p** in high yields, thus demonstrating the potential of our synthetic methodology. Thus, this methodology is applicable for the reactions of a variety of aliphatic, aryl, and heteroaryl aldehydes with (*S*)-*tert*-butanesulfinamide (**2**) in the presence of DBU, and the reactions were complete in 2–8 h. After completion of the reaction, the mixture was subjected to a simple aqueous work-up. The residue was subjected to silica gel column chromatography, and the corresponding products **3a–p** were isolated. The chiral purities of sulfinyl imines **3a** and **3b** were evaluated by comparison with the corresponding racemic products, and the enantiomeric excess was determined as >99% in both the cases (The enantioselectivity of **3a** and **3b** was determined as >99% by chiral HPLC. (See the Supporting Information for HPLC data)). Thus, the significance of this method is that there was no racemization observed upon condensation of aldehydes with (*S*)-*tert*-butanesulfinamide.

To illustrate the scalability of the standardized conditions, a scale-up batch was performed by using **1** (5 g, 47.17 mmol) and **2** (8.56 g, 70.74 mmol) in DMF (65 mL) in the presence of DBU (10.75 g, 70.74 mmol) at room temperature for 2 h. After chromatographic purification, the desired product **3a** was obtained in a comparable yield (8.4 g, 85%). From this experiment, it was confirmed that our method is applicable for the preparation of sulfinyl imines on gram scale also.

Table 3. Synthesis of *N*-*p*-toluenesulfinyl imines **4a–j**[a].



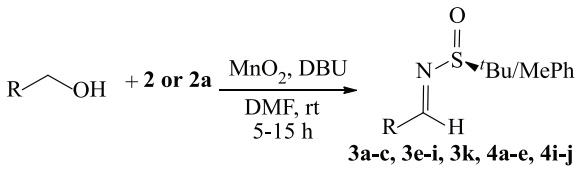
Entry	R	Time(h)	Product	Isolated yield (%)[b]
1	C_6H_5	3	**4a**	81
2	4-$MeOC_6H_4$	10	**4b**	78
3	4-NCC_6H_4	3	**4c**	85
4	4-$^tBuC_6H_4$	6	**4d**	80
5	3-BrC_6H_4	3	**4e**	91
6	2-HOC_6H_4	7	**4f**	82
7	3-Thienyl	5	**4g**	86
8	3-Furyl	5	**4h**	82
9	2-MeO-4-pyridyl	5	**4i**	85
10	8-Quinolinyl	6	**4j**	81

DBU: 1,8-diazabicyclo[5.4.0]undec-7-ene; DMF: dimethyl formamide; RT: room temperature.
[a]Reaction conditions: aldehyde (1.0 mmol) and **2a** (1.5 mmol) in DMF (1 mL) in the presence of DBU (1.5 mmol) at RT for 3–10 h.
[b]Isolated yield after chromatographic purification.

In addition to *N*-(*tert*-butylsulfinyl)imine (**2**), it was observed that the condensation was also effective with (*S*)-*p*-toluenesulfinamide (**2a**), as introduced by Davis, which is another commonly used chiral auxiliary.[8] Under the standardized conditions, it reacted with aldehydes to provide the corresponding imines **4a–k** in high yields (Table 3). With the optimized conditions in hand, the initial reaction was performed with **1** and **2a** in the presence of DBU at room temperature for 3 h and **4a** was obtained in 81% yield. The reaction was amenable for both electron-donating (Table 3, entry 2) and electron-withdrawing (Table 3, entry 3) aromatic aldehydes. Notably, the reaction also tolerated for substrates bearing *para, meta*, and *ortho* substituents (Table 3, entries 4–6), which were converted smoothly into the corresponding *N*-sulfinyl imines **4d**, **4e**, and **4f** in good yields. Similarly, five-membered heterocyclic aldehydes (Table 3, entries 7 and 8) were condensed with **2a** to provide **4g** and **4h** in 86% and 82% yields, respectively. 2-Methoxypyridine-4-carbaldehyde (Table 3, entry 9) upon condensation with **2a** was also effective, giving the corresponding imine **4i** in good yield. A bicyclic aldehyde (Table 3, entry 10) also produced the corresponding product **4j** in 81% yield. All the reactions were performed at room temperature, were completed in 3–10 h, and all the products were obtained in high yields. Unfortunately, enolizable aliphatic aldehydes upon condensation with (*S*)-*p*-toluenesulfinamide (**2a**) resulted in the corresponding products which were unstable as supported by 1H NMR.

Subsequently, we conducted the one-pot synthesis of *N*-sulfinyl imine[21] using benzyl alcohol (Table 4, entry 1), (*S*)-*tert*-butanesulfinamide **2**, and manganese dioxide in the presence of DBU in DMF at room temperature. As we anticipated, after 3 h, the formation of the corresponding product **3a** was observed by TLC; the reaction was continued, and complete conversion was observed after 5 h. The product was isolated in 75% yield, and the structure was confirmed by 1H NMR. The reaction proceeds through in situ oxidation of the alcohol to corresponding aldehyde in the presence of manganese dioxide, which upon subsequent condensation with the sulfinamide affords the corresponding *N*-sulfinyl imine. Electron-withdrawing and electron-donating aromatic alcohols (Table 4, entries 2 and 3) reacted with both the sulfinamides **2** and **2a** to give the corresponding products **3b**, **3c**, **4b**, and **4c** in good yields. Similarly, substrates bearing mono *ortho, para*, and *meta* substituents (Table 4, entries 4–7) also gave the corresponding imines. Simple and substituted pyridine alcohols (Table 4, entries 8 and 9) were converted into aldehydes and reacted with **2** and **2a** successfully to give the

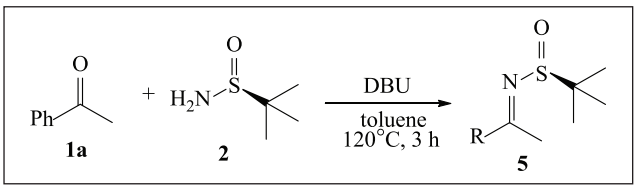
Table 4. One-pot synthesis of *N*-sulfinyl imines[a].



3a-c, 3e-i, 3k, 4a-e, 4i-j

Entry	R	Time (h)	Product	Isolated yield (%)[b]
1	C_6H_5	5	**3a**	75
		7	**4a**	72
2	4-$MeOC_6H_4$	15	**3b**	70
		15	**4b**	68
3	4-NCC_6H_4	5	**3c**	76
		7	**4c**	71
4	4-FC_6H_4	6	**3e**	75
5	3-BrC_6H_4	5	**3f**	81
		7	**4e**	76
6	2-$EtOOCC_6H_4$	10	**3g**	70
7	4-$^tBuC_6H_4$	10	**3h**	75
		12	**4d**	71
8	3-Pyridyl	5	**3i**	83
9	2-MeO-4-pyridyl	6	**4i**	75
10	8-Quinolinyl	12	**3k**	76
		13	**4j**	70
11	Aliphatic	15	–	np[c]

DBU: 1,8-diazabicyclo[5.4.0]undec-7-ene; DMF: dimethyl formamide; RT: room temperature.
[a]Reaction conditions: alcohol (1.0 mmol); **2**, **2a** (1.5 mmol); and MnO_2 (10 mmol) in DMF (1.5 mL) in the presence of DBU (1.5 mmol) at RT for 5–15 h.
[b]Isolated yield after chromatographic purification.
[c]np: No product formation was observed.



Scheme 1. *N*-Sulfinyl ketimine formation.

corresponding imines **3i** and **4i**. Bicyclic (quinolin-8-yl) methanol (Table 4, entry 10) provided imines **3k** and **4j** in 76% and 70% yields, respectively. Unfortunately, the one-pot synthesis under optimum conditions using aliphatic alcohols was unsuccessful (Table 4, entry 11).

Our efforts toward the formation of (*S*)-(*tert*-butanesulfinyl) imine under standardized conditions using acetophenone (**1a**) were unsuccessful. When we switched to toluene as the solvent and heated the reaction mixture at 120°C for 3 h, product **5** was obtained in 28% isolated yield, and no remarkable change was noted in the conversion beyond 3 h or even at higher temperatures (Scheme 1).

Conclusion

In conclusion, we have established DBU as an efficient reagent for the condensation of sulfinamides with aldehydes to provide *N*-sulfinyl imines at room temperature. The reactions proceed under mild and homogeneous conditions with clean reaction profiles and simple work-up. The method was shown to be appropriate for a broad range of aldehydes, including sterically hindered, electron-rich, and electron-deficient substrates. This methodology is also useful for the preparation of *N*-sulfinyl imines on gram scale. Remarkably, the one-pot reaction of aromatic and heteroaromatic alcohols with sulfinamides for the preparation of the corresponding *N*-sulfinyl imines resulted in good yields. Unfortunately, this one-pot protocol for the formation of *N*-sulfinyl imines was unsuccessful with aliphatic alcohols.

Experimental

All reagents and solvents used in this work were obtained from commercial sources and were used without further purification. TLC was performed on Merck silica gel $60F_{254}$ (0.25-mm thickness) plates and visualized under UV light. Column chromatography was performed using brand silica gel of 100–200 mesh. Melting points were determined in open capillary tubes using paraffin oil bath and are uncorrected. NMR data were collected for 1H at 400 MHz and for 13C at 100 MHz on an Agilent NMR spectrometer. Chemical shifts are reported in parts per million relative to tetramethylsilane (TMS) as an internal standard (δ 0), and the values are reported as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br s = broad singlet), and the coupling constants are in hertz. For 13C NMR, $CDCl_3$ (δ 77.27) was used as the internal standard, and spectra were obtained with complete proton decoupling. Mass spectra were recorded on an Agilent mass spectrometer in electrospray ionization (ESI) mode. High-resolution mass spectra were obtained on a WATERS Q-TOF Premier-HAB213 spectrometer in ESI mode.

General experimental procedures for the synthesis of N-sulfinyl imines **3** *and* **4**

In a round-bottom flask, to aldehyde (1.0 mmol) in DMF (1 mL) was added sulfinamide (**2** or **2a**) (1.5 mmol) followed by DBU (1.5 mmol). The solution was allowed to stir at room temperature for 2–10 h. The progress of the reaction was monitored by TLC. After complete conversion, the reaction mixture was diluted with ethyl acetate and washed with water. The organic layer was dried over anhydrous sodium sulfate, filtered, and evaporated. The crude product was subjected to column chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 80:20) to provide the corresponding *N*-sulfinyl imines.

General experimental procedures for the one-pot synthesis of N-sulfinyl imines **3** *and* **4**

In a round-bottom flask, to alcohol (1.0 mmol) and manganese dioxide (10 mmol) in DMF (1.5 mL), was added sulfinamide (**2** or **2a**) (1.5 mmol) followed by DBU (1.5 mmol). The suspension was allowed to stir at room temperature for

5–15 h. The progress of the reaction was monitored by TLC. After complete conversion, the reaction mixture was filtered through a celite pad and washed with portions of ethyl acetate. The organic layer was washed with water, dried over anhydrous sodium sulfate, filtered, and evaporated. The crude product was subjected to column chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 80:20) to provide the corresponding *N*-sulfinyl imines.

(S)-N-Benzylidene-2-methylpropane-2-sulfinamide (**3a**):[22] Colorless liquid; Yield: 87%; 1H NMR (400 MHz, $CDCl_3$): δ 8.56 (s, 1H), 7.83-7.81 (m, 2H), 7.51-7.42 (m, 3H), 1.24 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 162.7, 134.0, 132.4, 129.3, 128.9, 57.7, 22.5. MS (ESI): *m/z* 210.0 $[M + H]^+$.

(S)-N-(4-Methoxybenzylidene)-2-methylpropane-2-sulfinamide (**3b**):[22] Off-white solid; Yield: 81%; m.p. 90–92°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.48 (s, 1H), 7.77 (d, *J* = 9.2 Hz, 2H), 6.94 (d, *J* = 9.2 Hz, 2H), 3.83 (s, 3H), 1.22 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 163.0, 161.7, 131.2, 127.2, 114.3, 57.5, 55.4 22.5. MS (ESI): *m/z* 240.1 $[M + H]^+$.

(S)-N-(4-Cyanobenzylidene)-2-methylpropane-2-sulfinamide (**3c**):[23] Off-white solid; Yield: 92%; m.p. 96–98°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.59 (s, 1H), 7.93 (d, *J* = 8.4 Hz, 2H), 7.75 (d, *J* = 8.0 Hz, 2H), 1.25 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 161.0, 137.3, 132.7, 129.5, 118.0, 115.4, 58.3, 22.6. MS (ESI): *m/z* 235.1 $[M + H]^+$.

(S)-N-(2-Fluorobenzylidene)-2-methylpropane-2-sulfinamide (**3d**):[24] Colorless liquid; Yield: 83%; 1H NMR (400 MHz, $CDCl_3$): δ 8.85 (s, 1H), 7.96-7.92 (m, 1H), 7.45-7.43 (m, 1H), 7.20-7.16 (m, 1H), 7.12-7.07 (m, 1H), 1.22 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 163.8, 161.2, 156.5, 156.4, 134.1 (d, *J* = 35.2 Hz), 128.6, 124.5, 124.4, 122.0, 121.9, 116.3, 116.1, 57.8, 22.5. MS (ESI): *m/z* 228.1 $[M + H]^+$.

(S)-N-(4-Fluorobenzylidene)-2-methylpropane-2-sulfinamide (**3e**):[22] Colorless liquid; Yield: 87%; 1H NMR (400 MHz, $CDCl_3$): δ 8.48 (s, 1H), 7.81-7.77 (m, 2H), 7.10-7.06 (m, 2H), 1.19 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 166.4, 163.9, 161.3, 131.4 (d, *J* = 35.2 Hz), 130.4, 116.2, 116.0, 57.6, 22.5. MS (ESI): *m/z* 228.1 $[M + H]^+$.

(S)-N-(3-Bromobenzylidene)-2-methylpropane-2-sulfinamide (**3f**):[25] Colorless liquid; Yield: 92%; 1H NMR (400 MHz, $CDCl_3$): δ 8.50 (s, 1H), 7.99 (s, 1H), 7.71(d, *J* = 7.6 Hz, 1H), 7.61 (d, *J* = 8.4 Hz, 1H), 7.35-7.31 (m, 1H), 1.24 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 161.3, 135.8, 135.2, 131.5, 130.4, 128.3, 123.1, 58.0, 22.6. MS (ESI): *m/z* 290.0 $[M + 2]^+$.

(S)-Ethyl 2-(((tert-butylsulfinyl)imino)methyl) benzoate (**3g**): Pale yellow liquid; Yield: 90%; 1H NMR (400 MHz, $CDCl_3$): δ 9.22 (s, 1H), 8.0 (d, *J* = 3.6 Hz, 1H), 7.93 (d, *J* = 7.6 Hz, 1H), 7.57-7.52 (m, 2H), 4.39 (q, *J* = 6.8 Hz, 2H), 1.39 (d, *J* = 7.6 Hz, 3H), 1.37 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 166.5, 162.6, 134.3, 131.9, 131.7, 131.2, 130.4, 128.7, 61.8, 57.8, 22.6, 14.21. HRMS (ESI) *m/z*: Calcd for $C_{14}H_{19}NO_3S$ $[M + H]^+$: 281.3706, found: 282.0648.

(S)-N-(4-(tert-Butyl)benzylidene)-2-methylpropane-2-sulfinamide (**3h**):[24] White solid; Yield: 80%; m.p. 72–75°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.55 (s, 1H), 7.77(d, *J* = 8.8 Hz, 2H), 7.48 (d, *J* = 8.0 Hz, 2H), 1.33 (s, 9H), 1.24 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 162.4, 156.1, 131.5, 129.2, 125.8, 57.6, 35.1, 31.0, 22.5. MS (ESI): *m/z* 266.0 $[M + H]^+$.

(S)-2-Methyl-N-(pyridin-3-ylmethylene)propane-2-sulfinamide (**3i**):[22] Pale yellow liquid; Yield: 94%; 1H NMR (400 MHz, $CDCl_3$): δ 9.02 (s, 1H), 8.71-8.70 (m, 1H), 8.62 (s, 1H), 8.14 (d, *J* = 8.0 Hz, 1H), 7.42-7.39 (m, 1H), 1.26 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 160.3, 152.8, 150.9, 135.7, 129.6, 123.9, 58.1, 22.5. MS (ESI): *m/z* 211.1 $[M + 1]^+$.

(S)-N-((5-Bromo-2-methoxypyridin-4-yl)methylene)-2-methylpropane-2-sulfinamide (**3j**):[26] Pale yellow solid; Yield: 96%; m.p. 83–85°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.79 (s, 1H), 8.32 (s, 1H), 7.24 (s, 1H), 3.9 (3, 3H), 1.22 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 163.7, 160.5, 149.9, 141.2, 113.1, 110.2, 58.5, 54.1, 22.6. MS (ESI): *m/z* 321.0 $[M + 2]^+$.

(S)-2-Methyl-N-(quinolin-8-ylmethylene)propane-2-sulfinamide (**3k**):[27] White solid; Yield: 85%; m.p. 80–82°C; 1H NMR (400 MHz, $CDCl_3$): δ 10.06 (s, 1H), 8.99-8.98 (m, 1H), 8.45 (d, *J* = 7.2 Hz, 1H), 8.17 (d, *J* = 8.0 Hz, 1H), 7.97 (d, *J* = 8.4 Hz, 1H), 7.64-7.60 (m, 1H), 7.46-7.43 (m, 1H), 1.29 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 161.0, 150.8, 146.5, 136.0, 132.1, 131.2, 128.5, 128.2, 126.1, 121.7, 57.8, 22.7. MS (ESI): *m/z* 261.1 $[M + H]^+$.

(S)-N-(Furan-3-ylmethylene)-2-methylpropane-2-sulfinamide (**3l**):[22] Off-white solid; Yield: 91%; m.p. 114–116°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.50 (s, 1H), 7.86 (s, 1H), 7.44 (s, 1H), 6.79 (s, 1H), 1.19 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 154.3, 147.6, 144.6, 124.2, 107.8, 57.4, 22.4. MS (ESI): *m/z* 200.1 $[M + H]^+$.

(S)-N-(Cyclopropylmethylene)-2-methylpropane-2-sulfinamide (**3m**):[22] Colorless liquid; Yield: 90%; 1H NMR (400 MHz, $CDCl_3$): δ 7.43 (d, *J* = 7.6 Hz, 1H), 1.99-1.94 (m, 1H), 1.17 (s, 9H), 1.09-1.06 (m, 2H), 0.93-0.55 (m, 2H). 13C NMR (100 MHz, $CDCl_3$): δ 171.7, 56.5, 22.1, 22.0, 17.5, 8.5, 8.4. MS (ESI): *m/z* 174.0 $[M + H]^+$.

(S)-N-(Cyclohexylmethylene)-2-methylpropane-2-sulfinamide (**3n**):[22] Pale yellow liquid; Yield: 88%; 1H NMR (400 MHz, $CDCl_3$): δ 7.91 (d, *J* = 4.8 Hz, 1H), 2.46-2.38 (m, 1H), 1.90-1.80 (m, 2H), 1.78-1.72 (m, 2H), 1.68-1.60 (m, 2H), 1.32-1.25 (m, 4H), 1.14 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 172.7, 56.4, 43.9, 29.2, 25.8, 25.3 (2C), 22.3. MS (ESI): *m/z* 216.0 $[M + H]^+$.

(S)-N-(2,2-Dimethylpropylidene)-2-methylpropane-2-sulfinamide (**3o**):[24] Colorless liquid; Yield: 91%; 1H NMR (400 MHz, $CDCl_3$): δ 7.89 (s, 1H), 1.15 (s, 9H), 1.13 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 175.6, 56.4, 37.9, 26.6, 22.3. MS (ESI): *m/z* 190.0 $[M + H]^+$.

(S)-N-((E)-Hex-2-en-1-ylidene)-2-methylpropane-2-sulfinamide (**3p**):[28] Colorless semi-solid; Yield: 83%; 1H NMR (400 MHz, $CDCl_3$): δ 8.13 (d, *J* = 8.8 Hz, 1H), 6.54-6.46 (m, 1H), 6.40-6.35 (m, 1H), 2.22 (q, *J* = 7.2 Hz, 2H) 1.52-1.43 (m, 2H), 1.15 (s, 9H), 0.09 (t, *J* = 8.0 Hz, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 164.1, 151.5, 128.7, 57.1, 34.9, 22.4, 21.4, 13.6. MS (ESI): *m/z* 202.0 $[M + H]^+$.

(S)-N-Benzylidene-4-methylbenzenesulfinamide (**4a**):[29] Off-white solid; Yield: 81%; m.p. 78–90°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.74 (s, 1H), 7.83 (d, *J*=6.8 Hz, 2H), 7.62 (d, *J*=8.0 Hz, 2H), 7.48-7.41 (m, 3H), 7.29 (d, *J*=8.0 Hz, 2H), 2.37 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 160.6, 141.8, 141.7, 133.8, 132.5, 129.8, 129.5, 128.8, 124.7, 21.3. MS (ESI): *m/z* 244.0 $[M + H]^+$.

(S)-N-(4-Methoxybenzylidene)-4-methylbenzenesulfinamide (**4b**):[29] Off-white solid; Yield: 78%; m.p. 135–136°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.65 (s, 1H), 7.78 (d, *J*=8.8 Hz, 2H), 7.61 (d, *J*=8.4 Hz, 2H), 7.28 (d, *J*=8.0 Hz, 2H), 6.93 (d, *J*=8.4 Hz, 2H) 3.84 (s, 3H), 2.37 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 163.1, 159.7, 141.5, 131.5, 129.7, 127.0, 124.8, 115.7, 114.2, 55.4, 21.3. MS (ESI): *m/z* 274.0 $[M + H]^+$.

(S)-N-(4-Cyanobenzylidene)-4-methylbenzenesulfinamide (**4c**):[29] Off-white solid; Yield: 85%; m.p. 158–160°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.75 (s, 1H), 7.92 (d, *J*=8.0 Hz, 2H), 7.73 (d, *J*=8.0 Hz, 2H), 7.61 (d, *J*=8.0 Hz, 2H), 7.31 (d, *J*=7.6 Hz, 2H), 2.39 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 190.6, 158.7, 142.1, 140.8, 137.2, 132.9, 132.6, 130.0, 129.8, 124.6, 118.0, 115.6, 21.4. MS (ESI): *m/z* 268.9 $[M + H]^+$.

(S)-N-(4-(tert-Butyl)benzylidene)-4-methylbenzene sulfinamide (**4d**): Off-white solid; Yield: 80%; m.p. 108–110°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.72 (s, 1H), 7.77 (d, *J*=8.4 Hz, 2H), 7.61 (d, *J*=8.4 Hz, 2H), 7.46 (d, *J*=8.4 Hz, 2H), 7.28 (d, *J*=8.0 Hz, 2H), 2.38 (s, 3H), 1.32 (s, 9H). 13C NMR (100 MHz, $CDCl_3$): δ 160.3, 156.4, 142.0, 141.6, 131.3, 129.8, 129.4, 125.9, 124.8, 35.1, 31.1, 21.4. HRMS (ESI) *m/z*: Calcd for $C_{18}H_{21}NOS$ $[M + H]^+$: 299.4304, found: 300.1168.

(S)-N-(3-Bromobenzylidene)-4-methylbenzenesulfinamide (**4e**):[17] White solid; Yield: 91%; m.p. 94–96°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.66 (s, 1H), 8.00 (s, 1H), 7.70 (d, *J*=8.4 Hz, 1H), 7.62-7.60 (m, 3H), 7.33-7.29 (m, 3H), 2.38 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 159.1, 141.9, 141.3, 135.6, 135.3, 131.7, 130.4, 129.9, 128.5, 124.7, 123.1, 21.4. MS (ESI): *m/z* 322.0 $[M]^+$.

(S)-N-(2-Hydroxybenzylidene)-4-methylbenzenesulfinamide (**4f**):[29] White solid; Yield: 82%; m.p. 110–112°C; 1H NMR (400 MHz, $CDCl_3$): δ 10.85 (s, 1H), 8.83 (s, 1H), 7.58 (d, *J*=8.4 Hz, 2H), 7.45-7.38 (m, 2H), 7.31(d, *J*=8.0 Hz, 2H), 6.97-6.94 (m, 2H), 2.39 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 162.9, 160.2, 142.4, 141.4, 134.8, 133.4, 130.1, 125.7, 124.4, 119.8, 118.1, 117.3, 21.4. MS (ESI): *m/z* 260.0 $[M + H]^+$.

(S)-4-Methyl-N-(thiophen-3-ylmethylene)benzene sulfinamide (**4g**):[30] Pale yellow solid; Yield: 86%; m.p. 64–66°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.72 (s, 1H), 7.86 (s, 1H), 7.59 (d, *J*=8.4 Hz, 2H), 7.53 (d, *J*=4.8 Hz, 1H), 7.33-7.31 (m, 1H), 7.28 (d, *J*=8.0 Hz, 2H), 2.37 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 154.3, 141.8, 141.7, 138.2, 132.7, 129.8, 127.1, 126.1, 124.8, 21.4. MS (ESI): *m/z* 250.1 $[M + H]^+$.

(S)-N-(Furan-3-ylmethylene)-4-methylbenzenesulfinamide (**4h**):[31] Off-white solid; Yield: 82%; m.p. 75–77°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.69 (s, 1H), 7.88 (s, 1H), 7.58 (d, *J*=8.0 Hz, 2H), 7.42 (s, 1H), 7.27 (d, *J*=8.0 Hz, 2H), 6.78 (s, 1H), 2.36 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 152.4, 148.0, 144.7, 141.8, 141.7, 129.8, 124.7, 124.0, 107.9, 21.4. MS (ESI): *m/z* 234.0 $[M + H]^+$.

(S)-N-((2-Methoxypyridin-4-yl)methylene)-4-methyl benzenesulfinamide (**4i**): Off-white solid; Yield: 85%; m.p. 116–118°C; 1H NMR (400 MHz, $CDCl_3$): δ 8.65 (s, 1H), 8.24 (d, *J*=5.6 Hz, 1H), 7.60 (d, *J*=8.0 Hz, 2H), 7.30-7.24 (m, 3H), 7.07 (s, 1H), 3.94 (s, 3H), 2.39 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 164.9, 158.9, 147.8, 142.9, 142.0, 130.1, 129.9, 125.7, 124.7, 115.0, 111.2, 53.8, 21.4. HRMS (ESI) *m/z*: Calcd for $C_{14}H_{14}N_2O_2S$ $[M]^+$: 274.3382, found 274.0635.

(S)-4-Methyl-N-(quinolin-8-ylmethylene)benzenesulfinamide (**4j**): Off-white solid; Yield: 81%; m.p. 128–130°C; 1H NMR (400 MHz, $CDCl_3$): δ 10.22 (s, 1H), 8.96-8.94 (m, 1H), 8.39 (d, *J*=7.2 Hz, 1H), 8.13-8.11 (m, 1H), 7.91 (d, *J*=8.0 Hz, 1H), 7.68 (d, *J*=8.0 Hz, 2H), 7.56-7.53 (m, 1H), 7.43-7.40 (m, 1H), 7.27 (d, *J*=8.0 Hz, 2H), 2.35 (s, 3H). 13C NMR (100 MHz, $CDCl_3$): δ 158.9, 150.8, 146.5, 142.0, 141.5, 136.1, 132.4, 130.9, 129.8, 128.9, 128.1, 126.1, 124.8, 121.7, 21.4. HRMS (ESI) *m/z*: Calcd for $C_{17}H_{14}N_2OS$ $[M + H]^+$: 294.3709, found 295.0641.

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Supplemental material

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