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Palladium-catalyzed cross coupling reactions of 4-bromo-6*H*-1,2-oxazines

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Preliminary Communication

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Abstract

A number of 4-aryl- and 4-alkynyl-substituted 6*H*-1,2-oxazines **8** and **9** have been prepared in good yields via cross coupling reactions of halogenated precursors **2**, which in turn are easily accessible by bromination of 6*H*-1,2-oxazines **1**. Lewis-acid promoted reaction of 1,2-oxazine **9c** with 1-hexyne provided alkynyl-substituted pyridine derivative **12** thus demonstrating the potential of this approach for the synthesis of pyridines.

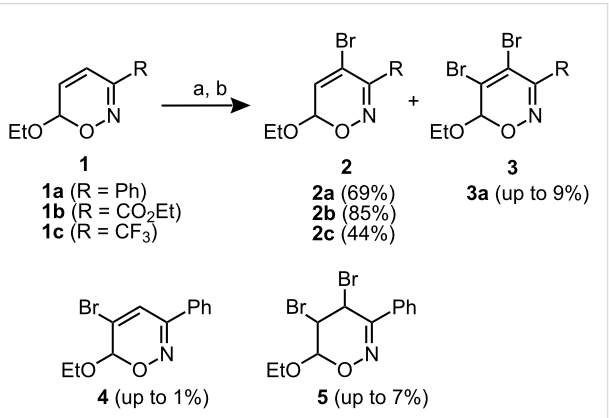
Introduction

A broad range of synthetic applications demonstrates that 1,2-oxazine derivatives constitute a versatile class of N,O heterocycles [1-13]. Considerable attention has been paid to 6*H*-1,2-oxazines **1** bearing a C-4,C-5-double bond [14-18], which are useful intermediates in the synthesis of γ-lactams [19], γ-amino acids [20], amino alcohols [20], aziridines [21], pyrrolizidines [22], and pyrrolidine derivatives [15,23,24]. In the context of our ongoing exploration of the synthetic potential of these heterocycles we were interested to modify the substitution pattern of the C-4,C-5 double bond of 6*H*-1,2-oxazines [25-27]. Herein, we describe our results dealing with the halogenation of 6*H*-1,2-oxazines **1** and the use of the resulting products as precursors in palladium-catalyzed cross coupling reactions.

Results and Discussion

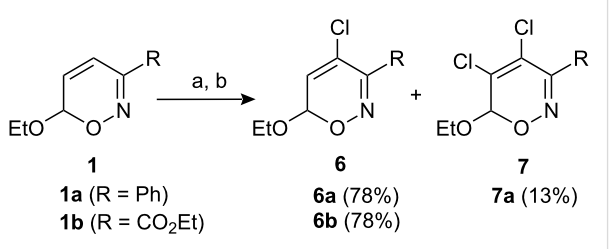
Not much is known about halogenated 6*H*-1,2-oxazines and only a few mostly inefficient procedures are described [28-32]. This prompted us to investigate a more practical access to halogenated 6*H*-1,2-oxazines. Gratifyingly, the desired 4-bromo-substituted 6*H*-1,2-oxazines **2a**–**2c** could be prepared in a one-pot procedure by bromine addition to precursors **1a**–**1c** [14] and HBr elimination by treatment with triethylamine (Scheme 1).

The 4-bromo-6*H*-1,2-oxazines were obtained in reasonable to good yields. The bromination of 3-phenyl-substituted 6*H*-1,2-oxazine **1a** often resulted in a mixture of several brominated products which are easily separable by chromatography. Depending on the reaction scale and the amount of bromine used (1.5 to 3 equiv) by-products such as **3a**, **4** and **5** could be isolated in varying yields. The unexpected formation of 4,5-dibromo-6*H*-1,2-oxazine **3a** can obviously be rationalized by addition of bromine to **2a** and elimination of HBr during the bromination reaction of **1a**.



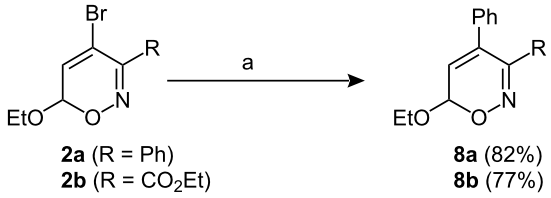
Scheme 1: Brominations of 6*H*-1,2-oxazines. a) Br_2, Et_2O, −30 °C, 2 h. b) Et_3N, −30 °C to r.t., overnight.

The literature describes just one related 4-chloro-substituted 6*H*-1,2-oxazine which was prepared by a hetero-Diels–Alder cycloaddition–elimination sequence of 2-chloro-1-nitroso-1-phenyl-ethene and 1-bromo-2-ethoxyethene in low yield (22%) [32]. As demonstrated in Scheme 2, a more efficient approach consists in chlorination of 6*H*-1,2-oxazines **1a**,**b** by addition of chlorine and subsequent base-induced dehydrochlorination. The expected 4-chloro-6*H*-1,2-oxazines **6a**,**b** were obtained in good yields. In analogy to the aforementioned bromination, the chlorination of 3-phenyl-6*H*-1,2-oxazine **1a** also led to dihalogenation furnishing 4,5-dichloro-substituted compound **7a** as a by-product in 13% yield.



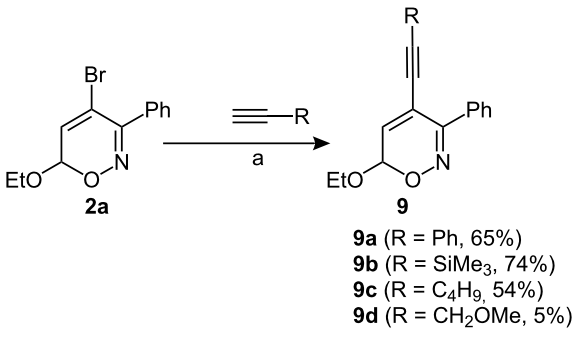
Scheme 2: Chlorinations of 6*H*-1,2-oxazines. a) Cl_2, Et_2O, −30 °C. b) Et_3N, −30 °C to r.t.

With the 4-halogenated 6*H*-1,2-oxazines **2** and **6** in hand, palladium-catalyzed cross couplings offer an efficient and useful approach for the synthesis of novel functionalized 6*H*-1,2-oxazines. The Suzuki-coupling of the 4-bromo-substituted heterocycles **2a**,**b** with phenylboronic acid in the presence of $Pd(PPh_3)_4$ and sodium carbonate at 80 °C in toluene gave the expected 4-phenyl-substituted 6*H*-1,2-oxazines **8a** or **8b** in 82 and 77% yield (Scheme 3).



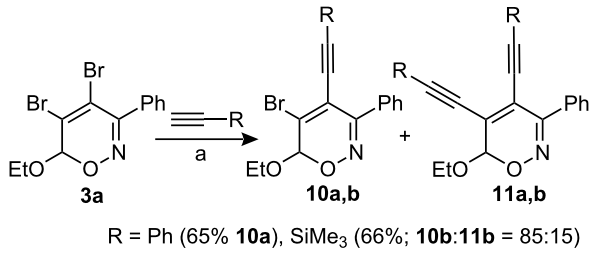
Scheme 3: Suzuki-couplings of 4-bromo-6*H*-1,2-oxazines. a) $ArB(OH)_2$, $Pd(PPh_3)_4$, Na_2CO_3, toluene, 80 °C, 3 h.

4-Bromo-6*H*-1,2-oxazine **2a** also serves as suitable model substrate for Sonogashira-reactions (Scheme 4). When the coupling reaction of **2a** with various terminal alkynes, such as phenylacetylene, trimethylsilylethyne and 1-hexyne, was performed under typical conditions [$PdCl_2(PPh_3)_2$, CuI, Et_3N, toluene], the expected 4-alkynyl-substituted heterocycles **9a**–**9c** were isolated in good yields. In contrast, when the same reaction conditions were applied to the coupling of **2a** and methyl propargyl ether, product **9d** was obtained only in very low yield. In addition, Sonogashira coupling of **2a** and methyl propargyl ether performed by an alternative protocol ($Pd(OAc)_2$, CuI, PPh_3, $NHiPr_2$ in DMF) afforded the expected product **9d** and a byproduct bearing a 4-enyne moiety at 4-position. This indicates an addition of a second alkyne molecule to the primary product **9**. Similar results were observed for the Sonogashira reaction of **2a** with propargylic alcohol [33].



Scheme 4: Sonogashira-couplings of 4-bromo-6*H*-1,2-oxazines. a) $PdCl_2(PPh_3)_2$, CuI, Et_3N, toluene, r.t., 6–20 h.

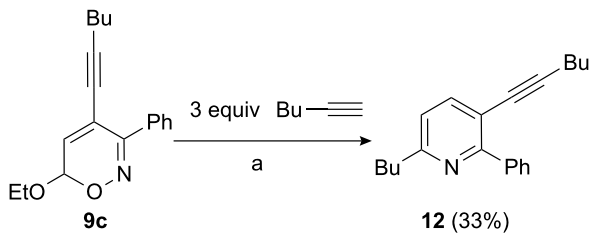
After successful simple cross couplings of mono-halogenated **2**, the 4,5-dibromo-3-phenyl-6*H*-1,2-oxazine **3a** seemed to be an attractive candidate for a twofold Sonogashira reaction (Scheme 5). Treatment of **3a** with an excess of phenylacetylene under conditions as described in Scheme 4 provided 5-bromo-4-alkynyl-substituted 6*H*-1,2-oxazine **10a** as single product in 65% yield. When the Sonogashira coupling was performed with trimethylsilylethyne under the same reaction conditions an inseparable 85:15-mixture of mono-alkynylated product **10b** and bis-alkynylated compound **11b** was obtained in reasonable yield. These reactions certainly deserve further optimization, however, they already show the potential of compounds such as **3a** to serve as precursors for two subsequent coupling reactions.



Scheme 5: Sonogashira-couplings of 4,5-dibromo-6*H*-1,2-oxazines. a) $PdCl_2(PPh_3)_2$, CuI, Et_3N, toluene, r.t., 4 h to overnight.

Conclusion and Perspective

In conclusion, we have successfully demonstrated that a series of 4-aryl- and 4-alkynyl-substituted 6*H*-1,2-oxazines **8**, **9**, and **10** are easily accessible in short reaction sequences starting from precursors **1**. These 6*H*-1,2-oxazines should allow access to many interesting five- and six-membered heterocycles. As illustrated in Scheme 6, the 4-hex-1-ynyl-3-phenyl-6*H*-1,2-oxazine **9c** can be converted into the trisubstituted pyridine derivative **12** by treatment of **9c** with boron trifluoride etherate in the presence of an excess of 1-hexyne via an azapyrylium intermediate [34,35]. Additional investigations are required to optimize the preparation diynes of type **11**. Conversion of the new functionalized 6*H*-1,2-oxazines to highly substituted pyridine derivatives will also be reported in due course.



Scheme 6: Preparation of trisubstituted pyridine derivatives: a) $BF_3{\cdot}OEt_2$, CH_2Cl_2, −78 °C to r.t., overnight.

Experimental

Bromination of 6*H*-1,2-oxazine **1a**, typical procedure

6*H*-1,2-Oxazine **1a** (5.35 g, 26.3 mmol) was dissolved in diethyl ether (200 mL) and treated with bromine (2.75 mL, 53.7 mmol) at −30 °C under argon atmosphere. After 2 h Et_3N (54.0 mL, 390 mmol) was added. The reaction mixture was warmed to r.t. overnight and quenched with water (100 mL). The aqueous phase was extracted with CH_2Cl_2 (2 × 50 mL) and the combined organic phases were dried with Na_2SO_4. Purification of the crude product by column chromatography (SiO_2, hexane:EtOAc 8:1, then 4:1) gave the 4-bromo-substituted 6*H*-1,2-oxazine **2a** (5.11 g, 69%), the 4,5-dibromo-substituted by-product **3a** (0.821 g, 9%), and starting material **1a** (0.335 g, 6%).

4-Bromo-6-ethoxy-3-phenyl-6*H*-1,2-oxazine (**2a**): yellow–brown oil. ^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.23 (t, *J* = 7.1 Hz, 3 H, CH_3), AB part of ABX_3 system (δ_A = 3.68, δ_B = 3.95, $J_{AX} = J_{BX}$ = 7.1 Hz, J_{AB} = 9.8 Hz, 2 H, OCH_2), 5.58 (d, *J* = 5.2 Hz, 1 H, 6-H), 6.70 (d, *J* = 5.2 Hz, 1 H, 5-H), 7.35–7.50, 7.50–7.60 (2 m, 3 H, 2 H, Ph) ppm. ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 14.8 (q, CH_3), 64.3 (t, OCH_2), 94.7 (d, C-6), 112.9 (s, C-4), 127.8, 128.0, 128.8, 129.7, 133.1 (4 d, s, Ph, C-5), 156.2 (s, C-3) ppm. For the complete characterization, see ref. [31].

4,5-Dibromo-6-ethoxy-3-phenyl-6*H*-1,2-oxazine (**3a**): brown oil. ^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.25 (t, *J* = 7.1 Hz, 3 H, CH_3), AB part of ABX_3 system (δ_A = 3.76, δ_B = 3.97, $J_{AX} = J_{BX}$ = 7.1 Hz, J_{AB} = 9.7 Hz, 2 H, OCH_2), 5.71 (s, 1 H, 6-H), 7.38–7.48, 7.49–7.56 (2 m, 3 H, 2 H, Ph) ppm. ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 14.7 (q, CH_3), 65.0 (t, OCH_2), 99.8 (d, C-6), 114.4, 124.8 (2 s, C-4, C-5), 128.1, 128.9, 129.9, 133.3 (3 d, s, Ph), 155.9 (s, C-3) ppm. IR (neat): 3065–2900 (=C–H, C–H), 1630 (C=N), 1600 (C=C) cm^{-1}. HRMS (80 eV, 40 °C) *m*/*z* calcd for $C_{12}H_{11}{}^{79}Br_2NO_2$: 358.9157; found: 358.9160.

Chlorination of 6*H*-1,2-oxazine **1b**, typical procedure

Chlorine gas was passed into diethyl ether (28 mL) at −30 °C until the solution became dark yellow. Then, 6*H*-1,2-oxazine **1b** (0.200 g, 1.00 mmol) was added and the reaction mixture was monitored by TLC; upon complete consumption, triethylamine (2.00 mL, 27.8 mmol) was added at −30 °C and the mixture was slowly warmed to r.t. After addition of brine, the phases were separated, the aqueous phase was extracted with CH_2Cl_2 (2 × 20 mL) and the combined organic phases were dried with Na_2SO_4. Column chromatography (SiO_2, hexane, hexane:EtOAc 9:1, then 4:1) afforded the 4-chloro-substituted product **6b** (0.182 g, 78%) as pale–yellow oil.

Ethyl 4-chloro-6-ethoxy-6*H*-1,2-oxazine-3-carboxylate (**6b**): ^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.22 (t, *J* = 7.1 Hz, 3 H, CH_3), 1.40 (t, *J* = 7.2 Hz, 3 H, CH_3), AB part of ABX_3 system (δ_A = 3.68, δ_B = 3.95, J_{AX} = J_{BX} = 7.1 Hz, J_{AB} = 9.6 Hz, 2 H, OCH_2), 4.40 (q, *J* = 7.2 Hz, 2 H, OCH_2), 5.72 (d, *J* = 5.0 Hz, 1 H, 6-H), 6.34 (d, *J* = 5.0 Hz, 1 H, 5-H) ppm. ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 13.9, 14.7 (2 q, CH_3), 62.5, 64.6 (2 t, OCH_2), 95.3 (d, C-6), 121.1 (s, C-4), 122.7 (d, C-5), 148.5 (s, C-3), 160.3 (s, C=O) ppm. IR (neat): 3105–2975 (=C–H, C–H), 1745 (C=O), 1615 (C=N) cm^{-1}. $C_9H_{12}ClNO_4$ (233.7): calcd. C, 46.27; H, 5.18; N, 5.99; found: C, 46.35; H, 5.16; N, 6.08.

Suzuki-coupling of 4-bromo-substituted 6*H*-1,2-oxazine **2a**, typical procedure

6*H*-1,2-Oxazine **2a** (0.0935 g, 0.33 mmol), phenylboronic acid (0.122 g, 1.00 mmol) and $Pd(PPh_3)_4$ (0.016 g, 0.0138 mmol) were dissolved in a mixture of toluene/MeOH (3 mL/0.75 mL) in a heat-gun-dried and argon-flushed flask. A 2M Na_2CO_3 solution (1.5 mL) was finally added and the reaction mixture was heated for 15 h at 80 °C. Then, the reaction mixture was cooled to r.t. and washed with 2M Na_2CO_3 (with 1% NH_3) solution. After separation of the phases, the aqueous phase was extracted with CH_2Cl_2 (3 × 5 mL) and the combined organic phases were dried with Na_2SO_4. The crude product was purified by column chromatography (SiO_2, hexane:EtOAc 9:1, then 4:1) to afford the Suzuki product **8a** (0.076 g, 82%) as a pale–yellow solid, mp 68–70 °C.

6-Ethoxy-3,4-diphenyl-6*H*-1,2-oxazine (**8a**): ^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.25 (t, *J* = 7.1 Hz, 3 H, CH_3), AB part of ABX_3 system (δ_A = 3.75, δ_B = 4.01, J_{AX} = J_{BX} = 7.1 Hz, J_{AB} = 9.8 Hz, 2 H, OCH_2), 5.73 (d, *J* = 4.9 Hz, 1 H, 6-H), 6.37 (d, *J* = 4.9 Hz, 1 H, 5-H), 7.05–7.10, 7.15–7.27, 7.30–7.35 (3 m, 4 H, 4 H, 2 H, Ph) ppm. ^{13}C NMR ($CDCl_3$, 75.5 MHz): δ = 15.0 (q, CH_3), 64.2 (t, OCH_2), 93.0 (d, C-6), 124.0 (d, C-5), 128.0, 128.2, 128.4, 128.7, 129.0, 130.2, 133.9, 136.5 (5 d, 3 s, Ph, C-4), 157.7 (s, C-3) ppm. IR (KBr): 3040–2930 (=C–H, C–H), 1620 (C=N), 1600 (C=C) cm^{-1}. $C_{18}H_{17}NO_2$ (279.3): calcd. C, 77.39; H, 6.13; N, 5.01; found: C, 77.82; H, 6.37; N, 5.08.

Sonogashira-coupling of 4-bromo-substituted 6*H*-1,2-oxazine **2a**, typical procedure

6*H*-1,2-Oxazine **2a** (0.850 g, 3.19 mmol), trimethylsilylethyne (0.87 mL, 6.17 mmol), $PdCl_2(PPh_3)_2$ (0.114 g, 0.16 mmol), CuI (0.019 g, 0.10 mmol) and Et_3N (1.3 mL) were dissolved in toluene (15 mL) in a heat-gun-dried and argon-flushed flask and the reaction mixture was stirred at r.t. for 20 h. The reaction mixture was quenched with water (5 mL). The aqueous phase was extracted with CH_2Cl_2 (3 × 10 mL) and the combined organic phases were dried with Na_2SO_4. Purification of the crude product by column chromatography (SiO_2, hexane: EtOAc 20:1, then 4:1) afforded the 4-alkynyl-substituted 6*H*-1,2-oxazine **9b** (0.711 g, 74%) as a colorless oil.

6-Ethoxy-3-phenyl-4-(trimethylsilylethynyl)-6*H*-1,2-oxazine (**9b**): ^{1}H NMR ($CDCl_3$, 250 MHz): δ = 0.71 (s, 9 H, $SiMe_3$), 1.21 (t, *J* = 7.1 Hz, 3 H, CH_3), AB part of ABX_3 system (δ_A = 3.68, δ_B = 3.96, J_{AX} = J_{BX} = 7.1 Hz, J_{AB} = 9.7 Hz, 2 H, OCH_2), 5.62 (d, *J* = 5.1 Hz, 1 H, 6-H), 5.69 (d, *J* = 5.1 Hz, 1 H, 5-H), 7.34–7.44, 7.67–7.73 (2 m, 3 H, 2 H, Ph) ppm. ^{13}C NMR ($CDCl_3$, 125.8 MHz): δ = −0.7 (q, $SiMe_3$), 14.9 (q, CH_3), 64.2 (t, OCH_2), 92.0 (d, C-6), 99.5, 101.9 (2 s, C≡C), 114.0 (s, C-4), 127.7, 128.7, 129.5, 130.1, 132.9 (4 d, s, Ph, C-5), 155.5 (s, C-3) ppm. IR (neat): 3085–2900 (=C–H, C–H), 2160 (C≡C), 1620 (C=C), 1580 (C=N) cm^{-1}. $C_{17}H_{21}NO_2Si$ (299.5): calcd. C, 68.19; H, 7.07; N, 4.68; found: C, 68.17; H, 7.08; N, 4.74.

Acknowledgments

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References

1. Gilchrist, T. L. *Chem. Soc. Rev.* **1983,** *12,* 53–73. doi:10.1039/cs9831200053
2. Tsoungas, P. G. *Heterocycles* **2002,** *57,* 915–953. doi:10.3987/REV-02-548
3. Reissig, H.-U.; Zimmer, R. In *Science of Synthesis Houben-Weyl Methods of Molecular Transformations;* Trost, B. M.; Molander, G. A., Eds.; Thieme: Stuttgart, Germany, 2006; Vol. 33, pp 371–389.
4. Lyapkalo, I. M.; Ioffe, S. L. *Russ. Chem. Rev. (engl. Transl.)* **1998,** *67,* 467–485.
5. Tishkov, A. A.; Reissig, H.-U.; Ioffe, S. L. *Synlett* **2002,** 863–866. doi:10.1055/s-2002-31908
6. Young, I. S.; Kerr, M. A. *Angew. Chem.* **2003,** *115,* 3131–3134. *Angew. Chem. Int. Ed.* **2003,** *42,* 3023–3026. doi:10.1002/anie.200351573
7. Helms, M.; Schade, W.; Pulz, R.; Watanabe, T.; Al-Harrasi, A.; Fisera, L.; Hlobilova, I.; Zahn, G.; Reissig, H.-U. *Eur. J. Org. Chem.* **2005,** 1003–1019. doi:10.1002/ejoc.200400627
8. Cardona, F.; Goti, A. *Angew. Chem.* **2005,** *117,* 8042–8045. *Angew. Chem. Int. Ed.* **2005,** *44,* 7832–7835. doi:10.1002/anie.200502640
9. Sibi, M. P.; Ma, Z.; Jasperse, C. P. *J. Am. Chem. Soc.* **2005,** *127,* 5764–5765. doi:10.1021/ja0421497
10. Kumarn, S.; Shaw, D. M.; Ley, S. V. *Chem. Commun.* **2006,** 3211–3213. doi:10.1039/b606338a
11. Lu, C.-D.; Zakarian, A. *Angew. Chem.* **2008,** *120,* 6935–6937. *Angew. Chem. Int. Ed.* **2008,** *47,* 6829–6831. doi:10.1002/anie.200801652
12. Brasholz, M.; Reissig, H.-U.; Zimmer, R. *Acc. Chem. Res.* **2009,** *42,* 45–56. doi:10.1021/ar800011h

13. Sukhorukov, A. Yu.; Lesiv, A. V.; Khomutova, Y. A.; Ioffe, S. L. *Synthesis* **2009,** 741–754. doi:10.1055/s-0028-1083360
14. Homann, K.; Angermann, J.; Collas, M.; Zimmer, R.; Reissig, H.-U. *J. Prakt. Chem.* **1998,** *340,* 649–655. doi:10.1002/prac.19983400709
15. Zimmer, R.; Orschel, B.; Scherer, S.; Reissig, H.-U. *Synthesis* **2002,** 1553–1563. doi:10.1055/s-2002-33328
16. Zimmer, R.; Reissig, H.-U. *Angew. Chem.* **1988,** *100,* 1576–1577. *Angew. Chem., Int. Ed. Engl.* **1988,** *27,* 1518–1519. doi:10.1002/anie.198815181
17. Zimmer, R.; Reissig, H.-U. *Liebigs Ann. Chem.* **1991,** 553–562. doi:10.1002/jlac.1991199101101
18. Zimmer, R.; Reissig, H.-U. *J. Org. Chem.* **1992,** *57,* 339–347. doi:10.1021/jo00027a058
19. Zimmer, R.; Reissig, H.-U.; Lindner, H. J. *Liebigs Ann. Chem.* **1992,** 621–624. doi:10.1002/jlac.1992199201106
20. Zimmer, R.; Hoffmann, M.; Reissig, H.-U. *Chem. Ber.* **1992,** *125,* 2243–2248. doi:10.1002/cber.19921251012
21. Zimmer, R.; Homann, K.; Reissig, H.-U. *Liebigs Ann. Chem.* **1993,** 1155–1157. doi:10.1002/jlac.1993199301186
22. Zimmer, R.; Collas, M.; Czerwonka, R.; Hain, U.; Reissig, H.-U. *Synthesis* **2008,** 237–244. doi:10.1055/s-2007-990946
23. Buchholz, M.; Reissig, H.-U. *Eur. J. Org. Chem.* **2003,** 3524–3533. doi:10.1002/ejoc.200300234
24. Reissig, H.-U.; Homann, K.; Hiller, F.; Zimmer, R. *Synthesis* **2007,** 2681–2689. doi:10.1055/s-2007-983802
25. Zimmer, R.; Homann, K.; Angermann, J.; Reissig, H.-U. *Synthesis* **1999,** 1223–1235. doi:10.1055/s-1999-3524
26. Buchholz, M.; Reissig, H.-U. *Synthesis* **2002,** 1412–1422. doi:10.1055/s-2002-33107
27. Schmidt, E.; Reissig, H.-U.; Zimmer, R. *Synthesis* **2006,** 2074–2084. doi:10.1055/s-2006-942403
28. Birkofer, L.; Feldmann, H. *Liebigs Ann. Chem.* **1964,** *677,* 150–153. doi:10.1002/jlac.19646770121
29. Abramovitch, R. A.; Shinkai, I.; Cue, B. W.; Ragan, F. A.; Atwood, J. C. *J. Heterocycl. Chem.* **1976,** *13,* 415–417. doi:10.1002/jhet.5570130247
30. Baird, M. S.; Li, X.; Al-Dulayymi, J. R.; Kurdjukov, A. I.; Pavlov, V. A. *J. Chem. Soc., Perkin Trans. 1* **1993,** 2507–2508. doi:10.1039/P19930002507
31. Paulini, K.; Reissig, H.-U. *Chem. Ber.* **1994,** *127,* 685–689. doi:10.1002/cber.19941270418
32. Zimmer, R.; Angermann, J.; Hain, U.; Hiller, F.; Reissig, H.-U. *Synthesis* **1997,** 1467–1474. doi:10.1055/s-1997-1373
33. Duhs, M.-A. Bachelor Thesis, Freie Universität Berlin, 2006.
34. Zimmer, R.; Reissig, H.-U.; Homann, K. *J. Prakt. Chem.* **1995,** *337,* 521–528. doi:10.1002/prac.199533701112
35. Homann, K.; Zimmer, R.; Reissig, H.-U. *Heterocycles* **1995,** *40,* 531–537. doi:10.3987/COM-94-S77

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