Chemical Science

ROYAL SOCIETY OF CHEMISTRY

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Cite this: *Chem. Sci.*, 2025, **16**, 8561

O-Trifluoromethylation of ketones: an alternative straightforward route to alkenyl trifluoromethyl ethers†

Chi Gao,‡ Yang Liu, ‡ Cheng-Sheng Li, He Guo, Sheng-Han Wang, Cong Xu * and Mang Wang *

Received 11th February 2025
Accepted 9th April 2025

DOI: 10.1039/d5sc01073j

rsc.li/chemical-science

Here we report an unprecedented *O*-trifluoromethylation of ketones using chloro(phenyl)trifluoromethyl-λ^3-iodane (CPTFI). Our method provides a new strategy for the facile synthesis of various synthetically valuable alkenyl trifluoromethyl ethers, particularly those CF_3O-substituted terminal alkenes and cyclic alkenes that have been elusive until now, from simple aromatic, aliphatic, and cyclic ketones. The success of this reaction is attributed to the full utilization of the multifunctionality of CPTFI: (1) its strong Lewis acid activation ability, which enables weak nucleophiles such as Cl anions to attack the carbonyl group; (2) its bifunctionality, which allows for the introduction of CF_3 and Cl into the carbonyl group in one step, thus enabling the obtainment of alkenyl trifluoromethyl ethers by further removal of HCl. The further transformation in the synthesis of CF_3O-cyclopropanes, which were previously largely unexplored, reveals the significant potential of alkenyl trifluoromethyl ethers as valuable CF_3O-containing building blocks in the discovery of innovative materials, pharmaceuticals, and agrochemicals.

Introduction

Fluorinated organic compounds constitute a significant class of organic molecules and play a pivotal role in both academic and industrial spheres due to the unique properties of fluorine.[1] Among various fluorine-containing functional groups, the trifluoromethoxy (CF_3O) group stands out owing to its favorable physicochemical attributes. Consequently, it frequently serves as a crucial skeletal motif in a wide array of pharmaceutical molecules, agrochemicals, natural products, and materials.[2] Furthermore, in light of the growing concern over per- and polyfluoroalkyl substances (PFASs), which are often referred to as "forever chemicals", the trifluoromethoxy group's relatively shorter environmental persistence may position it as a preferable substitute for other fluorinated groups in various fields.[3] Despite this immense potential, a limited number of CF_3O-containing molecules are currently commercially utilized with only a negligible percentage of fluorinated pharmaceuticals and agrochemicals on the market bearing the CF_3O group.[4] This scarcity is primarily attributed to the lack of practical and efficient synthetic methods for incorporating CF_3O into molecules. Thus, the development of novel and robust synthetic strategies for constructing the CF_3O group is crucial for unlocking the full potential of this versatile functional group and expanding its applications across diverse fields.

The construction of a CF_3O unit can be mainly approached through two basic strategies: step-by-step assembly and direct assembly (Fig. 1A).[2] The former strategy involves

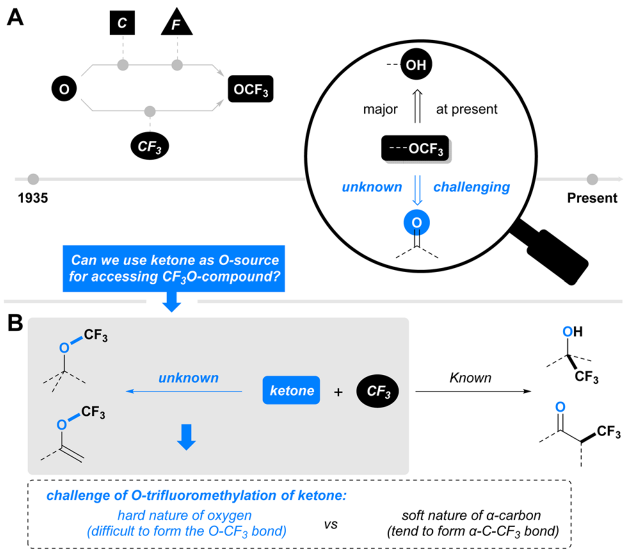


Fig. 1 (A) Overview of the strategies for construction of the CF_3O group. (B) Challenge of *O*-trifluoromethylation of ketones.

Jilin Province Key Laboratory of Organic Functional Molecular Design & Synthesis, Department of Chemistry, Northeast Normal University, Changchun 130024, China. E-mail: xuc348@nenu.edu.cn; wangm452@nenu.edu.cn

† Electronic supplementary information (ESI) available. CCDC 2377882 and 2421689. For ESI and crystallographic data in CIF or other electronic format see DOI: **https://doi.org/10.1039/d5sc01073j**

‡ These authors contributed equally to this work.

prefunctionalizing the oxygen atom with a reactive electrophilic single-carbon functional group, followed by nucleophilic fluorination. Although this *de novo* construction strategy is pioneering,[5a,b] its application has been largely limited by its harsh reaction conditions, operational intricacy, and corrosiveness of the reagents in the early years. Recent advancements have revitalized this strategy, making it more applicable.[5] The direct assembly strategy entails attaching the entire CF_3 group to the oxygen atom, relying heavily on the evolution of *O*-trifluoromethylation techniques. Despite being a long-sought-after transformation, it has been hampered by issues of efficiency and selectivity. The challenges primarily arise from the hard nature of the oxygen atom, which affects its innate reactivity with electrophilic CF_3 reagents.[6h]

Throughout the history of CF_3O-containing compound synthesis, *O*-sources have predominantly been compounds possessing hydroxyl (–OH) groups (Fig. 1A).[2,5,6h] There is an urgent need to expand other naturally or commercially occurring and abundant *O*-containing starting materials for constructing the CF_3O moiety and synthesizing CF_3O-compounds.[7] Ketones, as inexpensive and plentiful building blocks in organic synthesis with diverse reactivity,[8] hold promise as an alternative *O*-source. However, conventional trifluoromethylation of ketones totally focused on C–CF_3 bond formation, such as nucleophilic addition of carbonyl with the Ruppert–Prakash reagent, affording α-CF_3 alcohols.[1c] In addition, the reaction of enolizable ketones with an electrophilic CF_3 reagent (for example, Togni's reagent) was reported to occur at softer α-carbon sites, leading to α-CF_3 ketones.[1a,b,9] In stark contrast, *O*-trifluoromethylation of ketones remains an uncharted territory (Fig. 1B).

On the other hand, alkenyl ethers are prevalent in bioactive natural products and are often incorporated into potential drug molecules during the drug discovery process, owing to their extensive biological and pharmaceutical properties.[10a] Furthermore, these compounds are frequently utilized in both polymeric and organic synthesis as versatile synthons, highlighting their importance in modern chemistry and industry.[10] Given the unique properties of the CF_3O group, it can be anticipated that alkenyl trifluoromethyl ethers possess significant potential for a wide range of applications (Fig. 2A). However, the exploration of uncharted chemical territories and the subsequent discovery of new functions are often impeded by the lack of synthetic methodology capable of targeting these unique structural motifs.[11] Thanks to the recent advancements in trifluoromethoxylation strategies,[11c–e] the variety of alkenyl trifluoromethyl ethers has been further enriched. Despite being attractive, these reactions require the use of CF_3O-transfer reagents such as trifluoromethyl arylsulfonate (TFMS) and trifluoromethyl nonafluorobutanesulfonate (TFNf) which also need to be prepared from expensive electrophilic CF_3-transfer reagents or gas reagent bis(trifluoromethyl)peroxide (BTMP) which is synthesized from toxic industrial chemicals CO and F_2. Moreover, while the construction of CF_3O-alkenes has seen significant progress, the current synthetic repertoire is largely limited to non-cyclic internal variants. To the best of our knowledge, affording CF_3O-alkenes *via* *O*-trifluoromethylation using easy-handle CF_3-transfer reagent directly remains unknown to date and there is still a lack of general methods to access CF_3O-terminal alkenes and cyclic alkenes (Fig. 2B). Herein, we describe an unprecedented *O*-trifluoromethylation of ketones using chloro(phenyl)trifluoromethyl-λ^3-iodane (CPTFI) and introduce a new strategy to alkenyl trifluoromethyl ethers based on this new reaction (Fig. 2C).

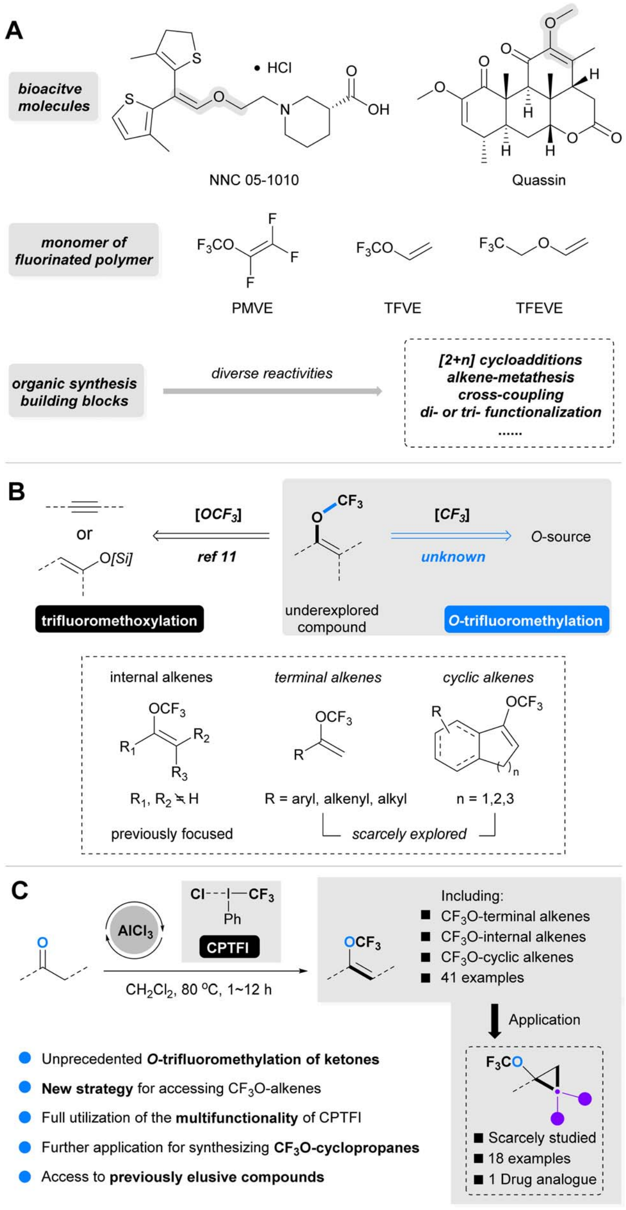


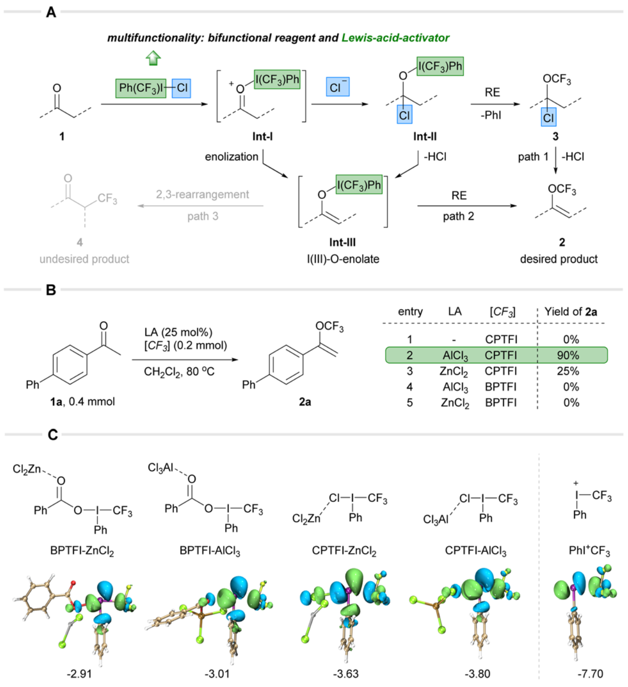
Fig. 2 (A) Importance of the alkenyl (fluoroalkyl) ether motif. (B) Current limited straightforward approaches to alkenyl trifluoromethyl ethers. (C) This work.

Results and discussion

Reaction design and discovery

The CPTFI ($Ph(CF_3)ICl$) developed by our group exhibits a unique CF_3 transfer ability in trifluoromethylation on both carbon and heteroatoms.[6] Using CPTFI, some transformations that are often difficult to realize using other reagents and methods can be achieved.[6f,h] Importantly, it is capable of introducing two important functional groups (CF_3 and Cl) to some substrates simultaneously and has been effectively utilized in the chlorotrifluoromethylation of alkenes.[6d,12] Additionally, as an iodine(III) reagent, CPTFI could also be a potential Lewis acid (LA) activator.[13] Considering the reactivity and multifunctionality of CPTFI mentioned above, we envisioned a CF_3-iodonium-mediated *O*-trifluoromethylation/chlorination of ketones for obtaining α-chlorinated trifluoromethyl ethers **3**, which provides a route to alkenyl trifluoromethyl ethers **2** by further dehydrochlorination (Fig. 3A path 1). In addition, the generation of I(III)-*O*-enolate (**Int-III**)[14] could also be possible *via* either direct enolization of oxonium (**Int-I**) or dehydrochlorination of a Cl-adduct (**Int-II**). Although **Int-III** may also afford desired **2** *via* reductive elimination (RE) (Fig. 3A path 2), there remains a risk of delivering undesired α-CF_3 ketones **4** *via* the 2,3-rearrangement[14] (Fig. 3A path 3). Though the above design for synthesizing **2** is challenging, achieving success would unlock a pathway to tackle the obstacles associated with the *O*-trifluoromethylation of ketones and the constraints encountered in the synthesis of alkenyl trifluoromethyl ethers.

Initially, the reaction of ketone **1a** and CPTFI was attempted in CH_2Cl_2 at 80 °C, but no desired product was observed after 12 h (Fig. 3B, entry 1). We recognized that CPTFI's inherent reactivity might be insufficient for reacting with carbonyl oxygen. In our previous work on the *O*-trifluoromethylation of carboxylic acids, we developed and utilized LA-activated benzoyloxy(phenyl) trifluoromethyl-λ^3-iodane (BPTFI).[6h] Density functional theory (DFT) calculations revealed that the LA-activation can lower the lowest unoccupied molecular orbital (LUMO) energy of such iodine(III) reagents, making their reactivity closer to that of corresponding iodonium ions. In the present work, we turned to study the activation efficiency of LA on CPTFI and compared it with that on BPTFI. As shown in Fig. 3C, the selected LAs exhibit higher activation efficiency for CPTFI than for BPTFI, with $AlCl_3$ proving more effective than $ZnCl_2$. For example, the LUMO energy of the CPTFI–$ZnCl_2$ complex is lowered to −3.63 eV (*vs.* −2.91 eV of BPTFI-$ZnCl_2$), while in the case of the CPTFI–$AlCl_3$ complex, the energy reaches −3.80 eV (*vs.* −3.01 eV of BPTFI-$AlCl_3$) (Fig. 3C). These results suggest that $AlCl_3$-activated CPTFI species are likely more reactive toward *O*-nucleophiles. Then, we investigated the reactivity of these LA-activated iodine(III) species toward ketone **1a**. To our delight, after the multidimensional evaluation of reaction parameters (for details, see the ESI†), we found that the reaction proceeded well in the presence of $AlCl_3$ (25 mol%), CPTFI (0.2 mmol), and **1a** (0.4 mmol, 2 equiv.) at 80 °C for 1 h in CH_2Cl_2, affording desired alkenyl trifluoromethyl ether **2a** in 90% NMR yield (Fig. 3B, entry 2). When $AlCl_3$ was replaced by $ZnCl_2$, the yield of **2a** decreased to 25%, indicating that the LUMO energy of $PhI(CF_3)$-X correlates with the activation efficiency of the corresponding LA toward CPTFI in this reaction (Fig. 3B, entry 3). By comparison, neither $AlCl_3$- nor $ZnCl_2$-activated BPTFI was capable of affording **2a**, demonstrating the necessity of the Cl ligand in these iodine(III) reagents for the transformation of **1a** into **2a** (Fig. 3B, entries 4 and 5).



entry	LA	[CF_3]	Yield of **2a**
1	-	CPTFI	0%
2	$AlCl_3$	CPTFI	90%
3	$ZnCl_2$	CPTFI	25%
4	$AlCl_3$	BPTFI	0%
5	$ZnCl_2$	BPTFI	0%

Fig. 3 (A) Reaction design. (B) Experimental results of the formation of **2a**. (C) DFT calculated LUMO energies (eV) for $PhI(CF_3)$-X.

Reaction scope

With the optimized conditions in hand, we turned to investigate the substrate scope of this reaction. As shown in Fig. 4, acetophenone derivatives featuring electron-donating groups (such as Ph, ^{i}Pr, ^{n}Bu, ^{t}Bu, cyclohexyl, MeO, $ArCH_2O$, PhO, and MeS) on the different positions of the phenyl ring were efficiently *O*-trifluoromethylated as expected, giving a series of alkenyl trifluoromethyl ethers (**2a–i**, **2o**, and **2t**) in 67–90% yields directly under standard conditions. Moreover, we found that the methyl ketone scope could be extended to other electron rich aromatic systems, such as naphthalene (**1v** and **1w**), polycycle (piperic **1x** and tonalide **1y**), benzothiophene (**1z**), and benzofuran (**1aa**), affording the corresponding CF_3O-alkenes (**2v–z** and **2aa**) in satisfactory yields. By comparison, in the cases of those methyl ketones with electron-withdrawing groups (**1j–n**, **1p–s**, and **1u**), the amount of remaining CF_3O-chlorides **3** increased to different extents under standard conditions. Pleasingly, these **3** could transform into **2** in moderate to good yields by increasing the reaction concentration, prolonging the reaction time, or increasing the amount of $AlCl_3$. In addition, the reaction was also applicable to α-branched acetophenone **1ab**, successfully affording an *E*/*Z* mixture of trisubstituted CF_3O-alkenes **2ab** in 69% yield. To our delight, the ketone scope was not limited to aromatic substrates and could be expanded to aliphatic ketones as well. Dialkyl ketone that possesses enolizable protons only on one side (**1ac**) was proved to be suitable for *O*-trifluoromethylation, providing desired CF_3O-alkenes **2ac** in 76% yield. As for the asymmetric linear aliphatic ketone such as 4-

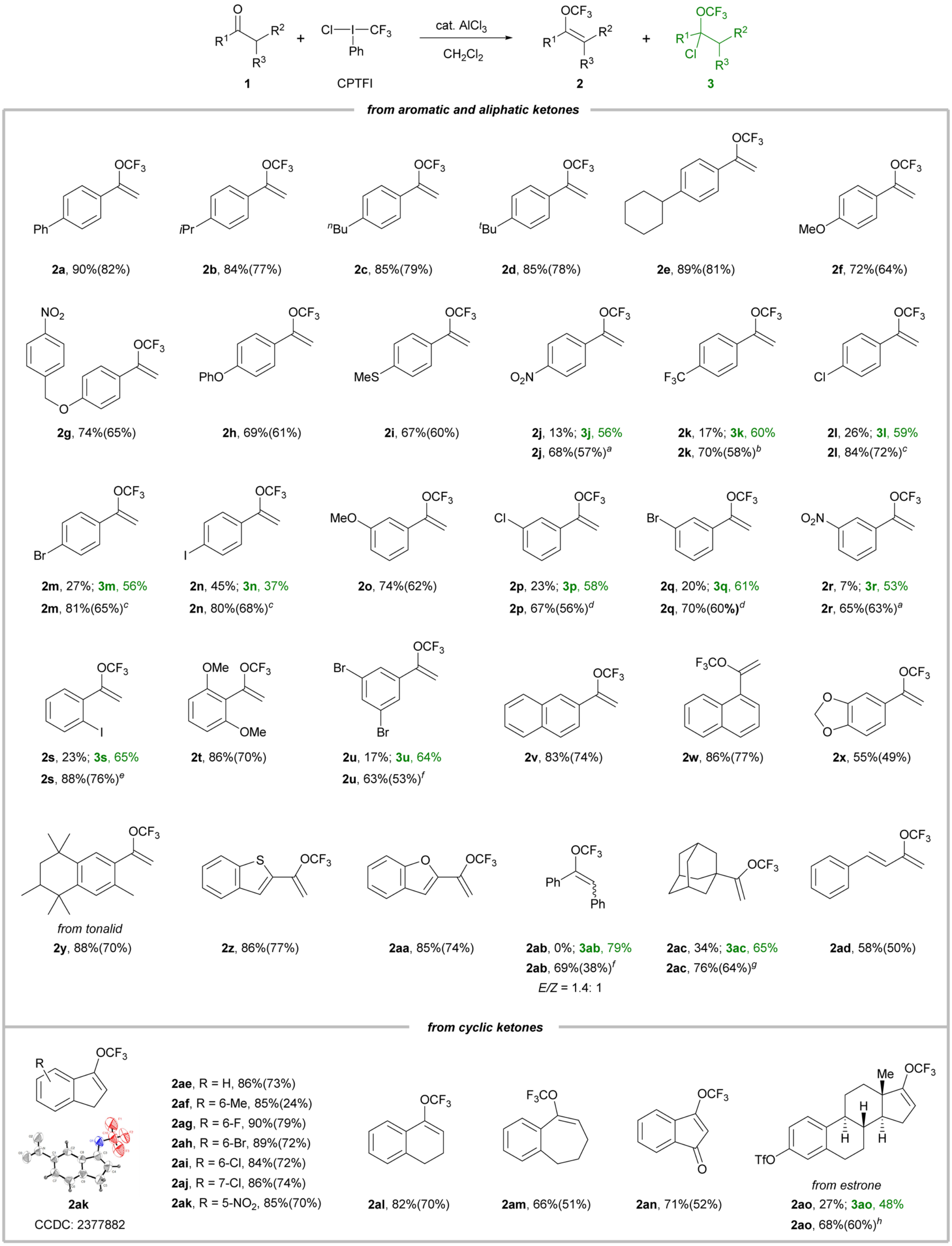


Fig. 4 Scope of ketones. Unless otherwise noted, the standard conditions were as follows: **1** (2 equiv.), CPTFI (0.2 mmol, 1 equiv.), $AlCl_3$ (25 mol%), CH_2Cl_2 (0.5 mL), 80 °C, 1 h. ^{19}F NMR yield using α,α,α-trifluorotoluene ($PhCF_3$) as an internal standard. ^{19}F NMR yields of **3** are in green. Isolated yields are given in parentheses. [a] $AlCl_3$ (50 mol%), CH_2Cl_2 (0.1 mL), 10 h. [b] CH_2Cl_2 (0.1 mL), 2 h. [c] CH_2Cl_2 (0.3 mL), 1.5 h. [d] CH_2Cl_2 (0.1 mL). [e] CH_2Cl_2 (0.3 mL), 2 h. [f] CH_2Cl_2 (0.1 mL), 10 h. [g] CH_2Cl_2 (0.1 mL), 5 h. [h] CH_2Cl_2 (1 mL), 1 h, then adding KOH (20 equiv.), MeOH (3 mL), 50 °C, 10 h.

phenyl-2-butanone **1ap,** although the *O*-trifluoromethylation chlorination proceeded well, the corresponding chloride **3ap** showed poor elimination reactivity and selectivity to afford an inseparable mixture of CF_3O-chloride and CF_3O-alkene isomers due to the similar reactivity of α-H in different sides. Symmetric linear aliphatic ketones such as myristic ketone could avoid the elimination selectivity issue and smoothly afforded an *E*/*Z* mixture of linear trisubstituted CF_3O-alkenes **2aq** in 88% NMR yield (for details see the ESI†). When conjugated methyl ketone was subjected to the reaction, 2-(OCF_3)-1,3-dienes **2ad** was obtained as the sole product in moderate yield. Notably, cyclic alkenyl trifluoromethyl ether, which is extremely rare (only one example in low yield),[11e] can now be readily synthesized from the corresponding cyclic ketone by our method. The reaction proceeded smoothly with 1-indanone bearing EDGs and EWGs, α-tetralone, 1-benzosuberone, 1,3-indandione, and estrone, affording products (**2ae–an**) in moderate to good yields. An exception was the estrone derivative **1ao**, which required additional base to promote the elimination of **3ao** to afford **2ao** in 60% isolated yield. The structure of product **2ak** was determined by single-crystal X-ray diffraction analysis.[15]

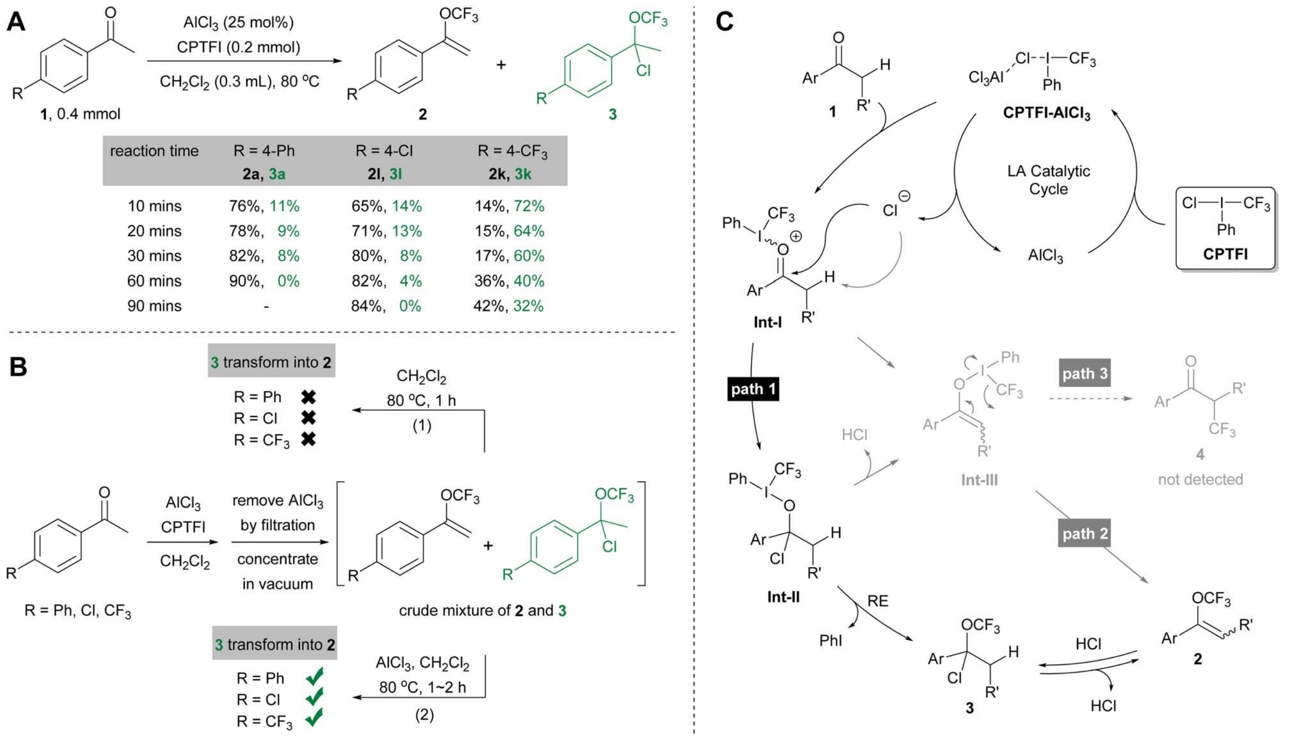
Mechanistic investigation

As mentioned above, two CF_3O-products were obtained in such unique *O*-trifluoromethylation of ketones, including alkenes **2** and chlorides **3**. α-*C*-Trifluoromethylated products **4** have never been detected in this reaction. To understand the mechanism, several control experiments were conducted. We chose three ketones that had different electronic properties as representative reactants and monitored their reaction process. As shown in Fig. 5A, the more electron-deficient the acetophenone derivatives are, the more chlorides **3** are detected in the reaction. This is likely due to the electron deficiency of chlorides **3**, which renders the subsequent E1 elimination difficult. Furthermore, a consistent tendency emerges throughout the reaction: as the amount of **2** increases, the amount of **3** correspondingly diminishes. These results indicate that **3** is likely the precursor of **2**. To further verify whether **2** is derived from **3**, we attempted to isolate **3** from the reaction mixture to test the conversion of **3** to **2** in an independent reaction. However, **3** was too sensitive to silica gel column chromatography to be isolated. Therefore, we decided to quickly filter out $AlCl_3$ after obtaining a certain proportion of the mixture of **2** and **3** and to continue stirring the mixture at 80 °C. At this time, we could not detect the conversion of **3** to **2** (Fig. 5B-(1)). By re-adding $AlCl_3$, an obvious transformation of **3** into **2** was detected again, demonstrating the promotional effect of $AlCl_3$ (Fig. 5B-(2)).

Based on the above preliminary results and our previous work,[6h] a plausible reaction mechanism is proposed in Fig. 5C. Initially, **CPTFI** is activated using $AlCl_3$ to form a more reactive **CPTFI–AlCl₃** complex. This Lewis-acidity-enhanced species then undergoes nucleophilic attack by the carbonyl oxygen of ketone to form oxonium **Int-I**. Subsequently, the nucleophilic addition of the Cl anion to the carbonyl groups of **Int-I** affords **Int-II**. Then α-chlorinated trifluoromethyl ether **3** is formed *via* RE of **Int-II**, followed by $AlCl_3$-promoted dehydrochlorination to furnish desired alkenyl trifluoromethyl ether **2** (Fig. 5C path 1). Notably, although the generation of I(III)-*O*-enolate (**Int-III**) is possible as we mentioned, all the reactions exhibit excellent regioselectivity of trifluoromethylation because no undesired α-CF_3 products **4** were detected (Fig. 5C path 3). Thus, we prefer path 1 over path 2 (the direct RE of I(III)-*O*-enolate (**Int-III**)) for generating alkenyl trifluoromethyl ether **2**.

Further application

To demonstrate the potential of alkenyl trifluoromethyl ethers **2** as valuable CF_3O-containing building blocks, the white solid



reaction time	R = 4-Ph **2a**, **3a**	R = 4-Cl **2l**, **3l**	R = 4-CF$_3$ **2k**, **3k**
10 mins	76%, 11%	65%, 14%	14%, 72%
20 mins	78%, 9%	71%, 13%	15%, 64%
30 mins	82%, 8%	80%, 8%	17%, 60%
60 mins	90%, 0%	82%, 4%	36%, 40%
90 mins	-	84%, 0%	42%, 32%

Fig. 5 (A) Monitoring the reaction process. (B) Study on the conversion of crude isolated **3** to **2** w/o $AlCl_3$. (C) Proposed mechanism.

product **2a** was synthesized on a 10 mmol scale under the standard reaction conditions in 72% isolated yield (Fig. 6A) and subjected to further transformations (Fig. 6B). Cyclopropanes, ranking as the sixth most prevalent ring structures in medicinal compounds, are only outpaced by cyclohexanes among alicyclic compounds.[16a] These compact carbocycles offer rigid frameworks that can bolster the binding affinity to biological targets by reducing conformational flexibility and enhancing the three-dimensional orientation compared to other alkyl or aryl groups.[16b,c] Additionally, the intrinsic ring strain in cyclopropanes results in robust core C–C and peripheral C–H bonds, which protect drug molecules from oxidative metabolism and make them suitable as bioisosteres for a variety of alkyl, aryl, and vinyl substitutions.[16d,e] Among various functionalized cyclopropanes, fluorine-containing ($-CF_3$, $-CF_2H$, and –F) variants have served as important structural motifs in many biologically active molecules, such as voxilaprevir,[17a] petesicatib[17b] and NLRP3 inhibitors.[17c] However, cyclopropyl trifluoromethyl ethers are almost unknown and there is no method that allows their broader synthesis; thus, their corresponding application remains largely unexplored. To our knowledge, there is only one example in the literature: perfluorocyclopropyl trifluoromethyl ether (b.p. −4 to −2 °C), which was synthesized from cyclopropanation of perfluoromethyl vinyl ether (PMVE) with hexafluoropropylene oxide (HFPO, a difluorocarbene precursor) under harsh conditions.[18] Therefore, it is of great value to develop a practical method for the synthesis of CF_3O-cyclopropanes.

Considering the most direct and general method for cyclopropane synthesis that involves a [2 + 1] cycloaddition of an alkene and a carbene, we first chose tosylhydrazone as the α-aryl carbene source to perform the cyclopropanation of CF_3O-alkene **2**. To our delight, after optimizing the reaction conditions, we found that the reaction proceeded well in the presence of **2** (0.1 mmol), tosylhydrazone (2 eq.), K_2CO_3 (3 eq.), FeTPPCl (3 mol%) and N_2 at 80 °C for 2 h in toluene (1 mL), affording desired

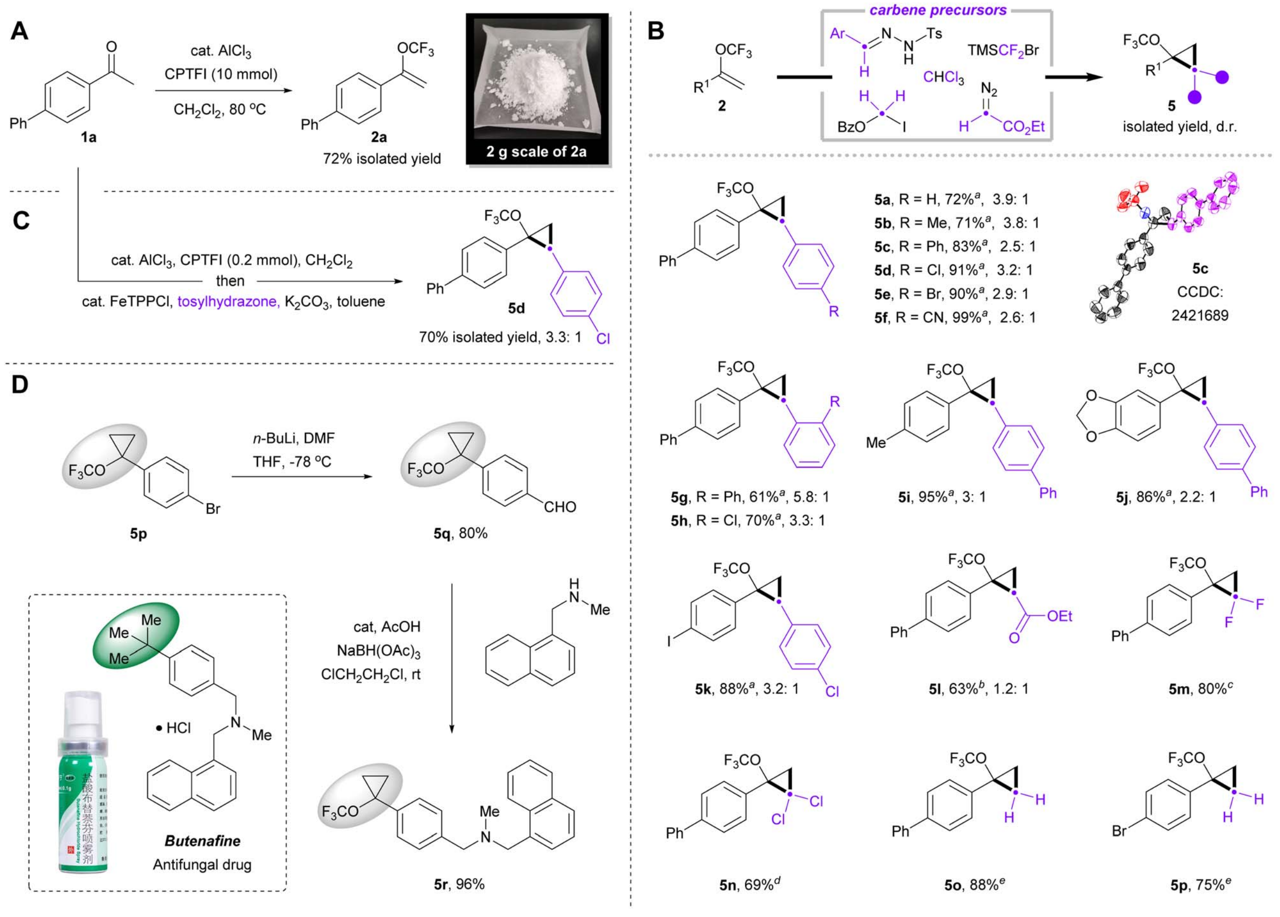


Fig. 6 (A) 10 mmol scale synthesis of **2a**. Conditions: **1a** (2 eq.), CPTFI (10 mmol, 1 eq.), $AlCl_3$ (25 mol%), CH_2Cl_2 (25 mL), 80 °C, 1 h. (B) Synthesis of CF_3O-cyclopropanes using alkenyl trifluoromethyl ethers as CF_3O-building blocks with various carbene precursors. Conditions: [a]**2a** (0.1 mmol), tosylhydrazone (2 eq.), K_2CO_3 (3 eq.), FeTPPCl (3 mol%), toluene (1 mL), 80 °C, N_2, 2 h. [b]**2a** (0.1 mmol, 1 eq.), ethyl diazoacetate (3 eq.), fac-Ir(dFppy)$_3$ (2 mol%), MeCN (1 mL), 18w blue LEDs, rt, N_2, 48 h. [c]**2a** (0.1 mmol, 1 eq.), $TMSCF_2Br$ (3 eq.), TBAB (6 mol%), toluene (1 mL), 110 °C, 4 h. [d]**2a** (0.1 mmol, 1 eq.), KO^tBu (12 eq.), $CHCl_3$ (12 eq.), CH_2Cl_2 (0.5 mL), −45 to 110 °C, 1 h. Diastereomeric ratio (d.r.) determined by ^{19}F NMR. [e]**2a** (0.1 mmol), $BzOCH_2I$ (3 eq.), Zn (3 eq.), FeTPPCl (3 mol%), THF (1 mL), 60 °C, N_2, 4 h. (C) One-pot synthesis of CF_3O-cyclopropane from ketone. Conditions: CPTFI (0.2 mmol, 1 eq.), **1a** (2 eq.), $AlCl_3$ (25 mol%), CH_2Cl_2 (0.5 mL), 80 °C, 1 h, then tosylhydrazone (2 eq.), K_2CO_3 (3 eq.), FeTPPCl (3 mol%), toluene (1 mL), 80 °C, N_2, 2 h. (D) Application in the synthesis of drug analogues.

CF_3O-cyclopropane **5a–k** in 61–99% isolated yields. It was found that the sterically more hindered 2-phenyl tosylhydrazone is less reactive than 4-phenyl (**5g**, 61%; **5c**, 83%). The structure of the major diastereoisomer of product **5c** was determined by a single-crystal X-ray diffraction analysis.[19] The obtained data show that the bond length *d* between C1 and C2 (1.524 Å) was longer than that of the other two C–C bonds in the cyclopropane ring (*d*(C2–C3) 1.495 Å and *d*(C1–C3) 1.492 Å, see ESI, Fig. S9†). It is worth noting that other carbene sources such as ethyl diazoacetate (ester carbene), $TMSCF_2Br$ (difluorocarbene), chloroform (dichlorocarbene) and $BzOCH_2I$ (methyl carbene)[20] were also tolerated in the cyclopropanation reaction of **2a** under corresponding reaction conditions, affording **5l–p** in 63–88% isolated yields (Fig. 6B). As shown in Fig. 6C, the one-pot cyclopropanation from ketone **1a** can be completed successively without preisolation of **2a**, and cyclopropyl trifluoromethyl ether **5d** has been isolated in 70% yields.

To verify the potential application value of these motifs, preliminary studies on these compounds were conducted. We evaluated the chemical stability of two representative trifluoromethoxy cyclopropanes, **5c** and **5o**, because we suspected that some of them could undergo ring-opening. Their treatment with HCl, NaOH, Et_3N, PIDA, H_2O_2, oxone, and $NaBO_3 \cdot 4H_2O$, respectively, at room temperature for 24 h did not lead to any decomposition (for details see the ESI†). Furthermore, compared with cyclopropanol tosylate (which is suspected to have similar behavior)[21] and CF_3-cyclopropane (a metabolically stable bioisostere of the *tert*-butyl group),[22] CF_3O-cyclopropane exhibits good chemical stability and reaction compatibility according to the preliminary test results shown in the ESI (Fig. S13 and S14†). To further demonstrate the potential value of our method in medicinal chemistry, we synthesized a CF_3O-cyclopropane-containing analogue of the antifungal drug *Butenafine* (Fig. 6D).[23] The successful synthesis of this compound (**5r**) provides strong support for medicinal chemists to study the effects of a *tert*-butyl-to-CF_3O-cyclopropane replacement on physicochemical properties and biological activities.

Conclusions

In summary, *O*-trifluoromethylation of ketones has long been an unresolved problem in organic chemistry. Additionally, a robust method for synthesizing alkenyl trifluoromethyl ethers is critically needed, yet remains largely underdeveloped. Our approach not only unlocks the first selective *O*-trifluoromethylation of ketones but also provides an alternative synthetic route to potentially valuable alkenyl trifluoromethyl ethers. The key to this unique trifluoromethylation reaction lies in our full utilization of the multifunctionality of CPTFI: (1) its strong Lewis acid activation ability, which enables the attack of weak nucleophiles such as Cl anions on the carbonyl group; (2) its bifunctionality, which allows for the introduction of CF_3 and Cl into the carbonyl group in one step, thus enabling the obtainment of alkenyl trifluoromethyl ethers by further removal of HCl. Additionally, the use of an $AlCl_3$ catalyst in the reaction serves not only to activate CPTFI but also to promote the elimination of HCl from the resulting chlorine adduct. Further application of product **2** in synthesizing previously almost unknown CF_3O-cyclopropanes with diverse carbene precursors demonstrates that alkenyl trifluoromethyl ethers have significant potential as CF_3O-containing building blocks in seeking the next innovative materials, pharmaceuticals, or agrochemicals.

Data availability

The data supporting this article have been included as part of the ESI.† Details about materials and methods, experimental procedures, reaction optimization data, crystallographic data, DFT calculation data, characterization data and NMR spectra are included.

Author contributions

C. X. and M. W. directed the projects and wrote the manuscript. C. G., Y. L., and C.-S. L. conducted the synthetic experiments. H. G. and S.-H. Wang helped synthesize some substrates and repeated the reactions. All authors have given approval to the final version of the manuscript.

Conflicts of interest

There are no conflicts to declare.

Acknowledgements

We gratefully acknowledge the Natural Science Foundation of Jilin Province (No. 20230101031JC and 20240101186JC) and the National Natural Science Foundation of China (No. 22471033 and 22471032) for financial support.

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