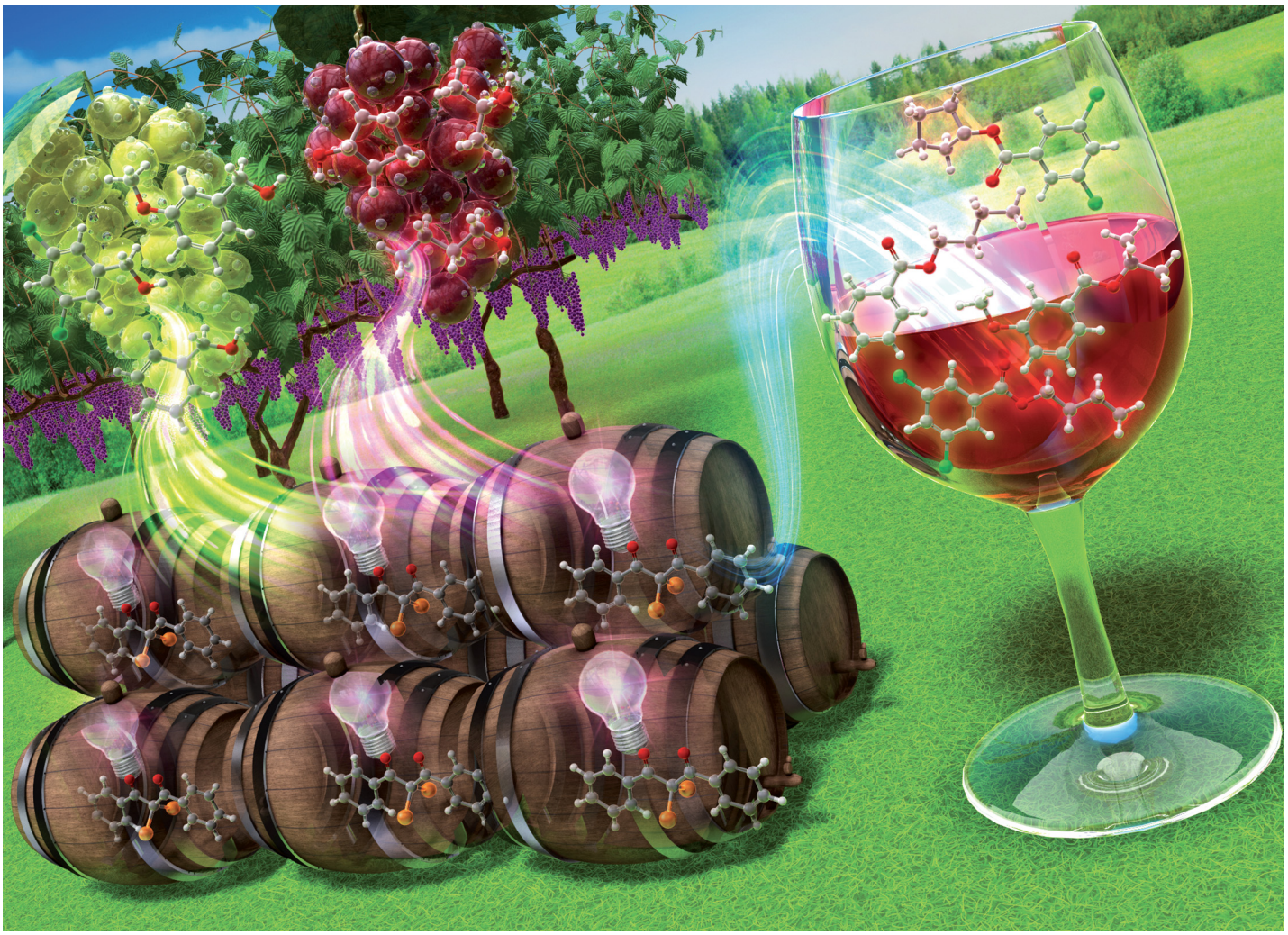

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The direct photochemical cross-esterification of alcohols *via* site-selective C–H bromination

The direct photochemical cross-esterification of alcohols proceeds *via* the *in situ* generation of acyl bromides. The C–H bond of a benzyl alcohol is selectively activated by a bromo source under light irradiation, enabling the cross-esterification to afford the functionalized esters.

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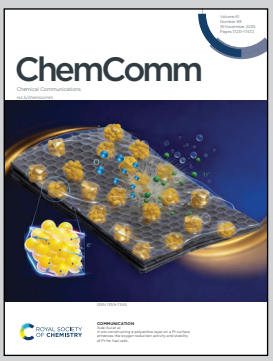

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The direct photochemical cross-esterification of alcohols *via* site-selective C–H bromination

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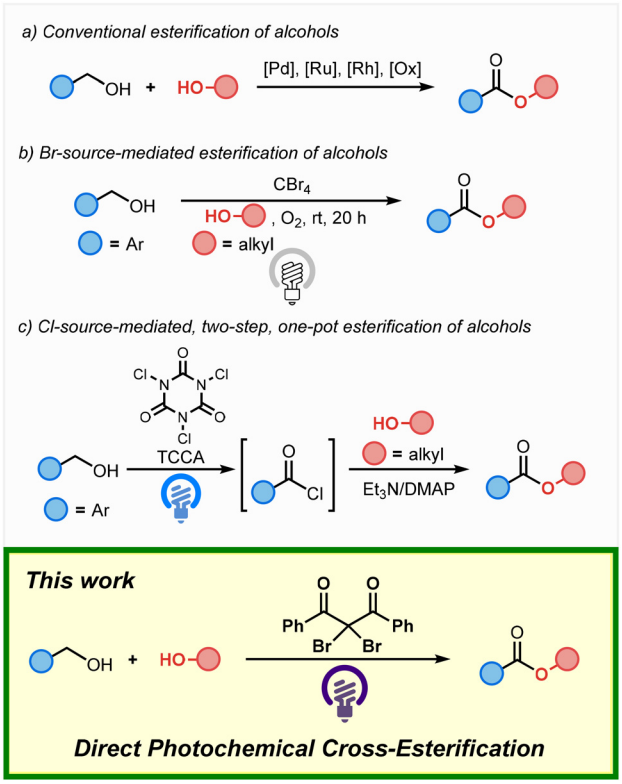
We have developed a direct photochemical cross-esterification of alcohols that proceeds *via* the *in situ* generation of acyl bromides. The C–H bond of a benzyl alcohol is selectively activated by a bromo source under light irradiation, enabling the cross-esterification to afford a variety of functionalized esters.

Esters represent an important structural motif found in a wide variety of bioactive compounds and functional materials. While conventional esterification reactions typically use carboxylic acids or aldehydes as substrates,[1] the direct oxidative esterification of alcohols has been developed as an alternative method. The esterification of alcohols typically employs transition-metal catalysts or stoichiometric oxidants (Scheme 1(a)).[2] Meanwhile, photochemical transformations have gained significant attention in recent years due to their potential in sustainable energy-conversion systems, and several methods for the photochemical esterification of alcohols have been developed. In 2012, Itoh and co-workers have reported the cross-esterification of benzyl alcohol with aliphatic alcohols such as methanol as the solvent in the presence of CBr_4 under an oxygen atmosphere and irradiation from a household lamp (Scheme 1(b)).[3] More recently, in 2024, the one-pot, two-step esterification of benzyl alcohol with alcohols using trichloroisocyanuric acid (TCCA), a stoichiometric amount of triethylamine, and a catalytic amount of 4-dimethylaminopyridine (DMAP) under blue-light irradiation has been reported (Scheme 1(c)).[4,5] While these reactions represent useful methods that use alcohols as substrates, there are still only a few examples of the photochemical esterification of alcohols. Therefore, the development of more efficient approaches to photochemical esterification reactions remains highly desirable.

Recently, we have developed the photochemical esterification of aldehydes with alcohols *via* C–H bromination.[6] Given that bromo sources such as bromotrichloromethane ($BrCCl_3$) effectively activate the C–H bonds of aldehydes, we hypothesized that they could also potentially activate the C–H bonds of benzyl alcohols, thus enabling the application of bromo sources in cross-esterification reactions. Here, we report the direct photochemical cross-esterification of alcohols *via* site-selective C–H bromination (Scheme 1; This work).



Scheme 1 Examples of photochemical cross-esterification reactions of alcohols.

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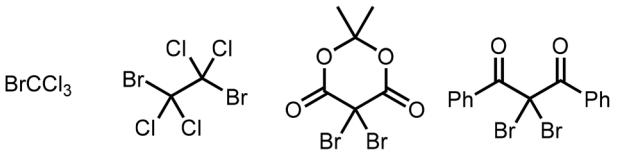
Table 1 Photochemical esterification of alcohols[a]

1a 2a 3a

Entry	Br source	Light source (nm)	Solvent	Yield (%)
1	**(i)**	380	CH_3CN	23
2	**(i)**	380	Hexane	30
3	**(i)**	380	Toluene	52
4	**(i)**	380	DCE	60
5	**(i)**	380	CH_2Cl_2	68
6	**(ii)**	380	CH_2Cl_2	77
7	**(iii)**	380	CH_2Cl_2	78
8	**(iv)**	380	CH_2Cl_2	86
9	**(iv)**	405	CH_2Cl_2	73
10	**(iv)**	365	CH_2Cl_2	95
11[b]	**(iv)**	365	CH_2Cl_2	94
12[bc]	**(iv)**	365	CH_2Cl_2	68
13[bd]	**(iv)**	365	CH_2Cl_2	72
14[b]	**(iv)**	—	CH_2Cl_2	0
15[b]	—	365	CH_2Cl_2	0



(i) (ii) (iii) (iv)

[a] All reactions were carried out with **1a** (0.4 mmol), **2a** (1.2 mmol), a Br source (6.0 equiv.) in the specified solvent (4.0 mL) at room temperature for 24 h under LED irradiation. [b] 0.8 mmol of ^{n}BuOH were used. [c] 3.0 equiv. of the Br source were used. [d] Without MS3Å.

We initially investigated the optimization of the reaction conditions for the photochemical esterification of benzyl alcohol (**1a**) with 1-butanol (**2a**) in the presence of $BrCCl_3$ (**i**) (Table 1). The reaction proceeded in common solvents such as CH_3CN, hexane, and toluene, giving the desired product (**3a**) in low to moderate yield (entries 1–3). Furthermore, halogenated solvents such as 1,2-dichloroethane (DCE) and CH_2Cl_2 increased the product yield (entries 4 and 5). The esterification proceeded smoothly with various Br sources, including 1,2-dibromo-1,1,2,2-tetrachloroethane (**ii**), 2,2-dibromo-1,3-diphenyl-1,3-propanedione (**iii**), and 2,2-dibromo-1,3-diphenyl-1,3-propane-dione (**iv**) (entries 6–8). Although a lower-energy light source (λ_{ex} = 405 nm) did not improve the yield of the product, a higher-energy light source (λ_{ex} = 365 nm) significantly increased the product yield (95%, entries 9 and 10). The molar absorption coefficients of Br source (**iv**) were determined to be 2.655 × 10^2 M^{-1} cm^{-1} at 405 nm and 4.783 × 10^2 M^{-1} cm^{-1} at 365 nm shown in SI. These results suggest that irradiation at 365 nm excites the Br source more efficiently, promoting cleavage of the C–Br bond and thereby improving the product yield. Reducing the amount of **2a** (2.0 equiv.) also afforded the product in high yield (entry 11). Reducing the amount of Br source (**iv**) (3.0 equiv.) afforded the product in a moderate yield (entry 12). When the reaction was carried out without MS3Å, the product yield decreased to 72% (entry 13). The control experiments, wherein the Br source (**iv**) or the light source were omitted, did not proceed, and it can therefore be concluded that these two factors effectively promote the reaction (entries 14 and 15). These results also show that the reaction affords the corresponding ester without the requirement for any additives such as bases, and bypasses the need for a sequential one-pot, two-step protocol.[4]

With the optimal conditions in hand, we next investigated the scope of the alcohols suitable for this reaction (Table 2). Benzyl alcohols with a variety of halogen substituents afforded the corresponding products in high yield (**3b–3j**). Under the applied reaction conditions, π-conjugated functionalities were also well tolerated (**3k–3m**). Aromatic alcohols substituted with either electron-donating or withdrawing groups also provided the corresponding products efficiently (**3n–3p**). Heteroaromatic substrate could be applied to the reaction (**3q**). The combination of aliphatic alcohols was not suitable for the reaction (**3r**). Notably, the method was applicable for the esterification of multiples sites in the same molecule, affording multi-substituted esters, which are found in various functional materials (**3s–3u**).[7] As multi-substituted esters are typically prepared *via* the Fischer esterification,[8] the present mild method starting from alcohols offers a valuable alternative for the efficient synthesis of these functional materials. Aliphatic alcohols yielded the desired esters in moderate to high yield, not only for primary alcohols but also in more sterically congested secondary alcohols and cyclic alcohols (**3a** and **3v–3ac**). Owing to the greater steric hindrance of secondary alcohols compared with primary alcohols, extending the reaction time led to a significant increase in product yields (**3z**, **3aa**, **3ac**). In contrast, the combination of benzyl alcohols was not suitable for the reaction (**3ad**).

To examine the reaction mechanism, a radical scavenger was employed (Scheme 2(1)). When the reaction was carried out in the presence of TEMPO, product formation was not observed. In addition, an acyl radical was trapped by TEMPO and detected as **4a** using mass spectrometry, suggesting that the reaction may proceed *via* a radical pathway. Additionally, when the reaction was conducted in the absence of **2a**, the formation of acyl bromide **5** was confirmed by ^{1}H and ^{13}C NMR spectroscopy (Scheme 2(2)). Therefore, the reaction should involve the generation of an acyl bromide intermediate *via* C–H bromination. When the reaction was carried out using the aldehyde instead of benzyl alcohol, the desired ester **3j** was obtained in 82% yield, suggesting that the reaction would proceed through the aldehyde as an intermediate (Scheme 2(3)).

A feasible reaction mechanism is proposed in Scheme 3. Homolytic cleavage of the Br source (**iv**) under light irradiation (λ_{ex} = 365 nm) generates an organic radical (**A**) and a bromo radical (**B**).[9] Radical **A** can induce the dissociation of the C–H bond of benzyl alcohol (**1a**) to form a benzyl radical (**C**), which then reacts with another equivalent of the Br source (**iv**) to produce an α-bromo benzyl alcohol (**D**).[10,11] The elimination of HBr from **D** produces benzaldehyde (**E**). Radical **A** dissociates the C–H bond of **E** to form an acyl radical (**F**), which then reacts with the Br source (**iv**) to form acyl bromide **4**.[11,12] Finally, 1-butanol (**2a**) reacts with **4** to furnish the desired ester (**3a**).

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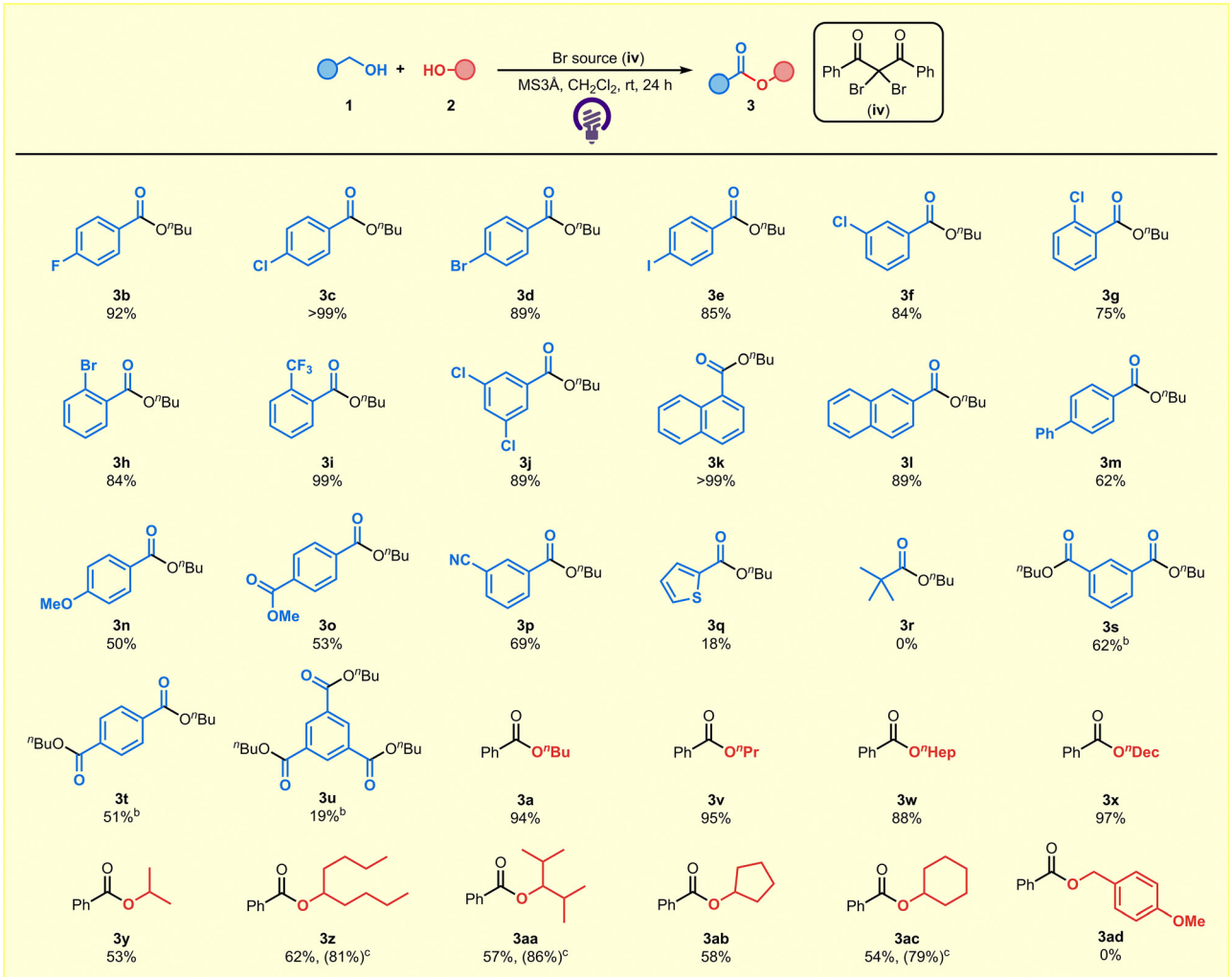
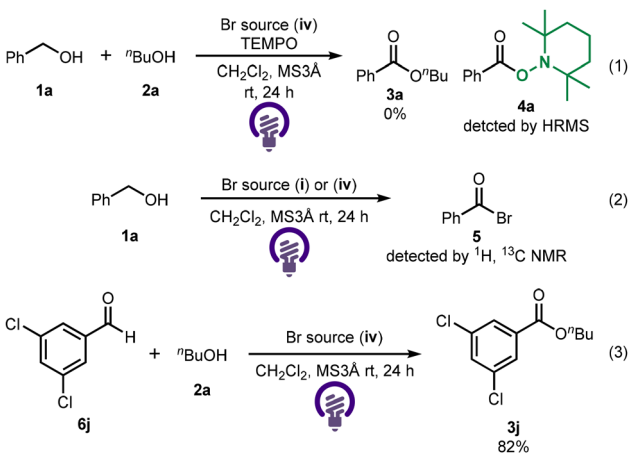
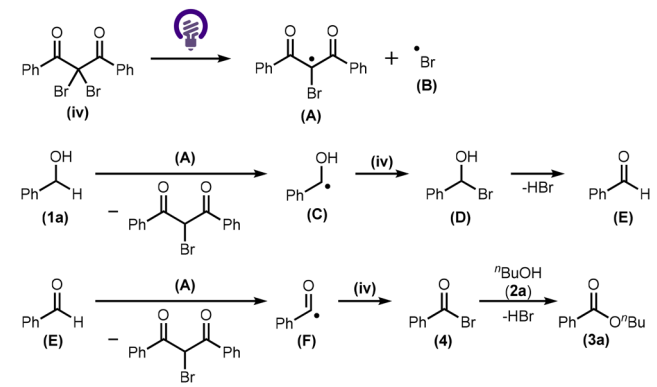
Table 2 Scope of the alcohols suitable for this photochemical esterification[a]



[a] All reactions were carried out using **1** (0.4 mmol), **2** (0.8 mmol), a Br source (**iv**) (2.4 mmol), and MS3Å (100 mg) in CH_2Cl_2 (4.0 mL) at room temperature under an argon atmosphere and LED irradiation (λ_{ex} = 365 nm, 18 W) for 24 h. [b] The reaction was carried out using **1** (0.4 mmol), **2** (1.6 mmol), a Br source (**iv**) (2.4 mmol), and MS3Å (100 mg) in CH_2Cl_2 (4.0 mL) at room temperature under an argon atmosphere and LED irradiation (λ_{ex} = 365 nm, 18 W) for 72 h. [c] The reaction was carried out using **1** (0.4 mmol), **2** (0.8 mmol), a Br source (**iv**) (2.4 mmol), and MS3Å (100 mg) in CH_2Cl_2 (4.0 mL) at room temperature under an argon atmosphere and LED irradiation (λ_{ex} = 365 nm, 18 W) for 48 h.



Scheme 2 Mechanistic aspects of the photochemical cross-esterification of alcohols.



Scheme 3 Proposed reaction mechanism.

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In summary, we have developed a method for the direct photochemical esterification of alcohols. The reaction affords the corresponding esters without the requirement for any additives such as bases, and bypasses the need for a sequential one-pot, two-step protocol. Various benzyl alcohols bearing electron-donating or electron-withdrawing substituents, as well as π-conjugated functionalities, were well tolerated in the reaction. Notably, this method is applicable to the synthesis of multi-substituted esters, which are commonly found in functional materials and are typically prepared *via* the Fischer esterification, which often proceeds under much harsher reaction conditions. The present reaction enables the synthesis of a wide range of functionalized esters from alcohols, making it a valuable tool for producing bioactive compounds and functional materials.

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Conflicts of interest

There are no conflicts to declare.

Data availability

The data supporting this article have been included as part of the supplementary information (SI). Supplementary information is available. See DOI: **https://doi.org/10.1039/d5cc03371c**.

Notes and references

1 (*a*) J. Oreta and J. Nishikido, *Esterification: Methods, Reactions, and Applications*, Wiley-VCH, Weinheim, 2nd edn, 2010; (*b*) S. Tang, J. Yuan, C. Liu and A. Lei, *Dalton Trans.*, 2014, **43**, 13460–13470; (*c*) S. Gaspa, A. Porcheddu and L. De Luca, *Tetrahedron Lett.*, 2016, **57**, 3433–3440; (*d*) K. Ekoue-Kovi and C. Wolf, *Chem. Eur. J.*, 2008, **14**, 6302–6315; (*e*) L. Ding, P. Su, Y. Shi, H. Huang, L. Zhu, H. Zhang and B. Wang, *Ind. Eng. Chem. Res.*, 2024, **63**, 18667–18698; (*f*) J. Li, D. Zhu, D. J. Young, Y. Wang and H. Li, *Eur J Org Chem*, 2025, **28**, e202401398.

2 (*a*) C. Liu, J. Wang, L. Meng, Y. Deng, Y. Li and A. Lei, *Angew. Chem., Int. Ed.*, 2011, **50**, 5144–5148; (*b*) D. Srimani, E. Balaraman, B. Gnanaprakasam, Y. Ben-David and D. Milstein, *Adv. Synth. Catal.*, 2012, **354**, 2403–2406; (*c*) J. Cheng, M. Zhu, C. Wang, J. Li, X. Jiang, Y. Wei, W. Tang, D. Xue and J. Xiao, *Chem. Sci.*, 2016, **7**, 4428–4434; (*d*) Y. Yu, J. Lin, A. Qin, H. Wang, J. Wang, W. Wang, G. Wu, Q. Zhang, H. Qian and S. Ma, *Org. Lett.*, 2024, **26**, 3469–3474; (*e*) R. Ray, R. D. Jana, M. Bhadra, D. Maiti and G. K. Lahiri, *Chem. Eur. J.*, 2014, **20**, 15618–15624; (*f*) S. Samanta, V. Pappula, M. Dinda and S. Adimurthy, *Org. Biomol. Chem.*, 2014, **12**, 9453–9456; (*g*) S. Gaspa, A. Porcheddu and L. De Luca, *Adv. Synth. Catal.*, 2016, **358**, 154–158.

3 T. Nobuta, A. Fujiya, S. Hirashima, N. Tada, T. Miura and A. Itoh, *Tetrahedron Lett.*, 2012, **53**, 5306–5308.

4 A. Dellisanti, E. Chessa, A. Porcheddu, M. Carraro, L. Pisano, L. De Luca and S. Gaspa, *Molecules*, 2024, **29**, 570.

5 H. Yi, X. Hu, C. Bian and A. Lei, *ChemSusChem*, 2017, **10**, 79–82.

6 Our recent reports see; (*a*) H. Ando, S. Kodaki, H. Takamura, I. Kadota and K. Tanaka, *Org. Biomol. Chem.*, 2024, **22**, 9032–9035; (*b*) H. Ando, H. Takamura, I. Kadota and K. Tanaka, *Chem. Commun.*, 2024, **60**, 4765–4768; (*c*) S. Nohara, S. Iwai, N. Yamaguchi, Y. Asada, Y. Kamiyama, Y. Tanaka, K. Tanaka and Y. Hoshino, *Synlett*, 2023, 2525–2529; (*d*) K. Tanaka, M. Kishimoto, Y. Tanaka, Y. Kamiyama, Y. Asada, M. Sukekawa, N. Ohtsuka, T. Suzuki, N. Momiyama, K. Honda and Y. Hoshino, *J. Org. Chem.*, 2022, **87**, 3319–3328; (*e*) M. R. El-kholany, T. Senoo, A. Mizutani, H. Takamura, T. Suzuki, I. Kadota and K. Tanaka, *Org. Lett.*, 2025, **27**, 4870–4874.

7 (*a*) M. Leloire, C. Walshe, P. Devaux, R. Giovine, S. Duval, T. Bousquet, S. Chibani, J. Paul, A. Moissette, H. Vezin, P. Nerisson, L. Cantrel, C. Volkringer and T. Loiseau, *Chem. Eur. J.*, 2022, **28**, e202104437; (*b*) S. Zhao, J. Zhang, X. Wang, L. Wang, J. Wang and C. Pang, *ACS Appl. Polym. Mater.*, 2023, **5**, 2408–2416; (*c*) O. Plietzsch, A. Schade, A. Hafner, J. Huuskonen, K. Rissanen, M. Nieger, T. Muller and S. Bräse, *Eur J Org Chem*, 2013, **2013**, 283–299.

8 (*a*) S. Huo, X. Deng, N. Yang, M. Qin, X. Zhang, X. Yao, C. An, P. Zhou and X. Lu, *Chem. Eng. J.*, 2024, **481**, 148562; (*b*) B. H. Wilson, H. S. Scott, O. T. Qazvini, S. G. Telfer, C. Mathonière, R. Clérac and P. E. Kruger, *Chem. Commun.*, 2018, **54**, 13391–13394; (*c*) D. De, V. Sharma, B. C. Sahu, R. K. Sahu and T. Maharana, *Polyhedron*, 2023, **230**, 116240; (*d*) G. R. M. O'Donohue, S. Chow, S. D. Houston, T. T. L. Nguyen, G. Paul Savage, H. E. Smyth and C. M. Williams, *Chem. Eur. J.*, 2025, **31**, e202404716.

9 (*a*) P. Bosch, F. Del Monte, J. L. Mateo and R. S. Davidson, *J. Photochem. Photobiol., A*, 1993, **73**, 197–204; (*b*) I. Saito, T. Sakurai, T. Kurimoto and M. Takayama, *Tetrahedron Lett.*, 1994, **35**, 4797–4800; (*c*) Y.-B. Wang, F. Chen, M. Li, Q. Bu, Z. Du, J. Liu, B. Dai and N. Liu, *Green Chem.*, 2023, **25**, 1191–1200; (*d*) X. Li, J. Fan, D. Cui, H. Yan, S. Shan, Y. Lu, X. Cheng and T. Loh, *Eur. J. Org. Chem.*, 2022, e202200340.

10 C. S. Colley, D. C. Grills, N. A. Besley, S. Jockusch, P. Matousek, A. W. Parker, M. Towrie, N. J. Turro, P. M. W. Gill and M. W. George, *J. Am. Chem. Soc.*, 2002, **124**, 14952–14958.

11 (*a*) S. J. Blanksby and G. B. Ellison, *Acc. Chem. Res.*, 2003, **36**, 255–263; (*b*) E. T. Denisov and V. E. Tumanov, *Russ. Chem. Rev.*, 2005, **74**, 825–858.

12 (*a*) N. Gong, Z. Zhao, D. James Young, X. Cao, Z. Ren and H. Li, *Chem. Eur. J.*, 2025, **31**, e202404225; (*b*) Z. Zhao, W. Li, Q. Shan, D. J. Young, Z.-G. Ren and H.-X. Li, *J. Org. Chem.*, 2025, **90**, 1616–1627; (*c*) S. Kang, M. T. La and H.-K. Kim, *Tetrahedron Lett.*, 2018, **59**, 3541–3546; (*d*) Y.-D. Kwon, M. T. La and H.-K. Kim, *New J. Chem.*, 2018, **42**, 10833–10841.