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Stereoselective synthesis of α-(dichloromethyl)-amines, α-(chloromethyl)amines, and α-chloro-aziridines†

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Protocols for the stereoselective synthesis of α-(dichloromethyl)amines, α-(chloromethyl)amines, and α-chloroaziridines are presented. Diastereoselective synthesis of α-(dichloromethyl)amines was achieved based on nucleophilic dichloromethylation of aromatic *N*-*tert*-butylsulfinyl aldimines with (dichloromethyl)trimethylsilane at a low reaction temperature. Slowly warming the reaction mixture up to room temperature gave α-chloro *cis*-aziridines. Additionally, with Bu_3SnH as the reductant, α-(dichloromethyl)amines were readily obtained from easily accessible α-(trichloromethyl)amines *via* mono-dechlorination. Over-reduction was successfully suppressed. Subsequent radical mono-dechlorination of the α-(dichloromethyl)amines gave the corresponding α-(chloromethyl)amines in good to excellent yields.

Introduction

More than 5000 natural products from both terrestrial and marine origins have been discovered to contain covalently bonded halogen substituent(s), predominantly chlorine.[1] These compounds are of great structural diversity, and exhibit a wide variety of biological activities, including antibiotic, antitumor, and analgesic activities.[1] For example, vancomycin has been used clinically as a drug to treat bacterial infections. From a biological point of view, the halogen-containing structural motif plays an important role in determining the selectivity and affinity of the natural product's interaction with its biological target.[2] Structural and mechanistic investigations on natural halogenating enzymes revealed that enzymatic introduction of halogens during natural product assembly alters the product's physical and electronic characteristics, thereby giving rise to its specific biological activity.[2,3] Therefore, halogenation has been a popular tool to fine-tune a drug candidate's biological properties in modern drug discovery.[4]

Chlorinated methyl groups, including chloromethyl, dichloromethyl, and trichloromethyl groups, are structural features present in a lot of bioactive natural products (such as barbamide and sintokamide A) and pharmaceuticals, such as Nasonex and Lotemax.[1,5] Developing methods for incorporation of chlorinated methyl groups into organic compounds has attracted a lot of attention over many years and remains a hot subject of intense study.[6,7] In this field, the Kharash reaction has often been employed to introduce a chlorinated methyl group into some organic compounds.[6] For example, Zakarian and coworkers described an efficient ruthenium-catalyzed radical chloroalkylation of titanium enolates, an approach for stereoselective introduction of the trichloromethyl and dichloromethyl groups.[6a,b] While existing methods have made it possible to synthesize many functionalized chlorinated molecules, developing more diverse methodologies that can incorporate chlorinated methyl groups into organic compounds is certainly highly desirable.

α-Chloroaziridines, a valuable subclass of C-heteroatom-substituted aziridines, are highly important intermediates in the synthesis of many other aziridine derivatives and diverse types of ring-opening products.[8,9] Since the work of Deyrup and co-workers on the synthesis of α-chloroaziridines was reported,[10] the synthesis and reactivity of chloroaziridines has drawn continuous attention. Though several synthetic strategies (such as Darzens-type reactions of imines with dichloromethyl-containing compounds,[11] nitrene addition to vinyl chlorides,[12] and addition of acyl chlorides across 2*H*-azirines[13]) have been published, the efficient synthesis of α-chloroaziridines remains a challenge, and, to the best of our knowledge, the asymmetric synthesis of α-chloroaziridines has not been disclosed.

We have been interested in the synthesis and reactivity of chlorinated amines. Recently, we found that trimethyl(trichloromethyl)silane ($TMSCCl_3$) and chloroform were excellent trichloromethylating reagents towards Ellman's *N*-*tert*-butylsulfinyl imines,[14] which enables highly stereoselective synthesis of α-(trichloromethyl)amines *via* a nucleophilic trichloromethylation strategy.[15] Besides, the obtained α-(trichloromethyl)amines can be

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used as synthetic precursors to prepare enantiomerically pure α,α-dichloroaziridines.[16] In our continuous efforts in developing efficient synthesis of chlorinated amines, herein we present a systematic study for stereoselective synthesis of α-(dichloromethyl)amines, α-(chloromethyl)amines, and α-chloroaziridines for the first time.

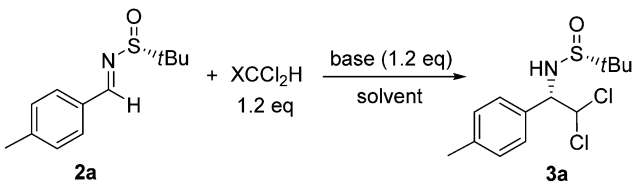
Results and discussion

α-(Dichloromethyl)amines are frequently involved in the synthesis of structurally diverse amines and aziridines.[17] However, synthetic methods for the α-(dichloromethyl)amines are very limited.[18] Lithium aluminum hydride reduction of α-(trichloromethyl)amines was employed to prepare the corresponding α-(dichloromethyl)amines.[18a,19] But this reaction suffers from low yields and over-reduction, and byproducts including amines with rearranged carbon skeletons and aziridines are also frequently found. Metal-mediated photolytic radical addition of ethyl iodide to chiral dichloroacetaldehyde *N*-acylhydrazones was reported to afford the target compounds.[20] However, the yields were very low, even when a large excess of radical precursors was used (usually 10–20 equivalents compared to *N*-acylhydrazones). A general method for the highly stereoselective synthesis of α-(dichloromethyl) amines, and especially, the asymmetric synthesis of structurally diverse α-(dichloromethyl)amines, is yet to be developed.

Using imine **2a** as a model substrate, we firstly examined its dichloromethylation reaction with dichloromethane (DCM) **1** (Table 1, entry 1–3). DCM is readily available and its addition reaction to aldehydes and ketones is well-known.[21] When a strong base, such as Lithium diisopropylamide (LDA) and sodium hexamethyldisilazane (NaHMDS), was slowly added into a reaction mixture of **2a** and DCM in DMF, no desired reaction took place, and the imine **2a** was partially recovered (entry 1–2). The use of *n*-BuLi to deprotonate DCM at a temperature of −90 °C followed by the addition of **2a** only resulted in a complex reaction mixture (entry 3).

We then turned our attention to commercially available (dichloromethyl)trimethylsilane ($TMSCCl_2H$) **4**. It is noteworthy that only scattered examples of direct dichloromethylation of carbonyl compounds with $TMSCCl_2H$ have been described,[22] while its dichloromethylation reaction towards imines has yet not been investigated.[23] Tetrabutylammonium triphenyldifluorosilicate (TBAT) was first tried as the mediator, for TBAT was reported to be quite efficient in the nucleophilic trichloromethylation reaction between trimethyl(trichloromethyl) silane ($TMSCCl_3$) and *N-tert*-butylsulfinyl aldimines.[15a] However,

Table 1 Survey of reaction conditions for the dichloromethylation of aromatic imine **2a**

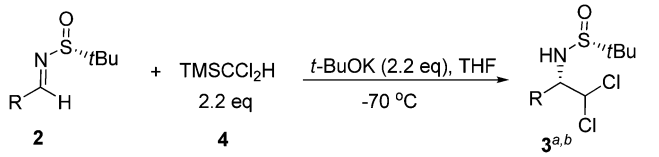


2a **3a**

Entry	X	Reaction conditions	Yield[a] (%)	dr[b]
1	X = H, **1**	LDA, DMF, −40 °C	0	—[d]
2	X = H, **1**	NaHMDS, DMF, −40 °C	0	—[d]
3	X = H, **1**	*n*-BuLi, THF, −90 °C	—[d]	—[d]
4	X = TMS, **4**	TBAT, THF, −70 °C	0	—[d]
5	X = TMS, **4**	TBAT, DMF, −40 °C	0	—[d]
6	X = TMS, **4**	*i*-Pr_2NEt, DMF, rt	0	—[d]
7	X = TMS, **4**	AcOK, DMF, −40 °C	7	—[d]
8	X = TMS, **4**	*t*-BuONa, DMF, −40 °C	35	—[d]
9	X = TMS, **4**	*t*-BuOK, THF, −70 °C	49	98 : 2
10[c]	X = TMS, **4**	*t*-BuOK, THF, −70 °C	90	98 : 2

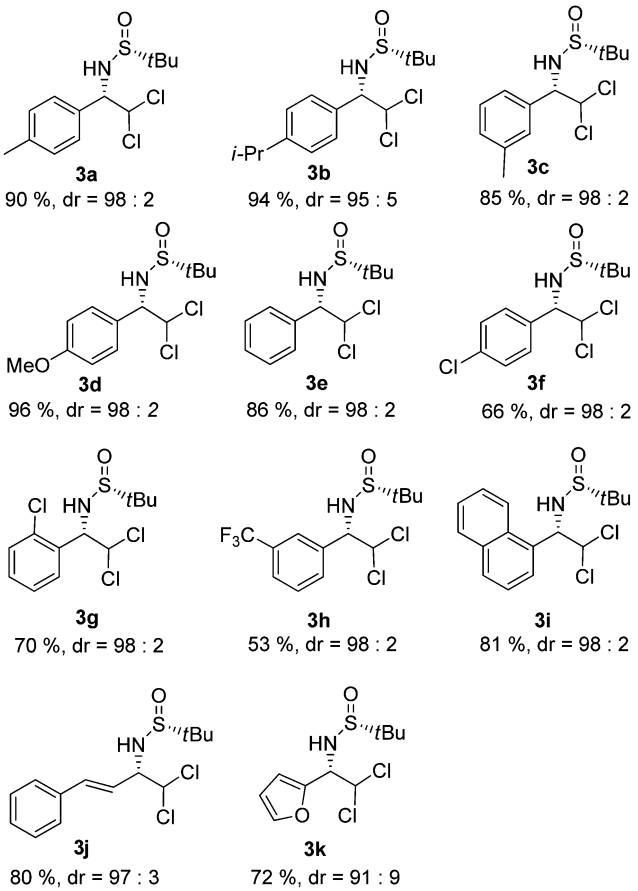
[a] Isolated yield. [b] Determined by ^1H NMR spectroscopy and HPLC analysis on the crude product. [c] The reactant ratio **2a** : **4** : base = 1 : 2.2 : 2.2. [d] Not determined.

Table 2 Synthesis of α-(dichloromethyl)amines **3** from **4** and imines **2**



2 **4** **3**[a,b]

Products **3**



[a] Isolated yield. [b] dr determined by ^1H NMR and LC-MC analysis on the crude product.

we were surprised to find that TBAT was not effective at all; no desired product **3a** was observed and compound **2a** was recovered almost completely (entry 4). Changing the solvent to more polar DMF had no beneficial effect on the reaction outcome (entry 5). Oxygen- and nitrogen-based bases were also tried (entry 6–10), and finally, strong bases, *t*-BuONa or *t*-BuOK, were found to be quite efficient in promoting this reaction (entry 8–9). Optimization of the reactant ratio (**2a** : **4** : *t*-BuOK = 1.0 : 2.2 : 2.2) further increased the yield to 90% (entry 10). Unlike $TMSCCl_3$, reagent **4** is not moisture sensitive and can also be readily prepared from TMSCl and DCM in a single step,[24] which provides significant advantages for practical synthesis.

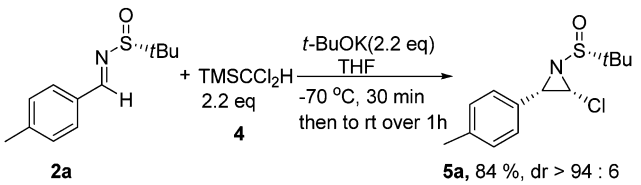
With the optimized reaction conditions (entry 10), we examined the substrate scope of this dichloromethylation reaction. As shown in Table 2, various aromatic, heteroaromatic, and α,β-unsaturated imines reacted with **4** smoothly, giving the corresponding α-(dichloromethyl)amines in good to excellent yields and with excellent diastereoselectivities. It seems that the electronical nature of the substituents on the aromatic ring has a significant effect on the yield: aromatic imines with electron-donating substituents (Table 2, **3a–3d**), such as methyl, isopropyl and methoxy group, give higher yields than those with electron-withdrawing substituents (**3f–3h**). For imine **2h** with a strong electron-withdrawing trifluromethyl group, a moderate yield of 53% was obtained (**3h**). Aliphatic imines derived from butyraldehyde or isobutyraldehyde decomposed rapidly under the strong basic conditions probably due to enolization. As a result, only a very small amount of product was produced (less than 5%). The configuration of the addition products **3a–3k** were assigned to be (*Rs*,*S*), based on a similar nonchelation-controlled transition-state mode comparable with that for the nucleophilic trichloromethylation of *N-tert*-butylsulfinyl imines.[15]

It was envisioned that the dichloromethylated sulfinamide anion species (the nitrogen-anion species of **3**) generated from the first nucleophilic addition step could further attack the electrophilic chloro-attached carbon atom, and a cascade addition-intramolecular substitution reaction of imines with $TMSCCl_2H$ may proceed. Thus it would provide a streamlined synthesis of α-chloroaziridines.[8] It is noteworthy that an elegant diastereoselective synthesis of α-iodoaziridines was recently reported by Bull and coworkers, starting from diiodomethane and *N-tert*-butylsulfinyl imines *via* a similar strategy.[25]

Using imine **2a** as the model compound, the possible cascade reaction between compound **2a** and **4** was examined at different reaction conditions. After screening several reaction parameters (including base, solvent, and temperature), we found that, under otherwise identical reaction conditions for the nucleophilic dichloromethylation of *N-tert*-butylsulfinyl imines, slowly warming the reaction mixture up to room temperature exclusively afforded the corresponding α-chloro *cis*-aziridine **5a** in a very good yield and with a very high diastereoselectivity (Scheme 1). These results indicated that the reaction outcome between $TMSCCl_2H$ and *N-tert*-butylsulfinyl imines was controlled by the reaction temperature. Specifically, quenching the reaction at a low temperature provided the corresponding addition products **3**, whereas allowing the reaction mixture to slowly warm up to room temperature afforded the α-chloro *cis*-aziridines.

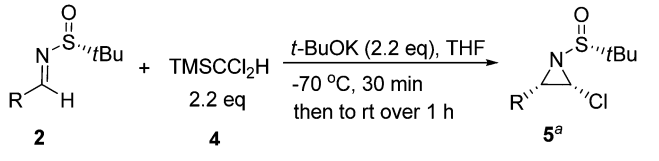
The scope and the results of the reaction are summarized in Table 3. As shown, the aromatic imines were smoothly converted into the corresponding α-chloro *cis*-aziridines. Donating substituent on the aromatic ring gave better yields (Table 3, **5a** and **5b**), paralleling the reactivity of *N-tert*-butylsulfinyl imines in the nucleophilic dichloromethylation (Table 2). The stereoselectivity is generally very high; in no case were we able to isolate other minor diastereoisomers. Unlike *N*-sulfinyl α-iodoaziridine, the α-chloro *cis*-aziridines **5** are stable to silica gel during column chromatography.[25]

The stereochemistry of α-chloroaziridines **5** was deduced from the magnitude of the coupling constant between CHAr and CHCl protons (J = 5.6 Hz),[11c] which revealed that the substituents at the aziridine ring adapted a *cis* configuration. Single-crystal X-ray analysis of **5c** further confirmed the absolute configuration of compound **5** (see Fig. 1). Interestingly, X-ray crystallography study also revealed that, in the crystal, molecules are linked through halogen bonding between the chloro

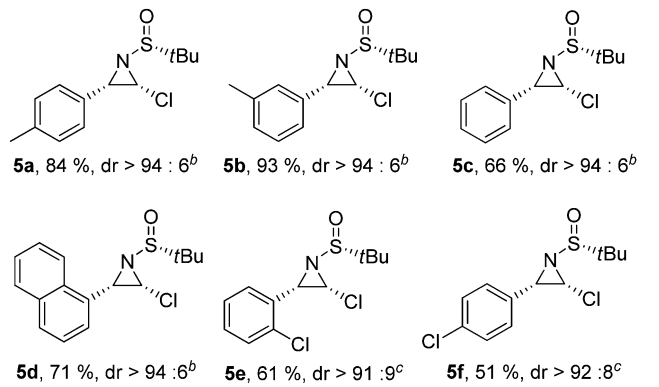


Scheme 1 Synthesis of the α-chloroaziridine **5a**.

Table 3 Scope of the intramolecular substitution reaction to afford α-chloro *cis*-aziridines **5**



Products **5**



[a] Isolated yield. [b] Where >94 : 6 stated, only the *cis*-diastereoisomer could be observed by ^{1}H NMR on the crude product. [c] dr determined by ^{1}H NMR on the crude product.

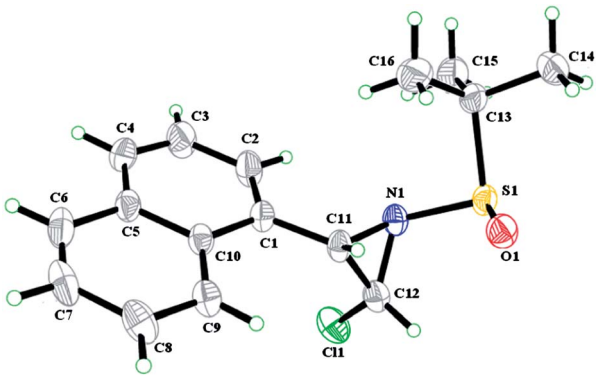


Fig. 1 Determination of the configuration of the α-chloro *cis*-aziridines **5**.

substituent and the sulfinamide oxygen,[26] forming chains running along the *b*-axis direction (see the ESI†).

The high *cis*-selectivity for compound **5** can be explained by a transition-state model, in which the Ar and *N*-sulfinyl groups are assumed to align in an *anti* conformation so as to avoid the eclipsing interactions. The N-group and chloride are placed in an antiperiplanar fashion and the other chloride is positioned away from the *N*-sulfinyl group. Thus, the intramolecular cyclization would lead to the observed stereoselectivity as shown in Fig. 2. A similar transition state was also reported for the asymmetric synthesis of *cis*-iodoaziridines from diiodomethane and *N*-tosylimines.[25]

Our direct dichloromethylation protocol is the first case of efficient and stereoselective synthesis of α-(dichloromethyl)-amines (Table 2), although this strategy has its own limitations. It could not be applied to enolizable imines, so the corresponding α-(dichloromethyl)amines and the subsequent aziridine products could not be obtained. Therefore, an alternative method to prepare structurally diverse α-(dichloromethyl)-amines needs to be developed.

A lot of mono-dechlorination methods using trichloromethyl derivatives as the starting materials have been investigated.[27,28] For such reactions, the dechlorination activity is strongly influenced by the electronic and steric environment of the substituents attached to the trichloromethyl group, and the ability to suppress over-reduction is of critical importance in achieving efficient chemoselective transformations.[27] Recently, catalyst Pt/C was used to enable precise reduction control of trichloromethyl ketones to dichloromethyl derivatives, and the amount of over-reduction product monochloromethyl ketone could be minimized to around 5%.[27a]

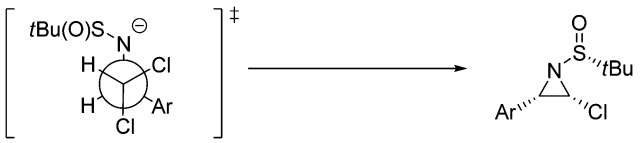
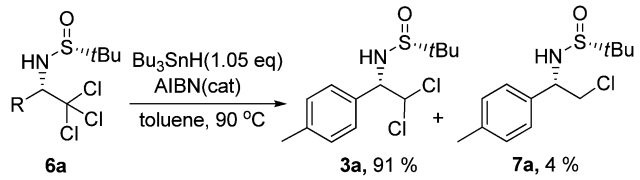


Fig. 2 The transition-state model for the formation of *cis*-chloroaziridines **5**.

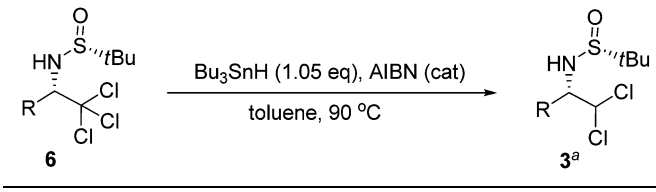


Scheme 2 Radical mono-dechlorination of α-(trichloromethyl)amine **6a**.

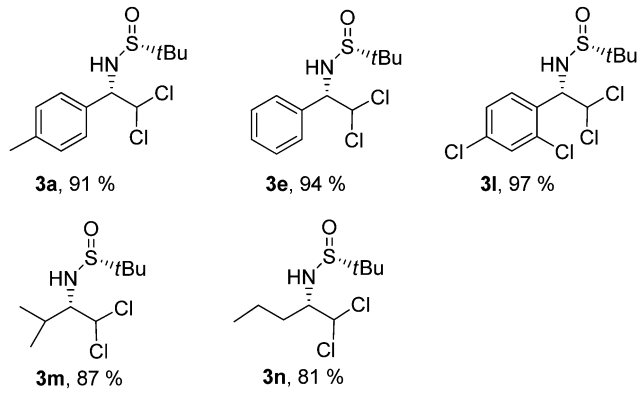
Now, we attempted to synthesize α-(dichloromethyl)amines from α-(trichloromethyl)amines *via* mono-dechlorination. Using compound **6a** as a model substrate, several reductants were examined. While $NaBH_4$, $LiAlH_4$ and Zn all resulted in the decomposition of the starting material,[28] Bu_3SnH proved successful in promoting the reaction.[27f–h] This reaction proceeded in excellent selectivity under optimized reaction conditions, consisting of only 1.05 equivalent of Bu_3SnH and catalytic amount of AIBN in toluene (Scheme 2). The corresponding α-(dichloromethyl)amine **3a** and α-(chloromethyl) amine **7a** were obtained in 91% and 4% yields, respectively, indicating that over-reduction was suppressed under the reported reaction conditions.

Using the optimal reaction conditions, the mono-dechlorination of several α-(trichloromethyl)amines were further investigated. As shown in Table 4, this reaction was applied to both aromatic and aliphatic substrates, and the desired products were obtained in very good to excellent yields for all cases. Remarkably, the chloro functional groups on the phenyl ring

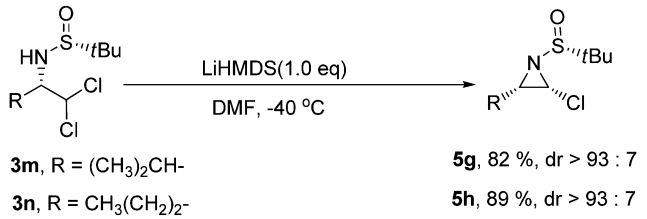
Table 4 Synthesis of **3** from α-(trichloromethyl)amines **6** *via* mono-dechlorination



Products **3**



[a] Isolated yield.



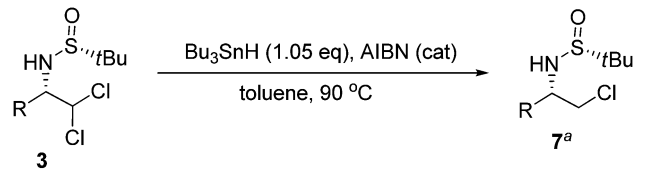
Scheme 3 Synthesis of aziridines 5 from the α-(dichloromethyl)-amines 3.

were intact (**3l**), opening possibilities for further functionalization. Thus, an alternative methodology was successfully developed for the synthesis of α-(dichloromethyl)amines.

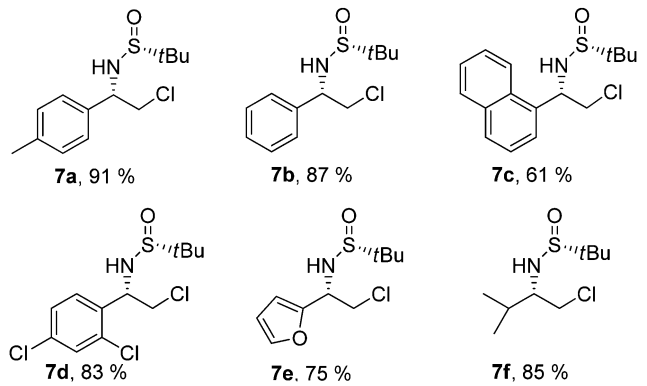
The obtained α-(dichloromethyl)amines are useful precursors for the synthesis of 2-chloro *cis*-aziridines, especially alkyl group-substituted aziridines that were not accessible from enolizable imines. Treatment of compounds **3m** and **3n** with lithium hexamethyldisilazane (LiHMDS) in DMF at a low reaction temperature gave the corresponding α-chloroaziridines **5g** and **5h** in good yields and with very high diastereoselectivities (>93 : 7), respectively (Scheme 3).

Encouraged by the success of the mono-dechlorination, we further applied this method to synthesize α-(chloromethyl)-amines, highly valuable synthetic intermediates for the preparation of a great number of bioactive molecules.[29] Currently, the most commonly used method involves the chlorination of vicinal amino alcohols.[30] However, the starting materials are of limited access and the reaction conditions for chlorination is very sensitive and restrictive. Another route to synthesize

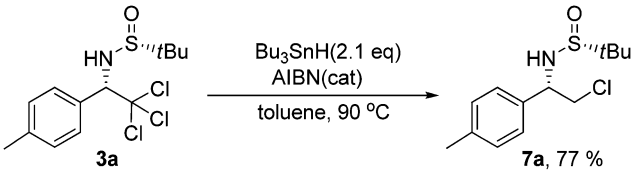
Table 5 Synthesis of α-(chloromethyl)amines 7 from the α-(dichloromethyl)amines 3



Products 7



[a] Isolated yield.



Scheme 4 A single-step synthesis of α-(chloromethyl)amine 7a from compound 3a.

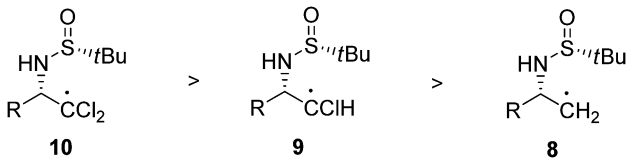


Fig. 3 Stability of the chlorinated methyl radicals.

α-(chloromethyl)amines employs an asymmetric reduction of N-protected α-chloroimines. Nevertheless, the type of substituent at the aziridine ring has a significant effect on the reaction outcome; in some cases the starting material can be transformed into the corresponding α-(chloromethyl)amines in a selective way,[31] whereas in many other cases reduction of α-chloroimines affords mixtures of the α-(chloromethyl)amines, aziridines, and dehalogenated amines.[19,32] Development of more general methods for the highly efficient synthesis of structurally diverse α-(chloromethyl)amines is still highly desirable.[33]

Using the same reaction conditions as shown in Table 4, several α-(dichloromethyl)amines were smoothly converted into the corresponding α-(chloromethyl)amines 7 in very good yields (Table 5). The chloro substituent on the phenyl ring reaction is well tolerated (**7d**) and the reaction is also applicable to both aliphatic and aromatic α-(dichloromethyl)amines.

To further explore the feasibility of a single-step synthesis of α-(chloromethyl)amines from α-(trichloromethyl)amines, compound **3a** was investigated under the above reaction conditions except that 2.1 equivalent of Bu_3SnH was used. This reaction proceeded smoothly, giving compound **7a** in 77% yield (Scheme 4). With the aforementioned experimental results for the synthesis of α-(dichloromethyl)- and α-(chloromethyl) amines, the order of the reactivity of the radical intermediates is listed as follows (Fig. 3):

Conclusion

Two highly efficient protocols for stereoselective synthesis of structurally diverse α-(dichloromethyl)amines are presented: one involves nucleophilic dichloromethylation of aromatic *N-tert*-butylsulfinyl aldimines with (dichloromethyl)-trimethylsilane ($TMSCCl_2H$), and the other employs a radical mono-dechlorination strategy using easily accessible α-(trichloromethyl)amines as the starting materials. Subsequent radical mono-dechlorination of the α-(dichloromethyl)amines gives the corresponding α-(chloromethyl)amines in good to excellent yields. Additionally,

the reaction outcome between *N-tert*-butylsulfinyl aldimines and $TMSCCl_2H$ is controlled by the reaction temperature: *N-tert*-butylsulfinyl aldimines undergoes the nucleophilic dichloromethylation at a low reaction temperature of −70 °C, whereas allowing the reaction mixture to warm up to room temperature affords 2-chloro *cis*-aziridines. Alternatively, 2-chloro *cis*-aziridines can be prepared from α-(dichloromethyl)amines based on a classical intramolecular substitution reaction.

Experimental

General methods

All commercial reagents and solvents were used directly as purchased without further purification. THF was distilled from sodium/benzophenone. *N*,*N*-Dimethylformamide was distilled from CaH_2. Flash chromatography was performed on silica gel with petroleum ether (PE)–EtOAc as the eluent. Melting points were uncorrected. Optical rotations were measured with a sodium lamp. ^{1}H NMR spectra were recorded at 400 MHz. Decoupled ^{13}C NMR spectra were recorded at 100 MHz. Chemical shifts (δ) are reported in parts per million (ppm) and referenced to the residual solvent peak, and *J* values are given in hertz (Hz).

General procedure for the synthesis of α-(dichloromethyl)-amine 3a from $TMSCHCl_2$ 4 and (*R*)-*N*-*tert*-butanesulfinyl imine 2a

t-BuOK (123 mg, 1.1 mmol) in THF (2 mL) was added dropwise to a mixture of imine **2a** (112 mg, 0.5 mmol) and $TMSCHCl_2$ **4** (173 mg, 1.1 mmol) in THF (2.0 mL) at −70 °C. The reaction mixture was stirred over 0.5 h. Then 1 N HCl (10 mL) was added at −70 °C, and the quenched reaction mixture was extracted three times with ethyl acetate (20 ML × 3). The combined organic layer was dried over anhydrous Na_2SO_4. Evaporation of the solvent afforded the crude product, which was subjected to flash chromatography to give pure α-(dichloromethyl)amine **3a**.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-*p*-tolylethyl)-2-methylpropane-2-sulfinamide (3a). Colorless solid (139 mg, 90%); mp 72.1–73.8 °C; $[\alpha]_D^{25}$ −20.5 ($c = 0.51$ in $CHCl_3$); IR (film): $\nu_{max} = 3388, 3103, 1456, 1028, 925, 741$ cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.30 (d, $J = 8.1$ Hz, 2H), 7.20 (d, $J = 8.0$ Hz, 2H), 6.02 (d, $J = 3.9$ Hz, 1H), 4.83 (dd, $J = 6.7$, 3.9 Hz, 1H), 4.06 (d, $J = 6.7$ Hz, 1H), 2.35 (s, 3H), 1.28 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 138.9, 133.4, 129.4, 127.9, 75.6, 65.8, 57.1, 22.7, 21.1; MS (ESI) *m*/*z*: 307.9 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{13}H_{19}Cl_2NOSNa$ 330.0457; found 330.0471.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-(4-isopropylphenyl)ethyl)-2-methylpropane-2-sulfinamide (3b). Light yellow solid (158 mg, 94%); mp 80.2–81.6 °C; $[\alpha]_D^{25}$ − 22.2 ($c = 0.56$ in $CHCl_3$); IR (film): $\nu_{max} = 3434, 2959, 1464, 1389, 1046, 851, 757$ cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.33 (d, $J = 8.2$ Hz, 2H), 7.24 (d, $J = 8.2$ Hz, 2H), 6.01 (d, $J = 3.8$ Hz, 1H), 4.84 (dd, $J = 6.8$, 3.8 Hz, 1H), 4.03 (d, $J = 6.7$ Hz, 1H), 2.92 (dd, $J = 13.8$, 6.9 Hz, 1H), 1.29 (s, 9H), 1.25 (s, 3H), 1.24 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 149.7, 133.8, 127.8, 126.8, 75.7, 66.0, 57.1, 33.8, 23.8, 22.7; MS (ESI) *m*/*z*: 335.9 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{15}H_{23}Cl_2NOSNa$ 358.0770; found 358.0775.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-*m*-tolylethyl)-2-methylpropane-2-sulfinamide (3c). Light yellow solid (131 mg, 85%); mp 99.1–100.4 °C; $[\alpha]_D^{25}$ − 31.9 ($c = 0.51$ in $CHCl_3$); IR (film): $\nu_{max} = 3334, 2962, 1460, 1056, 889, 815, 734$ cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.29 (d, $J = 7.9$ Hz, 1H), 7.19 (dd, $J = 12.4$, 6.4 Hz, 3H), 6.01 (d, $J = 4.0$ Hz, 1H), 4.82 (dd, $J = 6.7$, 4.0 Hz, 1H), 4.05 (d, $J = 6.8$ Hz, 1H), 2.38 (s, 3H), 1.29 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 138.4, 136.5, 129.7, 128.63, 128.56, 124.9, 75.7, 66.2, 57.2, 22.7, 21.5; MS (ESI) *m*/*z*: 308.1 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{13}H_{19}Cl_2NOSNa$ 330.0457; found 330.0465.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-(4-methoxyphenyl)ethyl)-2-methylpropane-2-sulfinamide (3d). Light yellow solid (156 mg, 96%); mp 80.8–81.7 °C; $[\alpha]_D^{25}$ − 20.6 ($c = 0.60$ in $CHCl_3$); IR (film): $\nu_{max} = 3401, 3112, 2923, 1513, 1246, 1026, 786$ cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.34 (d, $J = 8.7$ Hz, 2H), 6.92 (d, $J = 8.8$ Hz, 2H), 6.01 (d, $J = 3.9$ Hz, 1H), 4.82 (dd, $J = 6.5$, 3.9 Hz, 1H), 4.01 (d, $J = 6.5$ Hz, 1H), 3.81 (s, 3H), 1.28 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 156.0, 129.3, 128.4, 114.0, 75.7, 65.4, 57.1, 55.3, 22.6; MS (ESI) *m*/*z*: 324.1 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{13}H_{19}Cl_2NO_2SNa$ 346.0406; found 346.0415.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-phenylethyl)-2-methylpropane-2-sulfinamide (3e). Light yellow solid (127 mg, 86%); mp 62.1–62.6 °C; $[\alpha]_D^{25}$ − 27.3 ($c = 0.55$ in $CHCl_3$); IR (film): $\nu_{max} = 3479, 3991, 3119, 1455, 1028, 921, 739, 699$ cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.40 (dt, $J = 7.4$, 4.6 Hz, 5H), 6.04 (d, $J = 3.8$ Hz, 1H), 4.87 (dd, $J = 6.9$, 3.8 Hz, 1H), 4.09 (d, $J = 6.7$ Hz, 1H), 1.29 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 136.4, 129.0, 128.7, 128.0, 75.5, 66.0, 57.2, 22.7; MS (ESI) *m*/*z*: 294.0 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{12}H_{17}Cl_2NOSNa$ 316.0300; found 316.0306.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-(4-chlorophenyl)ethyl)-2-methylpropane-2-sulfinamide (3f). Light yellow solid (108 mg, 66%); mp 84.8–85.4 °C; $[\alpha]_D^{25}$ − 13.4 ($c = 0.60$ in $CHCl_3$); IR (film): $\nu_{max} = 3389, 3120, 1490, 1092, 1015, 919, 767$ cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.37 (s, 4H), 6.01 (d, $J = 3.8$ Hz, 1H), 4.85 (dd, $J = 7.1$, 3.8 Hz, 1H), 4.06 (d, $J = 7.0$ Hz, 1H), 1.28 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 135.0, 134.7, 129.5, 128.8, 75.1, 65.1, 57.3, 22.6; MS (ESI) *m*/*z*: 328.0 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{12}H_{16}Cl_3NOSNa$ 349.9910; found 349.9923.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-(2-chlorophenyl)ethyl)-2-methylpropane-2-sulfinamide (3g). Light yellow solid (115 mg, 70%); mp 88.5–90.2 °C; $[\alpha]_D^{25}$ − 35.4 ($c = 0.52$ in $CHCl_3$); IR (film): $\nu_{max} = 3152, 2962, 1470, 1042, 905, 747$ cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.48 (dd, $J = 7.4$, 2.0 Hz, 1H), 7.40 (dd, $J = 7.5$, 1.7 Hz, 1H), 7.36–7.29 (m, 2H), 6.11 (d, $J = 3.7$ Hz, 1H), 5.28 (dd, $J = 9.4$, 3.7 Hz, 1H), 4.41 (d, $J = 9.3$ Hz, 1H), 1.30 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 134.7, 132.7, 130.1, 129.9, 129.6, 127.2, 74.7, 64.1, 57.6, 22.6; MS (ESI) *m*/*z*: 328.0 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + H]^+$ calcd for $C_{12}H_{17}Cl_3NOS$ 328.0091; found 328.0098.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-(3-(trifluoromethyl)phenyl)ethyl)-2-methylpropane-2-sulfinamide (3h). White solid (96 mg, 53%); mp 65.3–67.4 °C; $[\alpha]_D^{25}$ − 17.2 ($c = 0.63$ in $CHCl_3$); IR (film): $\nu_{max} = 3274, 2922, 1456, 1056, 883, 726, 697$ cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.66 (d, $J = 9.1$ Hz, 3H), 7.55 (t, $J = 7.6$ Hz, 1H), 6.05 (d, $J = 3.7$ Hz, 1H), 4.94 (dd, $J = 7.2$, 3.7 Hz, 1H), 4.13 (d, $J = 7.1$ Hz, 1H), 1.29 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 137.2, 131.7, 129.2, 125.91, 125.87, 125.06, 125.02, 74.7, 64.1, 57.6, 22.6; MS (ESI) *m*/*z*: 362.0 $[M + H]^+$;

HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{13}H_{16}Cl_2F_3NOSNa$ 384.0174; found 384.0182.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-(naphthalen-1-yl)ethyl)-2-methylpropane-2-sulfinamide (3i). Light yellow solid (139 mg, 81%); mp 67.3–68.4 °C; $[\alpha]_D^{25}$ − 73.3 (c = 0.60 in $CHCl_3$); IR (film): ν_{max} = 3306, 2953, 2924, 1455, 1064, 858, 773 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.98 (d, J = 8.5 Hz, 1H), 7.90 (dd, J = 13.8, 8.2 Hz, 2H), 7.66–7.59 (m, 2H), 7.53 (ddd, J = 9.5, 5.3, 2.2 Hz, 2H), 6.22 (d, J = 4.2 Hz, 1H), 5.67 (dd, J = 7.4, 4.2 Hz, 1H), 4.46 (d, J = 7.3 Hz, 1H), 1.29 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 133.9, 132.3, 130.5, 129.5, 129.4, 127.1, 125.9, 125.8, 125.1, 121.9, 75.7, 62.6, 57.3, 22.7; MS (ESI) *m*/*z*: 343.9 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{16}H_{19}Cl_2NOSNa$ 366.0457; found 366.0466.

(*Rs*)-*N*-((*S*,*E*)-1,1-Dichloro-4-phenylbut-3-en-2-yl)-2-methylpropane-2-sulfinamide (3j). Light yellow solid (128 mg, 80%); mp 112.4–114.2 °C; $[\alpha]_D^{25}$ −16.7 (c = 0.55 in $CHCl_3$); IR (film): ν_{max} = 3092, 2986, 1449, 1058, 969, 780, 751 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.43 (d, J = 7.5 Hz, 2H), 7.36–7.27 (m, 3H), 6.85 (d, J = 15.9 Hz, 1H), 6.33 (dd, J = 15.9, 6.6 Hz, 1H), 5.87 (d, J = 3.0 Hz, 1H), 4.47–4.43 (m, 1H), 3.76 (d, J = 7.7 Hz, 1H), 1.29 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 136.1, 135.7, 128.6, 128.5, 126.9, 123.6, 75.6, 64.9, 57.1, 22.6; MS (ESI) *m*/*z*: 319.9 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{14}H_{19}Cl_2NOSNa$ 342.0457; found 342.0458.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-(furan-2-yl)ethyl)-2-methylpropane-2-sulfinamide (3k). Oil (102 mg, 72%); $[\alpha]_D^{25}$ + 2.8 (c = 0.52 in $CHCl_3$); IR (film): ν_{max} = 3400, 2988, 2929, 1624, 1171, 1030, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.42 (d, J = 1.1 Hz, 1H), 6.55 (d, J = 3.3 Hz, 1H), 6.39 (dd, J = 3.3, 1.8 Hz, 1H), 6.13 (d, J = 3.4 Hz, 1H), 4.88 (dd, J = 9.0, 3.4 Hz, 1H), 4.02 (d, J = 8.9 Hz, 1H), 1.31 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 149.8, 143.1, 110.8, 109.9, 73.9, 62.1, 57.5, 22.7; MS (ESI) *m*/*z*: 306 $[M + Na]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{10}H_{15}Cl_2NO_2SNa$ 306.0093; found 306.0091.

General procedure for the synthesis of 2-chloro *cis*-aziridine 5a from $TMSCHCl_2$ 4 and (*R*)-*N*-*tert*-butanesulfinyl imine 2a

t-BuOK (123 mg, 1.1 mmol) in THF (2 mL) was added to a reaction mixture of imine **2a** (112 mg, 0.5 mmol) and $TMSCHCl_2$ **4** (173 mg, 1.1 mmol) in THF (2.0 mL) at −70 °C. The reaction mixture was stirred for 0.5 h at this temperature and then was warmed up to room temperature over 1.0 h. The reaction was quenched by 1.0 N HCl (10 mL) and the quenched reaction mixture was extracted three times with ethyl acetate (20 ML × 3). The combined organic layer was dried over anhydrous Na_2SO_4. Evaporation of the solvent afforded the crude product, which was subjected to flash chromatography to give pure 2-chloro *cis*-aziridine **5a**.

(*Rs*,2*R*,3*S*)-1-(*tert*-Butylsulfinyl)-2-chloro-3-*p*-tolylaziridine (5a). Light yellow oil (114 mg, 84%); $[\alpha]_D^{25}$ + 69.6 (c = 0.59 in $CHCl_3$); IR (film): ν_{max} = 2924, 1459, 1290, 1086, 927, 707 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.31 (d, J = 8.1 Hz, 2H), 7.20 (d, J = 7.9 Hz, 2H), 4.56 (d, J = 5.6 Hz, 1H), 3.90 (d, J = 5.5 Hz, 1H), 2.37 (s, 3H), 1.20 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 138.4, 128.9, 128.7, 128.5, 57.6, 53.4, 37.5, 22.6, 21.2; MS (ESI) *m*/*z*: 294.1 $[M + Na]^+$; HRMS (ESI) *m*/*z*: $[M + H]^+$ calcd for $C_{13}H_{19}ClNOS$ 272.0870; found 272.0875.

(*Rs*,2*R*,3*S*)-1-(*tert*-Butylsulfinyl)-2-chloro-3-*m*-tolylaziridine (5b). Light yellow oil (126 mg, 93%); $[\alpha]_D^{25}$ + 155.9 (c = 0.95 in $CHCl_3$); IR (film): ν_{max} = 2923, 1477, 1293, 1082, 948, 810, 698 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.29–7.15 (m, 4H), 4.55 (d, J = 5.6 Hz, 1H), 3.90 (d, J = 5.6 Hz, 1H), 2.37 (s, 3H), 1.20 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 137.9, 131.4, 129.5, 129.4, 128.1, 125.9, 57.6, 53.3, 37.6, 22.6, 21.5; MS (ESI) *m*/*z*: 294.1 $[M + Na]^+$; HRMS (ESI) *m*/*z*: $[M + H]^+$ calcd for $C_{13}H_{19}ClNOS$ 272.0870; found 272.0880.

(*Rs*,2*R*,3*S*)-1-(*tert*-Butylsulfinyl)-2-chloro-3-phenylaziridine (5c). Light yellow solid (85 mg, 66%); mp 71.1–71.8 °C; $[\alpha]_D^{25}$ + 54.4 (c = 0.51 in $CHCl_3$); IR (film): ν_{max} = 2917, 1450, 1285, 1078, 918, 699 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.39 (ddd, J = 7.3, 4.2, 1.5 Hz, 5H), 4.57 (d, J = 5.6 Hz, 1H), 3.93 (d, J = 5.6 Hz, 1H), 1.20 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 131.4, 128.8, 128.5, 128.2, 57.6, 53.3, 37.5, 22.5; MS (ESI) *m*/*z*: 280.1 $[M + Na]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{12}H_{16}ClNOSNa$ 280.0533; found 280.0535.

(*Rs*,2*R*,3*S*)-1-(*tert*-Butylsulfinyl)-2-chloro-3-(naphthalen-1-yl)-aziridine (5d). White solid (109 mg, 71%); mp 121.2–121.9 °C; $[\alpha]_D^{25}$ + 45.3 (c = 0.60 in $CHCl_3$); IR (film): ν_{max} = 2974, 1463, 1286, 1059, 927, 770, 722 cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.16 (d, J = 8.2 Hz, 1H), 7.89 (dd, J = 18.6, 7.9 Hz, 2H), 7.56 (ddd, J = 21.1, 12.0, 7.2 Hz, 4H), 4.79 (d, J = 5.5 Hz, 1H), 4.62 (d, J = 5.5 Hz, 1H), 1.29 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 133.4, 132.4, 128.9, 127.3, 126.7, 126.2, 126.1, 124.9, 122.7, 57.7, 53.5, 35.7, 22.5; MS (ESI) *m*/*z*: 307.9 $[M + H]^+$; HRMS (ESI) *m*/*z*: $[M + H]^+$ calcd for $C_{16}H_{19}ClNOS$ 308.0870; found 308.0878.

(*Rs*,2*R*,3*S*)-1-(*tert*-Butylsulfinyl)-2-chloro-3-(2-chlorophenyl)-aziridine (5e). Light yellow oil (89 mg, 61%); $[\alpha]_D^{25}$ − 36.9 (c = 0.53 in $CHCl_3$); ^1H NMR ($CDCl_3$) δ 7.44–7.41 (m, 2H), 7.33–7.29 (m, 2H), 4.66 (d, J = 5.6 Hz, 1H), 4.32 (d, J = 5.6 Hz, 1H), 1.24 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 135.2, 129.8, 129.7, 129.6, 129.5, 126.4, 57.7, 52.9, 35.9, 22.5; MS (ESI) *m*/*z*: 314.0 $[M + Na]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{12}H_{15}Cl_2NOSNa$ 314.0144; found 314.0143.

(*Rs*,2*R*,3*S*)-1-(*tert*-Butylsulfinyl)-2-chloro-3-(4-chlorophenyl)-aziridine (5f). Light yellow oil (75 mg, 51%); $[\alpha]_D^{25}$ + 88.1 (c = 0.56 in $CHCl_3$); IR (film): ν_{max} = 2925, 1491, 1289, 1085, 861, 743 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.36 (s, 4H), 4.56 (d, J = 5.6 Hz, 1H), 3.89 (d, J = 5.6 Hz, 1H), 1.19 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 129.8, 129.5, 129.4, 126.3, 57.7, 52.9, 36.9, 22.5; MS (ESI) *m*/*z*: 314.0 $[M + Na]^+$; HRMS (ESI) *m*/*z*: $[M + Na]^+$ calcd for $C_{12}H_{15}Cl_2NOSNa$ 314.0144; found 314.0157.

General procedure for the synthesis of α-(dichloromethyl)-amine 3l from α-(trichloromethyl)amine

Bu_3SnH (153 mg, 0.525 mmol) and catalytic AIBN (5 mg) in toluene (1 mL) was added slowly to a solution of α-(trichloromethyl)amine **6l** (199 mg, 0.5 mmol) in toluene (2 mL) at 90 °C. The reaction mixture was stirred for 3 h and then cooled to room temperature. Half saturated KF–H_2O (10 mL) was added to the reaction mixture. After filtration of the precipitate, the reaction mixture was extracted three times with ethyl acetate (20 ML × 3). The combined organic layers were dried over anhydrous Na_2SO_4. Evaporation of the solvent afforded the crude product, which was subjected to flash chromatography to give pure α-(dichloromethyl)amine **3l**.

(*Rs*)-*N*-((*S*)-2,2-Dichloro-1-(2,4-dichlorophenyl)ethyl)-2-methylpropane-2-sulfinamide (3l). White solid (176 mg, 97%); mp

112.6–113.6 °C; $[\alpha]_D^{25}$ −14.2 (c = 0.57 in $CHCl_3$); IR (film): ν_{max} = 3121, 2868, 1478, 1038, 903, 797 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.43 (dd, J = 5.2, 3.0 Hz, 2H), 7.33 (dd, J = 8.5, 1.9 Hz, 1H), 6.07 (d, J = 3.6 Hz, 1H), 5.24 (dd, J = 9.4, 3.6 Hz, 1H), 4.37 (d, J = 9.4 Hz, 1H), 1.30 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 135.5, 133.4, 133.3, 130.7, 129.7, 127.5, 74.3, 63.5, 57.6, 22.6; MS (ESI) m/z: 361.8 $[M + H]^+$; HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{12}H_{16}Cl_4NOS$ 361.9701; found 361.9712.

(*Rs*)-*N*-((*S*)-1,1-Dichloro-3-methylbutan-2-yl)-2-methylpropane-2-sulfinamide (3m). White solid (113 mg, 87%); mp 54.8–56.5 °C; $[\alpha]_D^{25}$ − 23.1 (c = 0.52 in $CHCl_3$); IR (film): ν_{max} = 3466, 3111, 2965, 1474, 1015, 922, 749 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.91 (d, J = 2.3 Hz, 1H), 3.42 (d, J = 8.1 Hz, 1H), 3.33 (td, J = 7.9, 2.3 Hz, 1H), 1.92 (dd, J = 14.0, 6.9 Hz, 1H), 1.31 (s, 9H), 1.13 (d, J = 6.8 Hz, 3H), 1.07 (d, J = 6.7 Hz, 3H); ^{13}C NMR ($CDCl_3$) δ 75.8, 69.7, 57.4, 31.8, 23.1, 19.9, 19.4; MS (ESI) m/z: 260.0 $[M + H]^+$; HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_9H_{19}Cl_2NOSNa$ 282.0457; found 282.0466.

(*Rs*)-*N*-((*S*)-1,1-Dichloropentan-2-yl)-2-methylpropane-2-sulfinamide (3n). White solid (105 mg, 81%); mp 121.7–122.3 °C; $[\alpha]_D^{25}$ − 54.8 (c = 1.00 in $CHCl_3$); IR (film): ν_{max} = 3138, 2960, 2864, 1361, 1053, 899, 772 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.77 (d, J = 2.7 Hz, 1H), 3.63 (tdd, J = 7.7, 4.7, 2.7 Hz, 1H), 3.38 (d, J = 7.6 Hz, 1H), 1.84–1.76 (m, 1H), 1.64 (dddd, J = 10.2, 7.4, 4.9, 3.4 Hz, 2H), 1.49–1.39 (m, 1H), 1.27 (s, 9H), 0.98 (t, J = 7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$) δ 76.5, 63.8, 56.9, 34.4, 22.8, 18.9, 13.7; MS (EI) m/z: 259 $[M]^+$; HRMS (EI) m/z: $[M]^+$ calcd for $C_9H_{19}Cl_2NOS$ 259.0564; found 259.0563.

General procedure for the synthesis of 2-chloro *cis*-aziridine 5g from α-(dichloromethyl)amine 3m

LiHMDS (0.5 mmol, 1.0 mol L^{-1} in THF) was added to a solution of α-(dichloromethyl)amine **3m** (147 mg, 0.5 mmol) in DMF (1.5 mL) at −40 °C. The reaction mixture was stirred at this temperature over 0.5 h. Then half saturated NH_4Cl–H_2O (10 mL) was added at −40 °C. The quenched reaction mixture was extracted three times with ethyl acetate (20 ML × 3). The combined organic layer was dried over anhydrous Na_2SO_4. Evaporation of the solvent afforded the crude product, which was subjected to flash chromatography to give pure 2-chloro *cis*-aziridine **5g**.

(*Rs*,2*R*,3*S*)-1-(*tert*-Butylsulfinyl)-2-chloro-3-isopropylaziridine (5g). Oil (92 mg, 82%); $[\alpha]_D^{25}$ − 57.7 (c = 0.55 in $CHCl_3$); IR (film): ν_{max} = 2923, 2852, 1464, 1081, 964, 683 cm^{-1}; ^1H NMR ($CDCl_3$) δ 4.36 (d, J = 5.7 Hz, 1H), 2.55 (dd, J = 8.9, 5.7 Hz, 1H), 1.97–1.88 (m, 1H), 1.28 (s, 9H), 1.14 (d, J = 6.8 Hz, 3H), 1.08 (d, J = 6.8 Hz, 3H); ^{13}C NMR ($CDCl_3$) δ 57.0, 54.2, 43.1, 27.4, 22.3, 20.4, 19.7; MS (EI) m/z: 223 $[M]^+$; HRMS (EI) m/z: $[M]^+$ calcd for $C_9H_{18}ClNOS$ 223.0798; found 223.0795.

(*Rs*,2*R*,3*S*)-1-(*tert*-Butylsulfinyl)-2-chloro-3-propylaziridine (5h). White solid (100 mg, 89%), mp 64.6–66.6 °C; $[\alpha]_D^{25}$ − 155.8 (c = 0.61, $CHCl_3$); IR (film): ν_{max} = 2961, 1476, 1291, 1086, 923, 757, 716 cm^{-1}; ^1H NMR ($CDCl_3$) δ 4.36 (d, J = 5.5 Hz, 1H), 2.82 (ddd, J = 9.3, 5.5, 3.8 Hz, 1H), 1.85–1.77 (m, 1H), 1.71–1.63 (m, 1H), 1.58–1.50 (m, 2H), 1.26 (s, 9H), 1.02 (t, J = 7.3 Hz, 3H); ^{13}C NMR ($CDCl_3$) δ 66.3, 57.0, 52.9, 35.4, 29.1, 19.8, 13.9; MS (EI) m/z: 167 $[M - 56]^+$; HRMS (EI) m/z: $[M - 56]^+$ calcd for $C_5H_{10}ClNOS$ 167.0172; found 167.0170.

General procedure for the synthesis of α-(chloromethyl)amine 7a from α-(dichloromethyl)amine 3a

Bu_3SnH (153 mg, 0.525 mmol) and catalytic AIBN (5 mg) in toluene (1 mL) was added to a solution of α-(dichloromethyl) amine **3a** (112 mg, 0.5 mmol) in toluene (2 mL) at 90 °C. The reaction mixture was stirred over 3 h and then cooled to room temperature. Half saturated KF–H_2O (10 mL) was added to the reaction mixture. After filtration of the precipitate, the reaction mixture was extracted three times with ethyl acetate (20 ML × 3). The combined organic layers were dried over anhydrous Na_2SO_4. Evaporation of the solvent afforded the crude product, which was subjected to flash chromatography to give pure α-(chloromethyl)amine **7a**.

(*Rs*)-*N*-((*S*)-2-Chloro-1-*p*-tolylethyl)-2-methylpropane-2-sulfinamide (7a). Oil (125 mg, 91%); $[\alpha]_D^{25}$ − 21.4 (c = 0.50 in $CHCl_3$); IR (film): ν_{max} = 3404, 3118, 2922, 1456, 1027, 940, 734 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.28 (s, 1H), 7.26 (s, 1H), 7.19 (d, J = 7.9 Hz, 2H), 4.64 (dd, J = 10.5, 5.7 Hz, 1H), 3.83 (dd, J = 5.9, 2.3 Hz, 2H), 3.76 (d, J = 4.1 Hz, 1H), 2.35 (s, 3H), 1.24 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 138.4, 136.0, 129.5, 127.2, 59.4, 56.4, 48.4, 22.6, 21.1; MS (ESI) m/z: 274.0 $[M + H]^+$; HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{13}H_{21}ClNOS$ 274.1027; found 274.1026.

(*Rs*)-*N*-((*S*)-2-Chloro-1-phenylethyl)-2-methylpropane-2-sulfinamide (7b). Oil (113 mg, 87%); $[\alpha]_D^{25}$ −34.0 (c = 0.53 in $CHCl_3$); IR (film): ν_{max} = 3229, 1455, 1051, 924, 720, 697 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.42–7.34 (m, 5H), 4.71 (dd, J = 10.4, 5.7 Hz, 1H), 3.88 (d, J = 5.9 Hz, 2H), 3.78 (d, J = 4.0 Hz, 1H), 1.27 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 139.0, 128.9, 128.6, 127.3, 59.6, 56.5, 48.4, 22.6; MS (ESI) m/z: 260.0 $[M + H]^+$; HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{12}H_{19}ClNOS$ 260.0870; found 260.0878.

(*Rs*)-*N*-((*S*)-2-Chloro-1-(naphthalen-1-yl)ethyl)-2-methylpropane-2-sulfinamide (7c). Light yellow oil (95 mg, 61%); $[\alpha]_D^{25}$ − 80.5 (c = 0.54 in $CHCl_3$); IR (film): ν_{max} = 3201, 2923, 1464, 1364, 1050, 798 cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.12 (d, J = 8.5 Hz, 1H), 7.88 (dd, J = 15.1, 8.1 Hz, 2H), 7.64–7.50 (m, 4H), 5.50 (dd, J = 10.0, 5.5 Hz, 1H), 4.12–4.03 (m, 3H), 1.22 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 134.0, 133.8, 130.6, 129.3, 129.2, 126.8, 125.9, 125.1, 125.0, 122.5, 56.4, 55.2, 48.1, 22.6; MS (ESI) m/z: 310.0 $[M + H]^+$; HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{16}H_{20}ClNOSNa$ 332.0846; found 332.0855.

(*Rs*)-*N*-((*S*)-2-Chloro-1-(2,4-dichlorophenyl)ethyl)-2-methylpropane-2-sulfinamide (7d). White solid (136 mg, 83%); mp 91.0–91.8 °C; $[\alpha]_D^{25}$ − 9.2 (c = 0.52 in $CHCl_3$); IR (film): ν_{max} = 3431, 3123, 2958, 1589, 1470, 1095, 1014, 936, 782 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.45–7.40 (m, 2H), 7.31 (dd, J = 8.4, 2.1 Hz, 1H), 5.13 (dt, J = 6.8, 4.9 Hz, 1H), 4.11 (d, J = 6.9 Hz, 1H), 3.94 (dd, J = 11.4, 4.7 Hz, 1H), 3.85 (dd, J = 11.4, 5.1 Hz, 1H), 1.23 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 130.3, 129.7, 127.3, 113.8, 110.0, 56.9, 55.3, 47.8, 22.5; MS (ESI) m/z: 327.9 $[M + H]^+$; HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{12}H_{16}Cl_3NOSNa$ 349.9910; found 349.9913.

(*Rs*)-*N*-((*S*)-2-Chloro-1-(furan-2-yl)ethyl)-2-methylpropane-2-sulfinamide (7e). Light yellow oil (94 mg, 75%); $[\alpha]_D^{25}$ − 2.3 (c = 0.54 in $CHCl_3$); IR (film): ν_{max} = 3174, 2961, 1677, 1459, 1012, 740 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.40 (d, J = 1.2 Hz, 1H), 6.45 (d, J =

3.3 Hz, 1H), 6.36 (dd, $J = 3.2$, 1.8 Hz, 1H), 4.72 (dd, $J = 12.5$, 5.9 Hz, 1H), 3.88 (dd, $J = 5.6$, 0.9 Hz, 2H), 3.81 (d, $J = 7.0$ Hz, 1H), 1.25 (s, 9H); ^{13}C NMR ($CDCl_3$) δ 151.5, 142.7, 110.6, 108.7, 56.7, 55.0, 46.8, 22.5; MS (ESI) m/z: 249.9 $[M + H]^+$; HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{10}H_{17}ClNO_2S$ 250.0663; found 250.0673.

(*Rs*)-*N*-((*S*)-1-Chloro-3-methylbutan-2-yl)-2-methylpropane-2-sulfinamide (7f). White solid (96 mg, 85%); mp 63.9–64.8 °C; $[\alpha]_D^{25} - 62.8$ ($c = 0.51$ in $CHCl_3$); IR (film): $\nu_{max} = 3195$, 2958, 1439, 1049, 892, 735 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 3.66–3.57 (m, 2H), 3.35 (d, $J = 6.2$ Hz, 1H), 3.26 (ddd, $J = 11.4$, 6.4, 5.0 Hz, 1H), 2.05 (dq, $J = 13.5$, 6.8 Hz, 1H), 1.24 (s, 9H), 1.03 (d, $J = 6.8$ Hz, 6H); ^{13}C NMR ($CDCl_3$) δ 62.6, 56.2, 47.4, 30.2, 22.6, 19.1, 18.5; MS (ESI) m/z: 226.0 $[M + H]^+$; HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_9H_{21}ClNOS$ 226.1027; found 226.1037.

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Notes and references

1 *Naturally Occurring Organohalogen Compounds - A Comprehensive Update*, ed. G. W. Gribble, Springer Wien NewYork, Germany, 2010.

2 (*a*) F. H. Vaillancourt, E. Yeh, D. A. Vosburg, S. Garneau-Tsodikova and C. T. Walsh, *Chem. Rev.*, 2006, **106**, 3364; (*b*) G. W. Gribble, *J. Chem. Educ.*, 2004, **81**, 1441; (*c*) C. S. Neumann, D. G. Fujimori and C. T. Walsh, *Chem. Biol.*, 2008, **15**, 99.

3 (*a*) L. C. Blasiak, F. H. Vaillancourt, C. T. Walsh and C. L. Drennan, *Nature*, 2006, **440**, 368; (*b*) F. H. Vaillancourt, E. Yeh, D. A. Vosburg, S. E. O'Connor and C. T. Walsh, *Nature*, 2005, **436**, 1191; (*c*) F. H. Vaillancourt, J. Yin and C. T. Walsh, *Proc. Natl. Acad. Sci. U. S. A.*, 2005, **102**, 10111.

4 A. Yarnell, *Chem. Eng. News*, 2006, **84**, 12.

5 (*a*) N. Sitachitta, J. Rossi, M. A. Roberts, W. H. Gerwick, M. D. Fletcher and C. L. Willis, *J. Am. Chem. Soc.*, 1998, **120**, 7131; (*b*) D. P. Galonić, F. H. Vaillancourt and C. T. Walsh, *J. Am. Chem. Soc.*, 2006, **128**, 3900; (*c*) Z. Gu and A. Zakarian, *Angew. Chem., Int. Ed.*, 2010, **49**, 9702; (*d*) C. E. Pavesio and H. H. Decory, *Br. J. Ophthalmol.*, 2008, **92**, 455.

6 For selected examples of chlorinated methyl group introduction based on the Kharash reaction, see: (*a*) S. Beaumont, E. A. Ilardi, L. R. Monroe and A. Zakarian, *J. Am. Chem. Soc.*, 2010, **132**, 1482; (*b*) Z. Gu, A. T. Herrmann and A. Zakarian, *Angew. Chem., Int. Ed.*, 2011, **50**, 7136; (*c*) J. M. Barks, B. C. Gilbert, A. F. Parsons and B. Upeandran, *Synlett*, 2011, 1719; (*d*) T. Nakamura, H. Yorimitsu, H. Shinokubo and K. Oshima, *Synlett*, 1998, 1351; (*e*) C. Ricardo and T. Pintauer, *Chem. Commun.*, 2009, 3029; (*f*) R. P. Nair, T. H. Kim and B. J. Frost, *Organometallics*, 2009, **28**, 4681; (*g*) T. Pintauer, W. T. Eckenhoff, C. Ricardo, M. N. C. Balili, A. B. Biernesser, S. J. Noonan and M. J. W. Taylor, *Chem. – Eur. J.*, 2009, **15**, 38; (*h*) J. M. Muñoz-Molina, T. R. Belderraín and P. J. Péreza, *Adv. Synth. Catal.*, 2008, **350**, 2365.

7 (*a*) V.-A. Nguyen, C. L. Willis and W. H. Gerwick, *Chem. Commun.*, 2001, 1934; (*b*) A. Ard, R. G. Soengas, M. I. Nieto, C. Jimnez and J. Rodrguez, *Org. Lett.*, 2008, **10**, 2175; (*c*) M. K. Gupta, Z. Li and T. S. Snowden, *J. Org. Chem.*, 2012, **77**, 4854; (*d*) K. E. Henegar and R. Lira, *J. Org. Chem.*, 2012, **77**, 2999; (*e*) V. K. Aggarwal and A. Mereu, *J. Org. Chem.*, 2000, **65**, 7211; (*f*) J. Kister and C. Mioskowski, *J. Org. Chem.*, 2007, **72**, 3925; (*g*) M. Fujita and T. Hiyama, *J. Am. Chem. Soc.*, 1985, **107**, 4085; (*h*) S. E. Brantley and T. F. Molinski, *Org. Lett.*, 1999, **1**, 2165.

8 For a review on C-heteroatom substituted aziridines, see: G. S. Singh, M. D'hooghe and N. De Kimpe, *Chem. Rev.*, 2007, **107**, 2080.

9 (*a*) F. A. Davis and J. Deng, *Org. Lett.*, 2007, **9**, 1707; (*b*) F. Colpaert, S. Mangelinckx, N. Giubellina and N. De Kimpe, *Tetrahedron*, 2011, **67**, 1258; (*c*) J.-M. Gaillot, Y. Gelas-Mialhe and R. Vessiere, *Can. J. Chem.*, 1979, **57**, 1958; (*d*) Y. Sato, Y. Yonezawa and C.-G. Shin, *Heterocycles*, 1982, **19**, 1463; (*e*) F. Palacios, A. M. O. De-Retana, J. I. Gil and J. M. Alonso, *Tetrahedron*, 2004, **60**, 8937.

10 (*a*) J. A. Deyrup and R. B. Greenwald, *Tetrahedron Lett.*, 1966, **28**, 5091; (*b*) J. A. Deyrup and R. B. Greenwald, *J. Am. Chem. Soc.*, 1965, **87**, 4538; (*c*) J. A. Deyrup and R. B. Greenwald, *Tetrahedron Lett.*, 1965, **6**, 321.

11 (*a*) P. Coutrot and A. E. Gadi, *J. Organomet. Chem.*, 1985, **280**, C11; (*b*) N. Giubellina, S. Mangelinckx, K. W. Törnroos and N. De Kimpe, *J. Org. Chem.*, 2006, **71**, 5881; (*c*) H. Yamanaka, J. Kikui, K. Teramura and T. Ando, *J. Org. Chem.*, 1976, **41**, 3794; (*d*) S. D. Sharma, S. Kanwar and S. Rajpoot, *J. Heterocycl. Chem.*, 2006, **43**, 11; (*e*) E. Vedejs and W. O. Moss, *J. Am. Chem. Soc.*, 1993, **115**, 1607.

12 (*a*) L. Pellacani, F. Persia and P. Tardella, *Tetrahedron Lett.*, 1980, **21**, 4967; (*b*) D. J. Anderson, T. L. Gilchrist, D. C. Horwell and C. W. Rees, *J. Chem. Soc. C*, 1970, 576.

13 (*a*) A. Hassner, S. S. Burke and I. J. Cheng-Fan, *J. Am. Chem. Soc.*, 1975, **97**, 4692; (*b*) F. W. Fowler and A. Hassner, *J. Am. Chem. Soc.*, 1968, **90**, 2875.

14 For the applications of *N-tert*-butanesulfinyl imines in synthesis, see: (*a*) J. A. Ellman, T. D. Owens and T. P. Tang, *Acc. Chem. Res.*, 2002, **35**, 984; (*b*) M. T. Robak, M. A. Herbage and J. A. Ellman, *Chem. Rev.*, 2010, **110**, 3600.

15 (*a*) Y. Li, Y. Cao, J. Gu, W. Wang, H. Wang, T. Zheng and Z. Sun, *Eur. J. Org. Chem.*, 2011, 676; (*b*) Y. Li, T. Zheng, W. Wang, W. Xu, Y. Ma, S. Zhang, H. Wang and Z. Sun, *Adv. Synth. Catal.*, 2012, 308.

16 For selected examples of 2,2-dichloroaziridine synthesis, see: (*a*) M. Mihara, Y. Ishino, S. Minakata and M. Komatsu, *J. Org. Chem.*, 2005, **70**, 5320; (*b*) A. F. Khlebnikov, M. S. Novikov, E. Yu. Kusei, J. Kopf and

R. R. Kostikov, *Russ. J. Org. Chem.*, 1999, **39**, 559; (*c*) R. E. Brooks, J. O. Edwards, G. Levey and F. Smyth, *Tetrahedron*, 1966, **22**, 1279; (*d*) H. E. Zaugg and R. W. DeNet, *J. Org. Chem.*, 1971, **36**, 1937; (*e*) T. Masanori and S. Minoru, *Chem. Pharm. Bull.*, 1985, **28**, 3098.

17 (*a*) N. De Kimpe and L. Moens, *Tetrahedron*, 1990, **46**, 2965; (*b*) N. De Kimpe, R. Verhé, L. De Buyck and N. Schamp, *J. Org. Chem.*, 1980, **45**, 5319; (*c*) N. De Kimpe, N. Schamp and R. Verhé, *Synth. Commun.*, 1975, **5**, 403.

18 (*a*) M. Takamatsu and M. Sekiya, *Chem. Pharm. Bull.*, 1981, **29**, 616; (*b*) E. V. Kondrashov, E. V. Rudyakova, I. B. Rozentsveig, I. V. Ushakova and G. N. Rozentsveig, *Russ. J. Org. Chem.*, 2008, **44**, 86; (*c*) A. Guirado, B. Martiz, R. Andreu and D. Bautista, *Tetrahedron*, 2009, **65**, 5958; (*d*) Y. G. Bal'on and V. A. Smirnov, *Russ. J. Org. Chem.*, 1989, **25**, 2507.

19 N. De Kimpe, R. Verhé, L. De Buyck and N. Schamp, *J. Org. Chem.*, 1981, **46**, 2079.

20 (*a*) G. K. Friestad and J. Qin, *J. Am. Chem. Soc.*, 2001, **123**, 9922; (*b*) G. K. Friestad, J.-C. Marié, Y. Suh and J. Qin, *J. Org. Chem.*, 2006, **71**, 7016; (*c*) M. Zajac and R. Peters, *Org. Lett.*, 2007, **9**, 2007.

21 (*a*) J. M. Concellón, H. Rodríguez-Solla, M. Huerta and J. A. Pérez-Andrés, *Eur. J. Org. Chem.*, 2012, **11**, 1839; (*b*) T. Onishi, Y. Otake, N. Hirose, T. Nakano, T. Torii, M. Nakazawa and K. Izawa, *Tetrahedron Lett.*, 2001, **42**, 6337; (*c*) Z. Wang, J. Yin, S. Campagna, J. A. Pesti and J. M. Fortunak, *J. Org. Chem.*, 1999, **64**, 6918.

22 (*a*) A. Hosomi, M. Inaba and H. Sakurai, *Tetrahedron Lett.*, 1983, **24**, 4727; (*b*) M. Fujita, M. Obayashi and T. Hiyama, *Tetrahedron*, 1988, **44**, 4135; (*c*) M. Fujita and T. Hiyama, *J. Am. Chem. Soc.*, 1985, **107**, 4085; (*d*) H. Shinokubo, J. Kondo, A. Inoue and K. Oshima, *Chirality*, 2003, **15**, 31.

23 For the addition reaction of (difluoromethyl)trimethylsilane reaction with imines, see: Y. Zhao, W. Huang, J. Zheng and J. Hu, *Org. Lett.*, 2011, **13**, 5342.

24 K. Yoon and D. Y. Son, *J. Organomet. Chem.*, 1997, **545–546**, 185.

25 (*a*) T. Boultwood, D. P. Affron, A. D. Trowbridge and J. A. Bull, *J. Org. Chem.*, 2013, **78**, 6632; (*b*) J. A. Bull, T. Boultwood and T. A. Taylor, *Chem. Commun.*, 2012, **48**, 12246.

26 P. Metrangolo and G. Resnati, *Halogen Bonding: Fundamentals and Applications*, Springer, New York, 2007.

27 (*a*) T. Imanishi, Y. Fujiwara, Y. Sawama, Y. Monguchi and H. Sajikia, *Adv. Synth. Catal.*, 2012, **354**, 771; (*b*) K. V. Rajendran, D. J. Carr and D. G. Gilheany, *Tetrahedron Lett.*, 2011, **52**, 7113; (*c*) A. Guirado, B. Martiz, R. Andreu and D. Bautista, *Tetrahedron*, 2009, **65**, 5958; (*d*) B. A. Seigal, C. Fajardo and M. L. Snapper, *J. Am. Chem. Soc.*, 2005, **127**, 16329; (*e*) T. Mineno, H. Kansui and T. Kunieda, *Tetrahedron Lett.*, 2007, **48**, 5027; (*f*) F. M. Koch and R. Peters, *Angew. Chem., Int. Ed.*, 2007, **46**, 2685; (*g*) M. Zajac and R. Peters, *Chem. – Eur. J.*, 2009, **15**, 8204; (*h*) C. E. Song, J. K. Lee, S. H. Lee and S.-G. Lee, *Tetrahedron: Asymmetry*, 1995, **6**, 1063; (*i*) T. Mori, J. Kubo and Y. Morikawa, *Appl. Catal., A*, 2004, **271**, 69; (*j*) R. N. Ram and N. K. Meher, *Org. Lett.*, 2003, **5**, 145; (*k*) D. A. Ellis, D. J. Hart and L. Zhao, *Tetrahedron Lett.*, 2000, **41**, 9357; (*l*) H. Tanaka, S. Yamashita, M. Yamanoue and S. Torii, *J. Org. Chem.*, 1989, **54**, 444; (*m*) B. Baasner and E. Klauke, *J. Fluorine Chem.*, 1988, **40**, 359; (*n*) R. A. Benkeser and W. E. Smith, *J. Am. Chem. Soc.*, 1968, **90**, 5307.

28 For a review on reduction of trichloromethyl compounds by hydrogen donors induced by transition metal carbonyls, their complexes, or their salts, see: E. C. Chukovskaya, R. Kh. Freidlina and N. A. Kuzmina, *Synthesis*, 1983, 773.

29 (*a*) E. Mounetou, J. Legault, J. Lacroix and R. C. Gaudreault, *J. Med. Chem.*, 2003, **46**, 5055; (*b*) J. E. Bishop, C. A. Mathis, J. M. Gerdes, J. M. Whitney, A. M. Eaton and R. B. Mailmant, *J. Med. Chem.*, 1991, **34**, 1612; (*c*) A. B. Smith, G. K. Friestad, J. Barbosa, E. Bertounesque, J. J.-W. Duan, K. G. Hull, M. Iwashima, Y. Qiu, P. G. Spoors and B. A. Salvatore, *J. Am. Chem. Soc.*, 1999, **121**, 10478; (*d*) D.-Z. Feng, Y.-L. Song, X.-H. Jiang, L. Chen and Y.-Q. Long, *Org. Biomol. Chem.*, 2007, **5**, 2690; (*e*) A. Roy, L. A. Reddy, N. Dwivedi, J. Naram, R. Swapna, G. C. Malakondaiah, M. Ravikumar, D. Bhalerao, T. B. Pratap, P. P. Reddy, A. Bhattacharya and R. Bandichhor, *Tetrahedron Lett.*, 2011, **52**, 6968.

30 (*a*) L. De Luca, G. Giacomelli and A. Porcheddu, *Org. Lett.*, 2002, **4**, 553; (*b*) F. Xu, B. Simmons, R. A. Reamer, E. Corley, J. Murry and D. Tschaen, *J. Org. Chem.*, 2008, **73**, 312; (*c*) H. A. McManus and P. J. Guiry, *J. Org. Chem.*, 2002, **67**, 8566; (*d*) P. Västilä, I. M. Pastor and H. Adolfsson, *J. Org. Chem.*, 2005, **70**, 2921.

31 (*a*) A. V. Malkov, S. Stončius and P. Kočovský, *Angew. Chem., Int. Ed.*, 2007, **46**, 3722; (*b*) B. Denolf, E. Leemans and N. De Kimpe, *J. Org. Chem.*, 2007, **72**, 3211; (*c*) A. V. Malkov, K. Vranková, S. Stončius and P. Kočovský, *J. Org. Chem.*, 2009, **74**, 5839; (*d*) J. M. Concellón, H. Rodríguez-Solla, P. L. Bernad and C. Simal, *J. Org. Chem.*, 2009, **74**, 2452.

32 (*a*) N. De Kimpe, R. Verhé, L. De Buyck and N. Schamp, *Bull. Soc. Chim. Belg.*, 1975, **84**, 701; (*b*) N. De Kimpe, R. Verhé, L. De Buyck and N. Schamp, *Bull. Soc. Chim. Belg.*, 1983, **92**, 233.

33 Some examples of β-chloroamine synthesis based on selective ring-opening of aziridines, see: (*a*) E. Leemans, S. Mangelinckx and N. De Kimpe, *Synlett*, 2009, 1265; (*b*) M. K. Ghorai, A. Kumar and D. P. Tiwari, *J. Org. Chem.*, 2010, **75**, 137; (*c*) M. K. Pandey, A. Bisai and V. K. Singh, *Tetrahedron Lett.*, 2004, **45**, 9661.