Accessing Azetidines via Magnesium-Mediated Nitrogen Atom Transfer from Iminoiodinane to Donor-Acceptor Cyclopropanes

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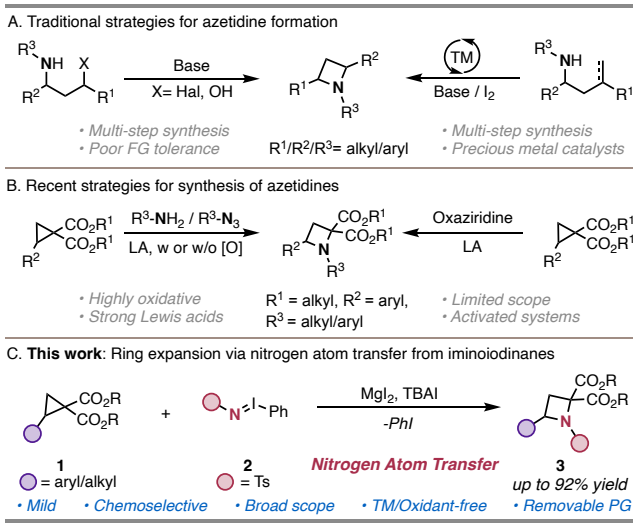
Abstract: Herein, we report a Lewis acid-mediated ring expansion of donor-acceptor cyclopropanes (DACs) to substituted azetidines via nucleophilic nitrogen atom transfer from readily accessible iminoiodinane. This protocol operates under mild, transition-metal-free conditions, and showcases excellent chemoselectivity, along with broad functional group tolerance. We report for the first time that unactivated donor-acceptor cyclopropanes can undergo ring expansion leading to aliphatic azetidines without relying on external oxidants or precious transition-metal catalysts. Mechanistically, the coordination of a Magnesium (Mg)-Lewis acid to the DAC promotes nucleophilic ring opening with a putative Mg-amide species generated from the iminoiodinane under the reaction conditions to furnish the azetidine products.

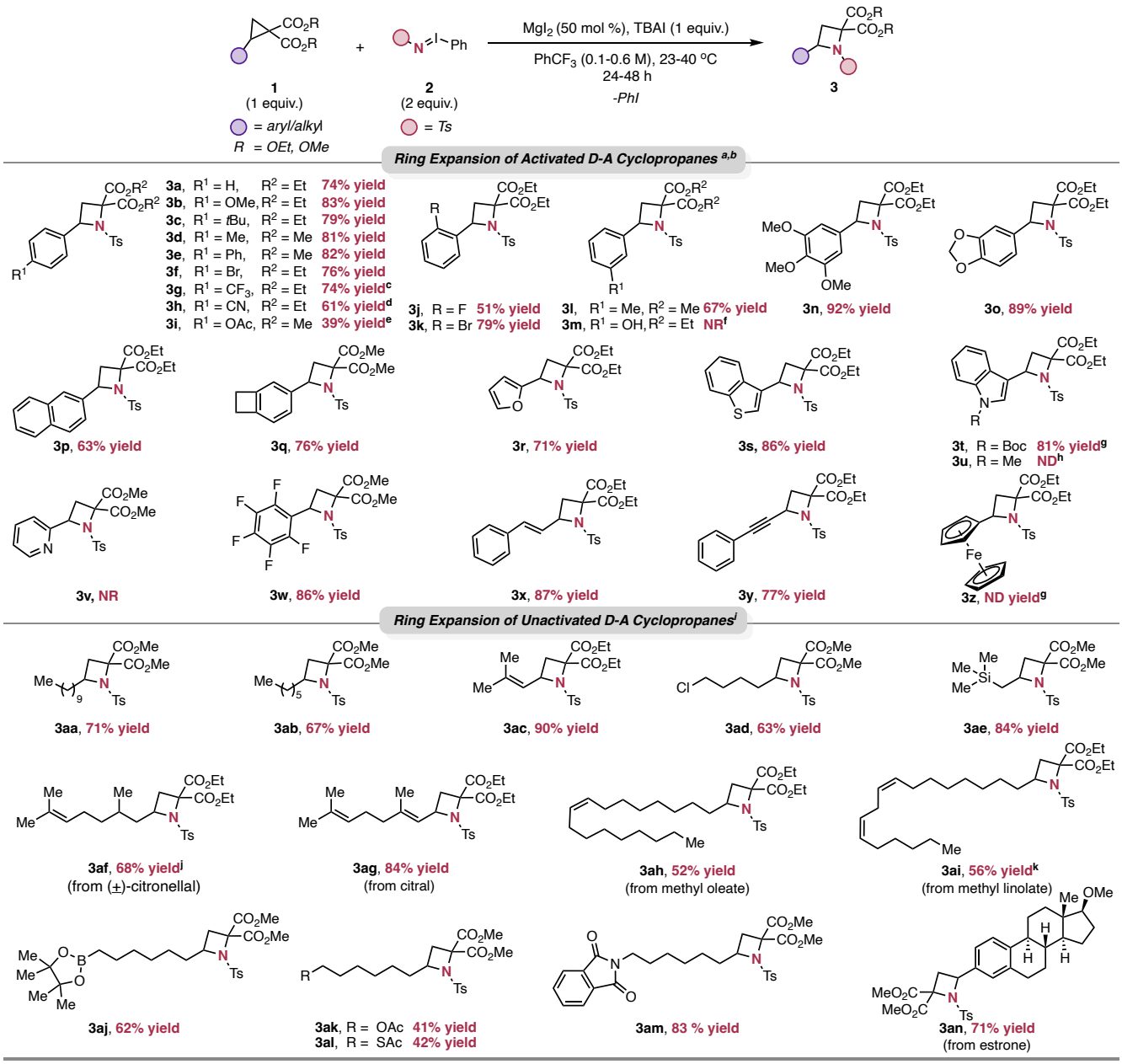
Azetidines, saturated four-membered nitrogen-containing heterocycles, are prominent structural motifs in numerous bioactive natural products and FDA-approved drugs such as Tebanicline,[1] Penaresidins A/B,[2] and Baricitinib.[3] Azetidines possess strong molecular rigidity, adequate stability, and isosteric characteristics with six-member heterocycles, which makes them privileged scaffolds for a broad range of applications in drug discovery.[4-6] Over the years, azetidines have been employed as ligands in transition-metal-catalyzed protocols and as chiral auxiliaries in asymmetric transformations.[7] Due to their inherent strain of 25 kcal mol^{-1}, azetidines serve as valuable synthetic handles for achieving 1,3-amino functionalized products.[8] Despite the prevalence of azetidine cores in medicinally relevant molecules and utility in organic synthesis, methods for the synthesis of azetidines have long been underdeveloped compared to other saturated nitrogen-containing heterocycles and remain a contemporary challenge in organic synthesis.[9] Some common azetidination strategies include the base-promoted intramolecular cyclization[10] of 1,3-amino alcohols, 1,3-halo amines (Scheme 1A, left), the coupling of homoallylic amines (Scheme 1A, right) as well as intermolecular cyclization alkene with amines/oximes.[11] Although well-established, these methods are often low-yielding and demonstrate poor functional group tolerance owning to the basic conditions employed.

In recent years, there has been growing interest in the development of direct azetidination protocols through ring-contraction or expansion of various ring systems such as pyrrolidinones, [12] aziridines,[13] azabicyclobutanes,[14] and donor-acceptor cyclopropanes (DACs). Among others, it has been shown that donor-acceptor cyclopropanes, "a masked 1,3-dipole," exhibit exceptional reactivity under Lewis acid-catalyzed conditions, enabling a wide range of transformations such as ring expansion,[15] nucleophilic and/or electrophilic substitution,[16,17] cycloaddition,[18] and many more.[19] In 2014, the Xu group harnessed the dipolar nature of DACs with azides through formal Lewis acid-promoted [3+3] cycloaddition and thermolysis to access azetidines (Scheme 1B, left).[20] Years later, Banerjee and co-workers demonstrated the Lewis acid-mediated azetidination of DACs using oxaziridines (Scheme 1B, right).[21] However, the scope is limited to highly electron-rich substrates, which restricts its broader applicability in target-oriented synthesis. Contemporaneously, the Lao group developed a cascade Lewis acid DAC ring opening with aromatic amines and subsequent intramolecular amination via hypoiodite relay catalysis to access substituted azetidines.[22] While innovative, the substrate scope of these azetidination protocols is hampered by the reliance on strong oxidants, harsh reaction conditions, and the employment of activated systems. Therefore, to address these shortcomings, the development of a robust, transition-metal-/exogenous oxidant-free, and mild nitrogen atom transfer protocol is highly warranted.[23] Herein, we report a Lewis acid-mediated ring expansion of donor-acceptor cyclopropanes (**1**) to generate substituted azetidines via nitrogen atom transfer from readily accessible iminoiodinanes (**2**) (Scheme 1C).



Scheme 1. Approaches for the synthesis of azetidines.

Table 1. Substrate scope of the azetidination reaction[a,b]



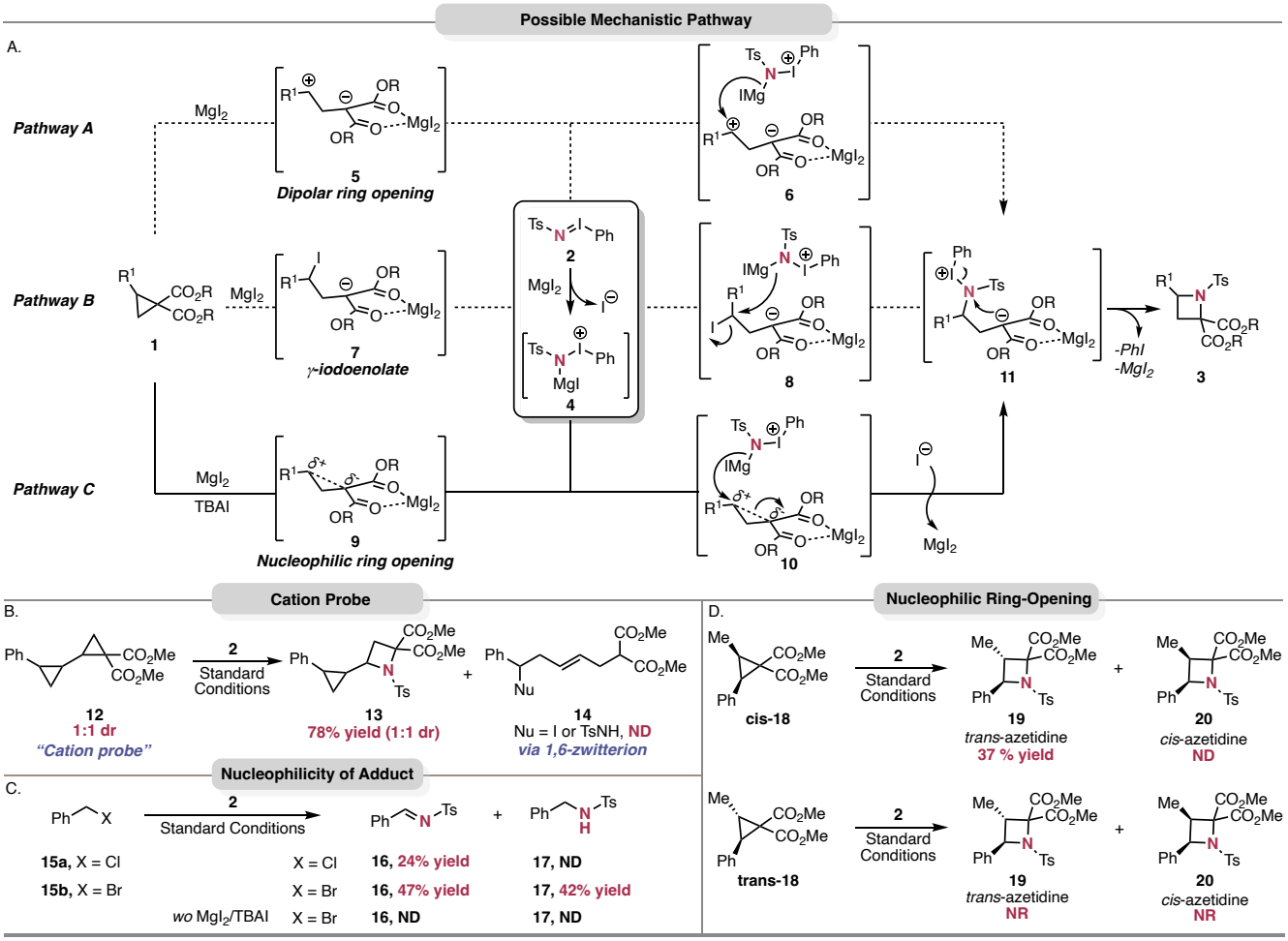
[a] Isolated yield. [b] Condition A: **1** (1 equiv.), **2** (2 equiv.) MgI_2 (50 mol%), TBAI (1 equiv.), $PhCF_3$ (0.1 M), rt, 24 h. [c] Reaction time = 36 h. [d] Reaction time = 48 h. [e] Reaction time = 48 h and 52% with SM recovered. [f] SM recovered. [g] Reaction time = 3 h. [h] SM consumed. [i] Condition B: **1** (1 equiv.), **2** (2 equiv.) MgI_2 (50 mol%), TBAI (1 equiv.), $PhCF_3$ (0.6 M), 40 °C, 48 h; [j] Racemic mixture. [k] 1:0.3 = ZZ:EZ ratio. NR = No Reaction, ND = Not Detected.

Recently our group,[24] Koenigs,[25] and others[26-28] have demonstrated that azoxy-triazenes, iminoiodinanes, and aryl/carbonyl azides can serve as effective nitrogen atom transfer sources for the aziridination of alkenes and related transformations. Hence, we envisioned that a similar nitrogen-atom-transfer event from these precursors to DACs could effectively lead to azetidines under mild conditions. Optimization studies indicated that azetidination of DAC **1a** leading to **3a** occurred effectively with iminoiodinane **2** and MgI_2 as a Lewis acid (Table S2, see Supporting Information). After an extensive optimization campaign, it was found that the combination of 50 mol % of MgI_2 and stoichiometric amounts of tetrabutylammonium iodide with iminoiodinane **2** and DAC **1a** generated azetidine **3a** in 74% yield (see Supporting Information).

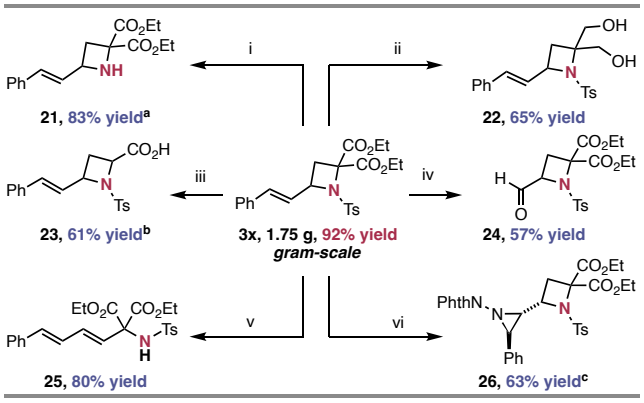
Having established the optimized conditions, the scope of the donor-acceptor cyclopropanes (**1**) was investigated for this azetidination protocol (Table 2). Aryl substituted DAC bearing alkyl, bicyclic, or halogen substituents exhibited high yields of the corresponding azetidine products (**3c-d, 3f, 3j-l, 3q,** and **3w;** 51-88%). Electron-rich DACs gave excellent yields (**3b** and **3n**) of desired azetidine products. The azetidination of electron-deficient DACs, which are difficult to react under conventional Lewis acid conditions, generated the azetidine products **3g** and **3h** in good yields. Extended π-systems, such as biphenyl and naphthalene

substituted DACs led to azetidines **3e** (82%) and **3p** (63%), respectively. Labile substituents like acetate (**1i**) and dioxole (**1o**), which are prone to deprotection under Lewis acid conditions, were well tolerated under our method. Unfortunately, substrates possessing highly Lewis-basic groups such as phenol (**1m)**, *N*-methyl indole (**1u**)**,** and pyridine (**1v)** failed to react. Heterocyclic DACs (**1r-t**) performed well under reaction conditions, yielding previously inaccessible azetidine analogs of furan (**3r**), benzo[*b*]thiophene (**3s**), and *N*-Boc indole (**3t**) in high yields. DACs **1x** and **1y** were tested to evaluate the chemoselectivity of our transformation. Notably, exclusive formation of the azetidine products (**3x-3y**) was observed; competitive nitrogen-atom transfer to the alkene moiety was not detected. Unfortunately, sensitive ferrocenyl substituted DAC (**1z**) did not result in the desired azetidine product (**3z**).

Next, challenging-to-react unactivated DACs were tested under the reaction conditions. Gratifyingly, aliphatic DACs **1aa** and **1ab** yielded azetidine products **3aa** and **3ab** in high yields (69-71%) (Table 1). To the best of our knowledge, this is the first example of azetidination of aliphatic DACs; highlighting a significant advancement over the prior reports.[20-22] Vinyl DAC **1ac** resulted in an excellent yield of azetidine product **3ac** (90%). Synthetic handles such as chloro- and trimethyl silane groups were well tolerated under reaction conditions (**3ad**-**3ae**). The DAC analogs of terpenoids including (±) citronellal (**1af**), citral (**1ag**), methyl oleate (**1ah**), and methyl lineolate (**1ai**) resulted in azetidine products (**3af**-**3ai**) chemoselectively in high yields. Substrates bearing sensitive functional groups such as pinacol borane, acetate, thioacetate, and phthalimido groups (**1aj-1am**), demonstrated good tolerance under our protocol (**3aj-3am,** 41-83% yield). Lastly, complex steroid DAC derivative **1an** reacted well under the reaction conditions leading to **3an** in good yield, demonstrating the feasibility of this method for late-stage installation of azetidine moieties.



Scheme 2. Reaction Mechanism and Mechanistic Studies. A) Possible mechanistic pathways. B) Cation probe experiment. C) Nucleophilicity of iminoiodinane adduct. D) Nucleophilic ring-opening studies. ND = Not detected. NR = No reaction.



Scheme 3. Synthetic utility of the azetidine products. [i] **3x** (1 equiv.), 1,2,3,5-Tetrakis(carbazol-9-yl)-4,6-dicyanobenzene, 2,4,5,6-Tetrakis(9*H*-carbazol-9-yl) isophthalonitrile (4-CzIPN,10 mol%), DIPEA, 390 nm, CH_3CN:H_2O (6:1), 48 h. [a] ^1H NMR yield [ii] $LiAlH_4$ (1.1 equiv.), Et_2O (0.1 M), 23 °C, 3 h. [iii] 2 M KOH in EtOH, reflux, 12 h; 6 M HCl, reflux, 6 h. [b]1.0:0.2 dr. [iv] 4-nitrobenzonitrile (1.5 equiv.), CH_3CN (0.1 M), 390 nm, 23 °C,18 h. [v] $Cu(OTf)_2$ (1 equiv.) CH_2Cl_2 (0.2 M), 23 °C, 1 h. [vi] Azoxy-triazene (1.0 equiv.), 1,4-dioxane (0.5 M), 390 nm, 23 °C, 24 h. [c]1.0:0.32:0.01 dr.

The mechanism of the transformation was then investigated. Conventionally, 1,3-dipolar species are generated through Lewis acid-promoted ring opening of DACs, which can undergo nitrogen atom transfer with an electrophilic nitrogen species.[21] The Novikon and Tomilov groups reported that bicyclopropyl systems in the presence of Lewis acids undergo ring-opening of both cyclopropanes rings to a 1,6-dipolar species, which then can be trapped with nucleophiles.[29] To identify the potential formation of a dipolar species in our transformation, we tested bicyclopropyl dipolar/cation probe **12** (Scheme 2B). Exposure of **12** under our reaction conditions furnished azetidine **13** with no detection of ring-open product **14**; thus, ruling out the formation of a dipolar intermediate (**5**, Scheme 2A, pathway A). Supporting studies featuring electrophilic and nucleophilic trapping experiments indicated no evidence of a dipolar species (see Supporting information). Next, we hypothesized that the MgI_2 present in solution could trigger a weakening of the carbon-carbon σ-bond of the DAC to form intermediate **9**, which could undergo a nucleophilic ring opening with Lewis acid-activated iminoiodinane **2** leading to intermediate **11**, followed by azetidination **(11→3)** (Scheme 2A, Pathway C). To support the nucleophilic nature of **2** under the reaction conditions, benzyl halides (**15**) were subjected to the reaction conditions in the absence of DAC. This resulted in a mixture of S_N2 alkylation products imine **16** and amine **17** (Scheme 2C). Notably, no reaction occurred in the absence of the Lewis acid and TBAI additive. These studies support that the combination of MgI_2 and TBAI with **2** leads to a putative Mg-amide(phenyl)iodonium species **4** that undergoes nucleophilic ring opening of intermediate **9**.[30,16a,b] An alternative mechanism (Scheme 2A, Pathway B) involving the formation of an γ-iodoenolate intermediate **7** and its engagement with **4** leading to the azetidine product can be scrutinized based on stereochemical probe studies (Scheme 2D). If retention of stereochemistry is preserved using *cis*-DAC (**18**), then the formation of γ-iodoenolate intermediate would be supported.[21,31] *Cis*-DAC (**18**) was tested under reaction conditions and led to the stereoinversion product *trans*-azetidine **19** (Scheme 2D, top); hence, ruling out the formation of a γ-iodoenolate intermediate (**7**). *Trans*-DAC **18** did not show any reactivity under reaction conditions (Scheme 2D, bottom), presumably due to unfavorable steric clash upon nucleophilic attack, which provides additional support for the mechanism involving nucleophilic ring opening of DAC. Based on these studies, we believe that pathway C is the most probable mechanism for our transformation.

Lastly, the synthetic utility of the transformation was explored. The scalability of this azetidination protocol was demonstrated on both activated and unactivated DACs (**1x** and **1aa**) at gram scale, where the yields were comparable to the isolation scale (**3x**, 1.75 g, 92% yield, and **3aa,** 1.16 g, 74% yield) (Scheme 3). Next, azetidine **3x** was subjected to a series of useful synthetic transformations. Under photoreductive conditions, azetidines **3x** led to tosyl deprotected to furnish azetidine **21** (83% ^1H NMR yield). Next, the ester groups on azetidine **3x** were reduced to generate diol **22,**[32] and a tandem saponification/decarboxylation of **3x** was performed to yield monoester **23** in good yields.[33] The styrene moiety of azetidine **3x** was amenable to anaerobic cleavage and aziridination using photoexcited 1,3-dipoles to generate **24** and **26**, respectively.[24,34] Finally, azetidine **3x** was subjected to Lewis acid-mediated ring-opening to furnish diene **25** in high yield via E1 elimination.[35]

In summary, we have developed a mild, transition-metal- and exogenous oxidant-free, scalable approach for a new library of azetidine moieties via nitrogen atom transfer from readily accessible iminoiodinane with donor-acceptor cyclopropanes in the presence of a Lewis-acid. This approach exhibits broad substrate scope as unactivated DACs can be employed for the first time to generate aliphatic azetidines chemoselectively in high yields. We anticipate that this robust protocol will be widely adopted in drug discovery programs for the synthesis of structurally unique bioactive azetidines.

Supporting Information

The authors have cited additional references within the Supporting Information.

Acknowledgements

[†]Ning Deng and Mahmoud Afrasi contributed to this work equally.

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Keywords: Donor-Acceptor Cyclopropane • Iminoiodinane • Ring Expansion • Azetidine • Chemoselectivity

[1] M. W. Holladay, J. T. Wasicak, N.-H. Lin, Y. He, K. B. Ryther, A. W. Bannon, M. J. Buckley, D. J. Kim, M. W. Decker, D. J. Anderson, *J. Med. Chem.* **1998**, *41*, 407–412.

[2] J. I. Kobayashi, J. F. Cheng, M. Ishibashi, M. R. Wälchli, S. Yamamura, Y. Ohizumi, *J. Chem. Soc, Perkin Trans. 1*, **1991**, *5*, 1135–1137.

[3] J. D. Rodgers, S. Shepard, T. P. Maduskuie, H. Wang, N. Falahatpisheh, M. Rafalski, A. G. Arvanitis, L. Sorace, R. K. Jalluri, J. S. Fridman, K. Vaddi, US Patent 0135461 A1, June 14, **2007**.

[4] D. R. Parmar, J. Y. Soni, R. Guduru, R. H. Rayani, R. V. Kusurkar, A. G. Vala, *Arch. Pharm*. **2021**, *354*, e2100062.

[5] I. O. Feskov, A. V. Chernykh, Y. O. Kuchkovska, C. G. Daniliuc, I. S. Kondratov, O. O. Grygorenko, *J. Org. Chem.* **2019**, *84*, 1363–1371.

[6] J. Basinger, B. Bookser, M. Chen, A. Hudson, J. Na, J. Renick, V. Santora, *US Patent 0334846 A1*, November 23, **2017**.

[7] a) G. S. Singh, M. D'hooghe and N. De Kimpe, in Comprehensive Heterocyclic Chemistry III, ed. C. V. Stevens, *Elsevier, Oxford, 3rd edn*, **2008**, *2*, 1–110; b) F. Couty, *Sci. Synth., ed.* **2009**, *40a*, 773–816; (c) G. Rousseau, S. Robin, in Modern Heterocyclic Chemistry, ed. J. Alzerez-Builla, J. J. Vaquero, J. Barluenga, *Wiley-VCH, Weinheim, 1st edn.* **2011**, *1*, 163–268; d) S. Liu, N. Shao, F.-Z. Li, X.-C. Yang, M.-C. Wang, *Org. Biomol. Chem.* **2017**, *15*, 9465–9474.

[8] a) L. Reisman, E. A. Rowe, E. M. Jackson, C. Thomas, T. Simone, P. A. Rupar, *J. Am. Chem. Soc.* **2018**, *140*, 15626–15630; b) F. Couty, O. David, F. Durrat, G. Evano, S. Lakhdar, J. Marrot, M. Vargas-Sanchez, *Eur. J. Org. Chem.* **2006**, 3479–3490.

[9] H. Mughal, M. Szostak, *Org. Biomol. Chem.* **2021**, *19*, 3274–3286.

[10] G. S. Singh, in *Advances in heterocyclic chemistry,* Elsevier, **2020**, *130*, 1–74.

[11] a) E. R. Wearing, Y.-C. Yeh, G. G. Terrones, S. G. Parikh, I. Kevlishvili, H. J. Kulik, C. S. Schindler, *Science* **2024**, *384*, 1468-1476. b) R. Dasi, A. Villinger, M. Brasholz, *Org. Lett.* **2022**, *24*, 8041-8046. c) M. R. Becker, E. R. Wearing, C. S. Schindler, *Nat. Chem.* **2020**, *12*, 898-905.

[12] N. Kern, A.-S. Felten, J.-M. Weibel, P. Pale, A. Blanc, *Org. Lett.* **2014**, *16*, 6104–6107.

[13] a) S. Malik, U.K. Nadir, and P.S. Pandey, *Synth. Commun*. **2010**, *40*, 1631–1638; b) S. Stankovic, S. Catak, M. D'hooghe, H. Goossens, A. K. Tehrani, P. Bogaert, M. Waroquier, V. V. Speybroeck, N. De Kimpe, *J. Org. Chem.* **2011**, *76*, 2157–2167.

[14] Y. Ji, L. Wojtas, J. M. Lopchuk, *Arkivoc* **2018**, 195–214.

[15] a)A. Jacob, P. G. Jones, D. B. Werz, *Org. Lett.* **2020**, *22*, 8720–8724.b) M. Bao, M. P. Doyle, *Org. Lett.* **2023**, *25*, 3029-3033.c) M. Bao, K. Lopez, R. Gurung, H. Arman, M. P. Doyle, *ACS Catal.* **2023**, *13*, 1621-1629.

[16] a) G. Mloston, M. Celeda, M. Kowalczyk, G. A. Oliver, D. B. Werz, *Euro. J. Org. Chem.* **2024**, e202400831; b) E. M. Budynina, K. L. Ivanov, I. D. Sorokin, M. Y. Melnikov, *Synthesis* **2017**, *49*, 3035–3068; c) S. J. Webster, L. B. Balázs, F. W. Goetzke, V. Stojalnikova, K. Liu, K. E. Christensen, H. W. Mackenzie, S. P. Fletcher, *J. Am. Chem. Soc.* **2024**, *146*, 24708–24715.

[17] Selected examples for donor-acceptor cyclopropane ring-opening strategies: a) S. Chakrabarty, I. Chatterjee, B. Wibbeling, C. G. Daniliuc, Studer, A. *Angew. Chem. Int. Ed.* **2014**, *53*, 5964–5968; b) J. Wallbaum, L. K. Garve, P. G. Jones, D. B. Werz, *Org. Lett.* **2017**, *19*, 98–101; c) S. Deswal, A. Guin, A. T. Biju, *Org. Lett.* **2023**, *25*, 1643–1648; d) A. Guin, S. Deswal, A. T. Biju, *J. Org. Chem.* **2022**, *87*, 6504–6513.

[18] A. U. Augustin, J. L. Merz, P. G. Jones, G. Mloston, D. B. Werz, *Org. Lett.* **2019**, *21*, 9405–9409.

[19] T. F. Schneider, J. Kaschel, D. B. Werz, *Agnew. Chem. Int. Ed.* **2014**, *53*, 5504–5523.

[20] H. H. Zhang, Y. C. Luo, H. P. Wang, W. Chen, P. F. Xu, *Org. Lett.* **2014**, *16*, 4896–4899.

[21] A. Ghosh, S. Mandal, P. K. Chattaraj, P. Banerjee, *Org. Lett.* **2016**, *18*, 4940-4943.

[22] J. Q. Han, H. H. Zhang, P. F. Xu, Y. C. Luo, *Org. Lett.* **2016**, *18*, 5212–5215.

[23] Y. Ju, R. S. Varma, *J. Org. Chem.* **2006**, *71*, 135–141.

[24] J. K. Mitchell, W. A. Hussain, A. H. Bansode, R. M. O'Connor, M. Parasram, *J. Am. Chem. Soc.* **2024**, *146*, 9499–9505.

[25] a) Y. Guo, C. Pei, C. Empel, S. Jana, R. M. Koenigs, *ChemPhotoChem*, **2022**, *6*, e202100293; b) Y. Guo, C. Pei, S. Jana, R. M. Koenigs, *ACS Catal.* **2020**, *11*, 337–342.

[26] J. W. W. Chang, T. M. U. Ton, P. W. H. Chan, *Chem. Rec.* **2011**, *11*, 331–357.

[27] Y.-C. Wang, X.-J. Lai, K. Huang, S. Yadav, G. Qiu, L. Zhang, H. Zhou, *Org. Chem. Front.* **2021**, *8*, 1677–1693.

[28] D. B. Bagal, S.-W. Park, H.-J. Song, S. Chang, *Chem. Commun.* **2017**, *53*, 8798–8801.

[29] a) D. A. Denisov, R. A. Novikov, K. V. Potapov, V. A. Korolev, E. V. Shulishov, Y. V. Tomilov, *ChemistrySelect* **2016**, *1*, 6374-6381; b) K. V. Potapov, D. A. Denisov, V. V. Glushkova, R. A. Novikov, Y. V. Tomilov, *J. Org. Chem.* **2020**, *85*, 15562-15576.

[30] a) M. Shimizu, *Sci. Synth.* **2004**, *7*, 661-667; b) R. Sanz, G. Vest, L. Despres, *Synth. Commun*. **1989**, *19*, 2909–2913; c) L. Davin, A. Hernán-Gómez, C. McLaughlin, A. R. Kennedy, R. McLellan, E. Hevia, *Dalton Trans.* **2019**, *48*, 8122–8130; d) R. Campbell, B. Conway, G. S. Fairweather, P. García-Álvarez, A. R. Kennedy, J. Klett, R. E. Mulvey, C. T. O'Hara, G. M. Robertson, *Dalton Trans.* **2010**, *39*, 511–519.

[31] S. Das, C. G. Daniliuc, A. Studer, *Agnew. Chem. Int. Ed.* **2017**, *56*, 11554-11558.

[32] J. Guo, G. Hu, Z. Chen, *Trans. Tianjin Univ.* **2012**, *18*, 8–14.

[33] S. P. Fritz, J. F. Moya, M. G. Unthank, E. M. McGarrigle, V. K. Aggarwal, *Synthesis* **2012**, *44*, 1584–1590.

[34] D. E. Wise, E. S. Gogarnoiu, A. D. Duke, J. M. Paolillo, T. L. Vacala, W. A. Hussain, M. Parasram, *J. Am. Chem. Soc.* **2022**, *144*, 15437–15442.

[35] M. K. Ghorai, A. Kumar, K. Das, *Org. Lett.* **2007**, *9*, 5441-5444.

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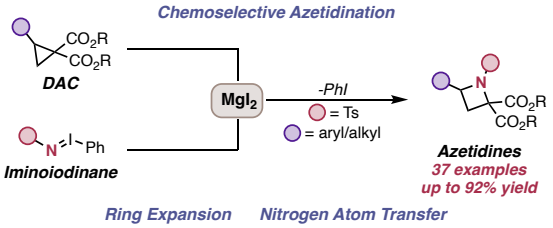

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