Metal-Free Tandem Rearrangement/Lactonization: Access to 3,3-Disubstituted Benzofuran-2-(3*H*)-ones

Micol Santi, Darren M. C. Ould, Jan Wenz, Yashar Soltani, Rebecca L. Melen* and Thomas Wirth*[a]

Abstract: A novel metal-free synthesis of 3,3-disubstituted benzofuran-2(3*H*)-ones from the reaction between *α*-aryl-*α*-diazoacetates and triarylboranes is presented. Initially, triarylboranes were successfully investigated in *α*-arylations of *α*-diazoacetates, however in the presence of an *ortho*-heteroatom substituent the boron enolate intermediate undergoes an intramolecular rearrangement to form a quaternary center. The intermediate cyclizes affording valuable 3,3-disubstituted benzofuranones in good yields.

Benzofuran-2-(3*H*)-ones are interesting oxygen-containing heterocycles which are found in several biologically active natural products such as yuccaols,[1] rosmadial,[2] (–)-fumimycin,[3] and abiesinol A[4] (Figure 1). Benzofuran-2-(3*H*)-ones can also be used as building blocks for the synthesis of sesquiterpenes such as aplysins and isolaurinterol,[5] and the flavonoid-related aurones.[6] Due to their quaternary carbon at the C-3 position, 3,3-disubstituted benzofuranones represent challenging synthetic targets. A recent popular approach towards such structures is the late-stage functionalization of benzofuranones, either metal-catalyzed or promoted by organocatalysts.[7] Methods for the synthesis of the lactone framework have also been investigated, such as metal catalyzed C–H activation/C–O bond formations,[8] tandem Friedel-Crafts/lactonization,[9] Reppe-type cyclocarbonylation,[10] and the condensation of phenol derivatives.[11] However, these methods often require pre-functionalized building blocks and methods to synthesize 3,3-diaryl and 3-aryl-3-benzylic structures remain limited (Figure 1).

Diazo compounds have been successfully employed as versatile precursors for the synthesis of many heteroatom-containing ring systems.[12] In particular, ourselves as well as the groups of Davies and Hashimoto have reported the rhodium-catalyzed decomposition of *α*-diazocarbonyl compounds to yield chiral dihydrobenzofuranes,[13] novel chiral indolines,[14] and precious lactone intermediates through flow synthesis.[15] The reaction between *α*-diazocarbonyl compounds and trialkylboranes[16] as well as triarylboranes[17] has been reported as an efficient method for C–C bond formation. But this approach to *α*-functionalized carbonyl compounds has found only a few applications in organic chemistry, often limited by steric hindrance between the organoborane and the diazo substrate.[18] Herein we present a novel, metal-free route to 3,3-disubstituted lactones from the reaction between *α*-diazocarbonyl compounds and triarylboranes. Initially, a library of boranes [BAr^F_3; Ar^F = 4-FC_6H_4 (**1b**), 2,6-$F_2C_6H_3$ (**1c**), C_6F_5 (**1d**) and 3,4,5-$F_3C_6H_2$ (**1e**)] was prepared with varying Lewis acidities as determined by the Gutmann-Beckett method, and compared to the Lewis acidity of commercially available BPh_3 (**1a**).[19]

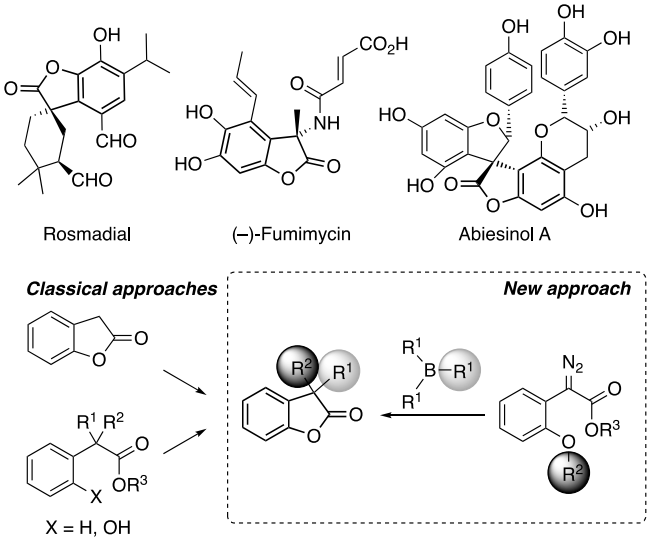


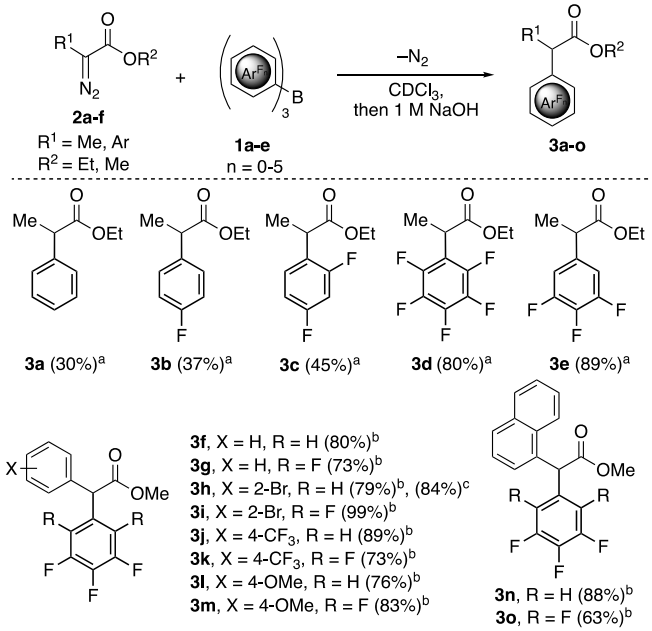
Figure 1. Natural products containing the benzofuranone core (top) and comparison between classical approaches and our new approach to benzofuran-2-(3*H*)-ones described in this work (bottom).

The Lewis acidities of the triarylboranes were found to increase in the order **1a** < **1b** < **1c** < **1d** < **1e** (see SI). Initially, these boranes were investigated in 1,2-aryl transfer reactions in which an aryl group is transferred from BAr_3 to an *α*-diazocarbonyl compound **2a**-**f** to yield **3a**-**o** in excellent conversions (> 90%) when reacted in a 1:1 ratio (Scheme 1). Importantly, the reaction was found to be sensitive to steric hindrance between the boron reagent and the diazo substrate, and typically only one aryl group is transferred.[18a,b] However, when employing the less sterically demanding ethyl 2-diazopropanoate (**2a**), the efficiency of the reaction was greatly improved allowing for transfer of more than one aryl group permitting a sub-stoichiometric amount of the borane to be employed. Thus, in the case of the most Lewis acidic boranes **1d** and **1e**, the ethyl 2-arylpropanoates **3d**-**e** are isolated in high yields (80% and 89%, respectively) upon aqueous basic work-up when using a 3:1 ratio of diazo-compound to borane. Indeed, the yields of the reaction of boranes **1a**-**e** with **2a** increased with the Lewis acidity of the borane when using a 3:1 ratio with **3a**-**e** being isolated in 30-89% yields. This suggests that with the least Lewis acidic borane, triphenylborane (**1a**), only one substituent is transferred from the borane to the substrate, whereas the more Lewis acidic fluorinated boranes **1b** and **1c** are capable of transferring up to two aryl groups showing conversions determined by *in situ* ^{19}F NMR spectroscopy of 60% and 66%, respectively. The most Lewis acidic boranes **1d** and **1e** resulted in transfer of all three fluorinated aryl groups. $B(C_6F_5)_3$ (**1d**) showed transfer of two aryl groups at room temperature after 15 minutes, and of all three aryl groups after 8 h at 60 °C, whereas the most Lewis acidic 3,4,5-fluorinated borane **1e** transferred all three aryl groups at room temperature within 1 h.

Sterically more demanding *α*-aryl-*α*-diazoacetates **2b**-**f** showed no reactivity with the less Lewis acidic boranes **1a**-**c** even

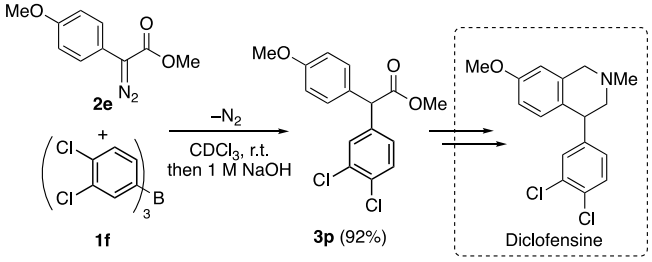
[a] Ms. M. Santi, Mr. D. M. C. Ould, Dr. J. Wenz, Dr. Y. Soltani, Dr. R. L. Melen, Prof. T. Wirth
School of Chemistry, Cardiff University, Main Building, Park Place, Cardiff CF10 3AT, Wales, UK
E-mail: MelenR@cardiff.ac.uk; Wirth@cf.ac.uk

Supporting information for this article is given via a link at the end of the document.



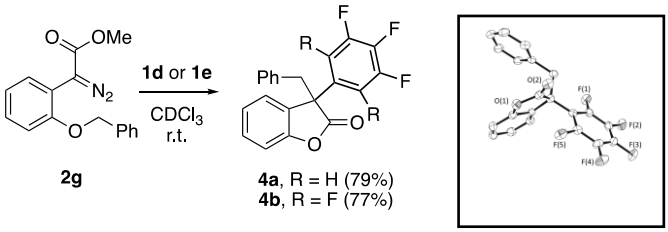
Scheme 1. [a] Reaction between boranes **1a**-**e** (0.1 mmol) with diazoester **2a** (0.3 mmol); [b] Reaction between boranes **1d**-**e** (0.1 mmol) with diazoesters **2b**-**f** (0.1 mmol); [c] Reaction on a 0.5 mmol scale.

at elevated temperatures. With more Lewis acidic boranes **1d**-**e**, a single aryl-group was transferred from the borane at room temperature and the pharmaceutically interesting[20] gem-diarylalkyl products **3f**-**o** were obtained in very good yields within 12 h. In the case of methyl phenyldiazoacetate (**2b**), all three aryl groups were transferred from **1e** when heated in a 1:3 ratio affording the desired product **3f** in 79% yield after 7 days. The incorporation of mono- or poly-haloarene functionalities such as those generated in **3f**-**o** is of paramount importance for the pharmaceutical,[21] agrochemical and electronic industries.[22] To investigate the applicability of our *α*-functionalization reaction, we employed our methodology in the synthesis of **3p** for the preparation of diclofensine (Scheme 2). Developed by Hoffmann-La Roche, diclofensine is an antidepressant drug containing a dichloroarene-substituted tetrahydroisoquinoline.[23] The novel 3,4-chlorinated borane **1f** was prepared which was only slightly less Lewis acidic than the 3,4,5-fluorinated borane (**1e**) using the Gutmann-Beckett method (see SI). As expected, the reaction of **1f** with **2e** led to the formation of **3p** in 92% yield. Current known routes to **3p** employ rhodium based catalysts.[24]



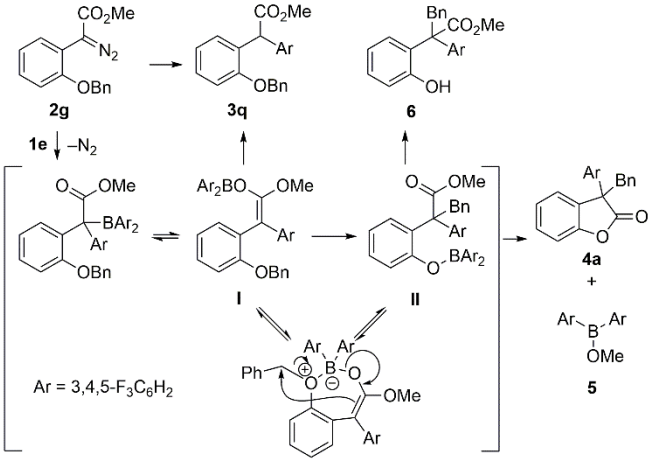
Scheme 2. Towards the synthesis of diclofensine.

Interestingly, when attempting the borane-mediated arylation of 2-benzyloxy substituted diazo derivative **2g** with boranes **1d** or **1e**, lactones **4a** and **4b** resulted as determined by single crystal X-ray diffraction (Scheme 3 and SI).



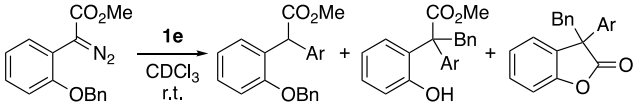
Scheme 3. Rearrangement of 2-benzyloxyphenyl methyl acetate **2g** into 3,3-benzofuran-2-(3*H*)-ones **4a** and **4b** in presence of borane **1d** or **1e** (1 eq.). Solid-state structure of **4b** (insert). Thermal ellipsoids drawn at 50% probability and H-atoms omitted for clarity.

Here, an unprecedented rearrangement occurs of the benzyl group to the benzylic carbon atom following initial arylation. In this reaction sequence, 3,3-disubstituted benzofuran-2-(3*H*)-ones **4a** and **4b** are accessible from the room temperature reaction in good yields of 79% (**4a**) when using borane **1e** and 77% (**4b**) when using **1d**. Compound **2g** was then used as a model substrate along with borane **1e** for kinetic and mechanistic studies of this addition/rearrangement/ cyclization sequence. Examination of the *in situ* ^{1}H and ^{19}F NMR spectra suggests the formation of two main intermediates being the boron enolate **I**, which rearranges to the phenol derivative **II** (Scheme 4). Mechanistically, the first step is the 1,2-aryl shift from the borane to the substrate **2** with loss of dinitrogen and formation of **I** as reported previously for similar reactions.[18a] Boron enolate **I** is not stable at room temperature and fully converts into **II** within 1 h. Finally, **II** forms lactone **4a** and the diarylboronic ether **5** as side product within 24 hours. Evidence for the mechanism and the nature of **I** and **II** were obtained by changing the reaction times and the pH of the quenching solution for the reaction of diazoacetate **2g** with borane **1e** as shown in Table 1. The formation of **I** was proven by the presence of **3q** following basic work-up after 5, 10, 15 or 20 minutes (Table 1, entries 1-4). In addition to **3q**, the formation of **6** was observed in the crude reaction mixture with increasing yields as **3q** was consumed. Moreover, the NMR ratio between **I** and **II** after 5 minutes (~1:1.4) reflected the ratio between **3q** and **6** (1:1.35), confirming the latter as the corresponding hydrolyzed products for **I** and **II**, respectively. Due to the reactive phenolic hydroxy group, it was not possible to isolate **6** due to its natural tendency to form lactone **4a**. However, when the reaction was quenched after 1 h with a saturated solution of NH_4Cl (pH 5), **6** and **4a** were observed in the ^{1}H NMR spectrum with 45% and 22% yield, respectively (entry 5).



Scheme 4. Postulated mechanism for lactone formation.

Table 1. Mechanistic studies.[a]



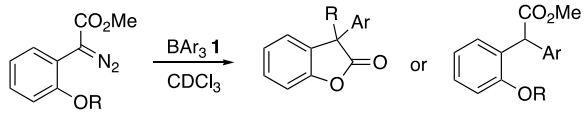
2g			3q	6	4a
Entry	**Time**	**Work-up**	**3q** [%][b]	**6** [%][b]	**4a** [%][b]
1	5 min	NaOH 1 M	33	47	0
2	10 min	NaOH 1 M	19	49	0
3	15 min	NaOH 1 M	17	52	0
4	20 min	NaOH 1 M	15	60	0
5	60 min	NH_4Cl sat.	5	45	22

[a] Reaction between **2g** (0.1 mmol) and **1e** (0.1 mmol); [b] NMR yield, mesitylene used as internal standard. Ar = 3,4,5-$F_3C_6H_2$.

With less reactive substrates or less Lewis acidic boranes (**1a**), similar compounds to **6** could be isolated and fully characterized as additional evidence for this intermediate (see SI). Although it was not possible to isolate the diarylboronic ether **5**, ^{1}H, ^{11}B and ^{19}F NMR spectra support its formation.[25]

Following mechanistic investigation, we turned our attention to the influence of the borane Lewis acid and nature of the *ortho*-substituted diazo derivative **2** in the tandem rearrangement/lactonization reaction to expand the substrate scope (Table 2). As before, the reactivity is strongly dependent on both the Lewis acidity of the borane and the nature of the migrating group. When the model substrate **2g** (R = Bn) reacts with less Lewis acidic boranes such as **1a**, the consumption of the starting material was slow with **2g** still detectable after 12 h. After 14 days at room temperature only 21% yield of the desired product **4c** and 48% yield of the corresponding *α*-functionalized ester (**3**, Ar = Ph) were isolated. In contrast, when borane **1d** was used, a rapid gas evolution (N_2) was observed and **2g** was consumed within 5 minutes and converted to intermediate **II** after 48 h. However, lactone **4b** was detected only after 4 days by ^{1}H NMR spectroscopy and isolated in 77% yield after 7 days at room temperature. The more Lewis acidic borane **1e** showed much more rapid reactions generating **4a** in 79% yield after just 24 h at room temperature. For diazo substrates **2** with electron-poor aryl substituents (R = 4-CF_3-C_6H_4-CH_2) higher reaction temperatures (50 ºC) were necessary to afford the desired products **4d**, **4e** and **4f** in 54%, 72%, and 26% yield, respectively; with the more Lewis acidic boranes **1d** and **1e** giving the best results. It was found that increasing the temperature accelerates the conversion of the diazo compound into **I**, and the cyclization from **II** to the lactone product, but has no effect on the conversion of **I** into **II**. Electron-rich migrating groups on the diazo starting material **2** (R = 4-MeO-C_6H_4-CH_2) were found to be more reactive affording the desired lactone **4g** in 91% yield within 16 h and **4i** in 54% yield after 72 h at room temperature. However, this enhanced reactivity led to a complex mixture of intermediates when **1d** was employed and no desired product **4h** was isolated. Other substrates also worked well in these reactions including substrates **2** bearing moderate electron-donating group in both the *para*- (R = 4-Me-C_6H_4-CH_2) and the more sterically demanding *ortho*-position (R = 2-Me-C_6H_4-CH_2; 2-Ph-C_6H_4-CH_2) with boranes **1e** and **1d** to generate the desired products **4j**-**o** in moderate to good yields (52-91%). Furthermore, *para*-brominated migrating groups (R = 4-Br-C_6H_4-CH_2) were also well tolerated generating **4p**-**q** in good yields offering precursors for further functionalizations. In addition to benzylic functionalities, allylic and cinnamic groups (R = allyl; (*E*)-Ph-CH=$CHCH_2$) were also found to be applicable in the tandem aryl transfer / rearrangement / lactonization reaction generating products **4r**-**u** in moderate to good yields.

Table 2. Substrate scope for tandem rearrangement/lactonization.[a]

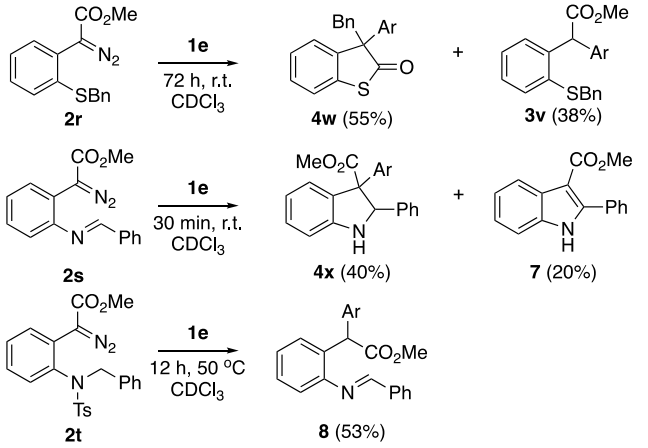


2g-q			4		3
Entry	**Ar**	**R**	**T [ºC]**	**Time [d]**	**Product: yield (%)**
1	3,4,5-$F_3C_6H_2$	$PhCH_2$	25	1	**4a**: 79
2	C_6F_5	$PhCH_2$	25	7	**4b**: 77
3	C_6H_5	$PhCH_2$	25	14	**4c**: 21
4	3,4,5-$F_3C_6H_2$	4-CF_3-C_6H_4-CH_2	50	1	**4d**: 54
5	C_6F_5	4-CF_3-C_6H_4-CH_2	50	1	**4e**: 72
6	C_6H_5	4-CF_3-C_6H_4-CH_2	50	1	**4f**: 26
7	3,4,5-$F_3C_6H_2$	4-MeO-C_6H_4-CH_2	25	0.7	**4g**: 91
8	C_6F_5	4-MeO-C_6H_4-CH_2	25	1	**4h**: 0
9	C_6H_5	4-MeO-C_6H_4-CH_2	25	3	**4i**: 54
10	3,4,5-$F_3C_6H_2$	4-Me-C_6H_4-CH_2	25	1	**4j**: 87
11	C_6F_5	4-Me-C_6H_4-CH_2	50	1	**4k**: 63
12	3,4,5-$F_3C_6H_2$	2-Me-C_6H_4-CH_2	25	1	**4l**: 78
13	C_6F_5	2-Me-C_6H_4-CH_2	50	1	**4m**: 59
14	3,4,5-$F_3C_6H_2$	2-Ph-C_6H_4-CH_2	25	1	**4n**: 91
15	C_6F_5	2-Ph-C_6H_4-CH_2	50	1	**4o**: 52
16	3,4,5-$F_3C_6H_2$	4-Br-C_6H_4-CH_2	25	1	**4p**: 74
17	C_6F_5	4-Br-C_6H_4-CH_2	50	1	**4q**: 73
18	3,4,5-$F_3C_6H_2$	allyl	25	1	**4r**: 57
19	C_6F_5	allyl	50	1	**4s**: 60
20	3,4,5-$F_3C_6H_2$	(*E*)-Ph-CH=$CHCH_2$	25	1	**4t**: 53
21	C_6F_5	(*E*)-Ph-CH=$CHCH_2$	50	1	**4u**: 33
22	3,4,5-$F_3C_6H_2$	*n*-hexyl	25	1	**3r**: 59
23[b]	3,4,5-$F_3C_6H_2$	4-Me-C_6H_4-CH_2	25	1	**4v**: 82

[a] Reaction between **2** (0.1 mmol) and **1** (0.1 mmol) in $CDCl_3$; [b] Methyl 5-bromo-2-((4-methylbenzyl)oxy)phenyl)-2-diazoacetate **2q** was used as starting material.

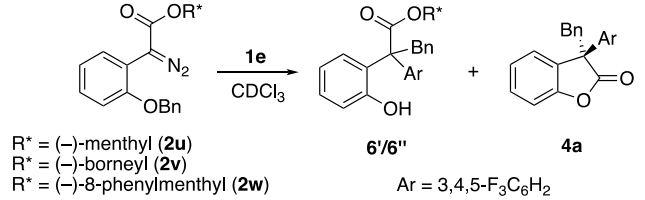
The limit of this transformation was reached when migrating groups less able to stabilize a carbocation were involved. For example, when **2p** (R = *n*-hexyl) was used, the corresponding *α*-functionalized ester **3r** was isolated as the only product in 59% yield with no rearrangement taking place. This confirms the hypothesis of a carbocationic species involved in the migration from the phenolic oxygen to the C-3 carbon. A crossover reaction was performed using diazoesters **2g** (R = Bn) and methyl 5-bromo-2-((4-methylbenzyl)oxy)phenyl)-2-diazoacetate (**2q**) with borane **1e** which resulted in the formation of **4a** and **4v** in a 1:1 ratio. The absence of any observation of the crossover reaction product **4j** suggests that the migration happens *via* an intramolecular rearrangement (Scheme 4 and SI). Treatment of the diazo compound **2g** under similar reaction conditions with triethylborane did not result in any reaction, while reaction with borontrifluoride etherate led to decomposition.[26] Reaction of **2i** with either phenylboronic acid or with triphenylboroxine[27] resulted only in the α-phenylated product as determined by ^{1}H NMR.

Finally, we explored the scope of other heteroatoms on the *ortho*-substituted diazo derivative **2**. Sulfur and nitrogen-containing diazo compounds (**2r** and **2s**) undergo similar rearrangements affording **4w** and **4x** as major products while *N*-tosyl substrate **2t** resulted in a detosylated product **8** (Scheme 5).



Scheme 5. Scope of sulfur- and nitrogen-containing starting materials. Reaction between **2r**-**t** (0.1 mmol) and **1e** (0.1 mmol) in $CDCl_3$. Ar = 3,4,5-$F_3C_6H_2$.

To conclude, we sought to try to induce enantioselective formation of the quaternary carbon C-3 position by installing a chiral auxiliary on the ester moiety of the diazo starting materials **2u**-**w** (Scheme 6). When (–)-menthol was used as an auxiliary, the reactions of **2u** with **1e** occurred with full consumption of the starting material within 30 minutes at room temperature affording **6'** and **6''** in a 1:1.8 diastereoselective ratio upon basic work-up. Higher temperature led to **4a** formation in 21% and 44% *ee* after 7 and 12 days at 50 ºC, respectively. (–)-Borneol (**2v**) and (–)-8-phenylmenthol (**2w**) auxiliaries did not provide enhanced selectivities in the formation of **4a** (29% and 14% *ee* respectively) even when altering the reaction conditions (see SI).



Scheme 6. Use of chiral auxiliaries. Reaction between **2u**-**w** (0.1 mmol) and **1e** (0.1 mmol) in $CDCl_3$. Ar = 3,4,5-$F_3C_6H_2$.

In summary, we have demonstrated the use of highly Lewis acidic boranes to efficiently incorporate halogenated aryl groups in *α*-position to carbonyls. In the case of 2-benzyloxy substituted diazo derivatives we present a novel, metal-free and direct approach to benzofuran-2-(3*H*)-ones affording the products in moderate to excellent yields. To the best of our knowledge, this is the first report toward such structures in which the lactone framework is formed and the C-3 position is fully substituted in a single-step metal-free reaction.

Keywords: Benzofuranone • Diazo compounds • Boron • Rearrangement • Metal-free

[1] C. Balestrieri, F. Felice, S. Piacente, C. Pizza, P. Montoro, W. Oleszek, V. Visciano, M. L. Balestrieri, *Biochem. Pharmacol.* **2006**, *71*, 1479.

[2] N. Nakatani, R. Inatani, *Agric. Biol. Chem.* **1983**, *47*, 353.

[3] Y.-J. Kwon, M.-J. Sohn, C.-J. Zheng, W.-G. Kim, *Org. Lett*. **2007**, *9*, 2449.

[4] S.-I. Wada, T. Hitomi, H. Tokuda, R. Tanaka, *Chem. Biodiv.* **2010**, *7*, 2303.

[5] D. C. Harrowven, M. C. Lucas, P. D. Howes, *Tetrahedron* **2001**, *57*, 791.

[6] S. Venkateswarlu, G. K. Panchagnula, M. B. Guraiah, G. V. Subbaraju, *Tetrahedron* **2005**, *61,* 3013.

[7] For selected recent examples, see: a) Y. Li, X. Li, J.-P. Chenga, *Adv. Synth. Catal.* **2014**, *356*, 1172; b) Z. Huang, X. Yang, F. Yang, T. Lu, Q. Zhou, *Org. Lett.* **2017**, *19*, 3524; c) T. Cruchter, M. G. Medvedev, X. Shen, T. Mietke, K. Harms, M. Marsch, E. Meggers, *ACS Catal.* **2017**, *7*, 5151; d) B. B. Dhotare, M. Kumar, S. K. Nayak, *J. Org. Chem*. **2018**, *83*, 10089; d) Y. Chen, B.-D. Cui, Y. Wang, W.-Y. Han, N.-W. Wan, M. Bai, W.-C. Yuan, Y.-Z. Chen, *J. Org. Chem*. **2018**, *83*, 10465; e) Y. Liu, C. Zhou, M. Xiong, J. Jiang, J. Wang, *Org. Lett.* **2018**, *20*, 5889.

[8] a) X.-F. Cheng, Y. Li, Y.-M. Su, F. Yin, J.-Y. Wang, J. Sheng, H. U. Vora, X.-S. Wang, J.-Q. Yu, *J. Am. Chem. Soc.* **2013**, *135*, 1236; b) M. Yang, X. Jiang, W.-J. Shi, Q.-L. Zhu, Z.-J. Shi, *Org. Lett.* **2013**, *15*, 690.

[9] a) L. Chen, F. Zhou, T.-D. Shi, J. Zhou, *J. Org. Chem.* **2012**, *77*, 4354; b) B. B. Dhotare, M. K. Choudhary, S. K. Nayak, *Synth. Commun*. **2016**, *46*, 1772; c) M. Miceli, E. Roma, P. Rosa, M. Feroci, M. A. Loreto, D. Tofani, T. Gasperi, *Molecules* **2018**, *23*, 710.

[10] a) W. Reppe, H. Kröper, H. J. Pistor, H. Schlenck, *Liebigs Ann. Chem.* **1953**, *582*, 38; b) E. Yoneda, T. Sugioka, K. Hirao, S.-W. Zhang, S. Takahashi, *J. Chem. Soc. Perkin Trans. 1* **1998**, 477; c) V. Hirchbeck, I. Fleischer, *Chem. Eur. J.* **2018**, *24*, 2854.

[11] a) K. Ladenburg, K. Folkers, R. T. Major*, J. Am. Chem. Soc*. **1936**, *58*, 1292; b) A. Puglisi, C. Giustini, A. Ricucci, E. Perotti, L. Massaro, D. Morra, F. Ciucci, A. Zucchet, A. Antenucci, M. Moliterno, S. Placidi, F. Sciubba, L. Galantini, R. Salvio, M. Bella, *Chem. Eur. J.* **2018**, *24*, 6941; c) L. Ortiz-Rojano, M. Martínez-Mingo, C. García-García, M. Ribagorda, M. C. Carreño, *Eur. J. Org. Chem.* **2018**, 1034.

[12] A. Ford, H. Miel, A. Ring, C. N. Slattery, A. R. Maguire, M. A. McKervey, *Chem. Rev*. **2015**, *115*, 9981.

[13] a) H. Saito, H. Oishi, S. Kitagaki, S. Nakamura, M. Anada, S. Hashimoto, *Org. Lett.* **2002**, *4*, 3887; b) R. P. Reddy, G. H. Lee, H. M. L. Davies, *Org. Lett.* **2006**, *8*, 3437.

[14] M. Santi, S. T. R. Müller, A. A. Folgueiras-Amador, A. Uttry, P. Hellier, T. Wirth, *Eur. J. Org. Chem.* **2017**, 1889.

[15] S. T. R. Müller, A. Murat, P. Hellier, T. Wirth, *Org. Process Res. Dev*. **2016**, *20*, 495.

[16] For selected examples see: a) J. Hooz, S. Linke. *J. Am. Chem. Soc.* **1968**, *90*, 5936; b) J. Hooz, D. M. Gunn, *J. Am. Chem. Soc.* **1969**, *91*, 619; c) J. Hooz, J. N. Bridson, *J. Am. Chem. Soc.* **1973**, *95*, 602; d) J. Hooz, J. N. Bridson, J. G. Calzada, H. C. Brown, M. M. Midland; A. B Levy, *J. Org. Chem*. **1973**, *38*, 2574; e) J. Hooz, J. Oudenes, J. L. Roberts, A. Benderly, *J. Org. Chem*. **1987**, *52*, 1347.

[17] a) R. C. Neu, C. Jiang, D. W. Stephan, *Dalton Trans.* **2013**, *42*, 726; b) R. C. Neu, D. W. Stephan, *Organometallics* **2012**, *31*, 46.

[18] For selected examples, see: a) M. A. Sanchez-Carmona, D. A. Contreras-Cruz, L. D. Miranda, *Org. Biomol. Chem.* **2011**, *9*, 6506; b) H. Li, Y. Zhang, J. Wang, *Synthesis* **2013**, *45*, 3090; c) S. G. Davies, A. M. Fletcher, J. E. Thomson, *Chem. Commun*. **2013**, *49*, 8586.

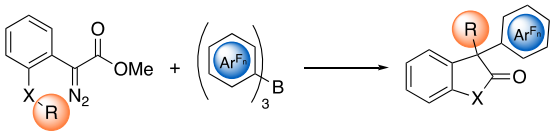
[19] a) U. Mayer, V. Gutmann, W. Gerger, *Monatsh. Chem*. **1975**, *106*, 1235; b) M. A. Beckett, G. C. Strickland, J. R. Holland, K. S. Varma, *Polymer* **1996**, *37*, 4629.

[20] For example see: D. Ameen, T. Snape, *J. Med. Chem. Commun*. **2013**, *4*, 893.

[21] a) K. Müller, C. Faeh, F. Diederich, *Science* **2007**, *317*, 1881; b) J. Wang, M. Sánchez-Roselló, J.-L. Aceña, C. del Pozo, A. E. Sorochinsky, S. Fustero, V. A. Soloshonok, H. Liu, *Chem. Rev*. **2014**, *114*, 2432.

[22] a) A. R. Murphy, J. M. J. Fréchet, *Chem. Rev*. **2007**, *107*, 1066; b) F. Babudri, G. M. Farinola, F. Naso, R. Ragni, *Chem. Commun*. **2007**, 1003.
[23] N. Nakachi, Y. Kiuchi, M. Inagaki, M. Inazu, Y. Yamazaki, K. Oguchi, *Eur. J. Pharmacol*. **1995**, *281*, 195.
[24] J. Ghorai, P. Anbarasan, *J. Org. Chem.* **2015**, *80*, 3455.
[25] D. Donghi, D. Maggioni, T. Beringhelli, G. D'Alfonso, P. Mercandelli, A. Sironi, *Eur. J. Inorg. Chem*. **2008**, 1645.
[26] A. Gioiello, F. Venturoni, B. Natalini, R. Pellicciari, *J. Org. Chem*. **2009**, *74*, 3520.
[27] C. Peng, W. Zhang, G. Yan, J. Wang, *Org. Lett*. **2009**, *11*, 1667.

3,3-Disubstituted lactones were obtained in excellent yields from the reaction of diazo compounds and triarylboranes. The multi-step reaction proceeds through an aryl-transfer followed by benzyl group migration and finally a cyclization reaction.



Tandem aryl transfer/rearrangment/cyclization

Micol Santi, Darren M. C. Ould, Jan Wenz, Yashar Soltani, Rebecca L. Melen and Thomas Wirth**

Page No. – Page No.

Metal-free tandem Rearrangement/Lactonization: Access to 3,3-Disubstituted Benzofuran-2-(3*H*)-ones