Palladium Catalysis in the Preparation of Alkynylpyrimidines

Jan Solberg and Kjell Undheim

Department of Chemistry, University of Oslo, 0315 Oslo 3, Norway

Solberg, Jan and Undheim, Kjell, 1986. Palladium Catalysis in the Preparation of Alkynylpyrimidines. – Acta Chem. Scand. B 40: 381–386.

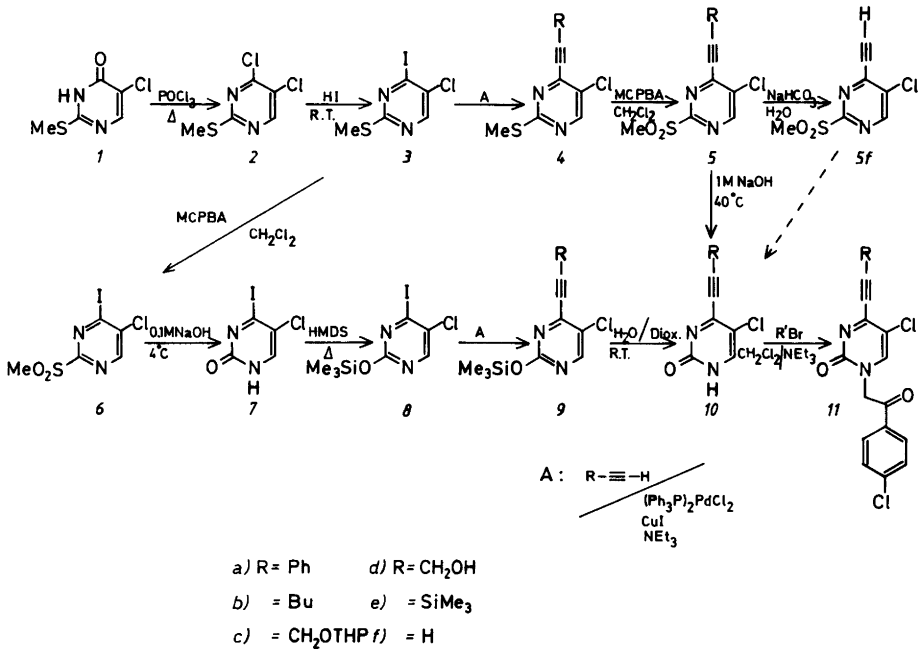
4-Ethynyl derivatives of 5-chloro-2-methylthiopyrimidines, and of 5-chloro-2(1*H*)-pyrimidinones as trimethylsilyl derivatives, have been prepared by cross-coupling reactions between 4-iodopyrimidines and acetylenes using palladium catalysis. Reactions for the conversion of the coupling products to 2(1*H*)-pyrimidinones are described. Simple 4-alkynyl derivatives of 2(1*H*)-pyrimidinones are sensitive to alkali, especially the free acetylenic derivative. Phenyl substitution of the acetylenic function gave chemically stable compounds.

Carbon-carbon bond formation in π-electron deficient heterocycles may be effected by formation of 1:1-adducts with organometallic reagents (*e.g.* from Li, Mg, Cu, Zn, Ti), and subsequent dehydrogenation to the respective heteroaromatics.[1,2] The nature of the organometallic reagent will greatly affect the regioselectivity;[3] tri-isopropoxytitanium reagents may be highly regioselective.[4] Because of our interest in the biological properties of substituted 2(1*H*)-pyrimidinones, particularly as arrestor of the cell cycle during mitosis,[5] we also investigated methods for the introduction of an alkynyl substituent into 1-substituted 2(1*H*)-pyrimidinones. With ethynyllithium and ethynylmagnesium reagents, 1:1 adducts of the 3,4- and 3,6-dihydro isomers are formed; with the tri-isopropoxytitanium reagent, exclusive addition of the ethynyl substituent in the 4-position was observed.[6] The adducts with simple acetylenes, however, were difficult to rearomatize without decomposition. We therefore report an alternative route for the preparation of ethynyl derivatives using palladium catalyzed coupling reactions.

Terminal alkynes undergo facile cross-coupling with aryl and heteroaryl halides in the presence of amines, the catalyst being Pd(O) which is generated *in situ* from the bis(triphenylphosphine)-palladium dichloride-copper(I) iodide system.[7] This reaction has been applied to simple alkyl 2- and 4-iodopyrimidines.[7b] We herein report studies on coupling reactions of the 4-iodo compound *3*. The latter was available by selective exchange of the 4-chloro substituent in *2* using hydroiodic acid at ambient temperature. Compound *2* was prepared by the phosphorus oxychloride reaction with the 4-pyrimidinone *1*.

The coupling proceeds exclusively at C-4 because iodo compounds are generally more reactive in coupling reactions than chloro compounds, and the iodine is situated in an activated pyrimidine position. Yields of about 80 % were isolated in the coupling reactions between *3* and 1-hexyne or phenylacetylene. Both propargyl alcohol and its *O*-tetrahydropyranyl derivative coupled to furnish *4c* and *4d*. In the case of acetylene, its trimethylsilyl derivative[8] was used in order to prevent couplings at both ends of the triple bond.

For the subsequent conversion of *4* to the 2-pyrimidinones *10*, the former were oxidized to the sulfones *5* by means of *m*-chloroperbenzoic acid and the sulfones hydrolyzed under alkaline conditions. The 4-phenylacetylene derivative *5a* readily yields *10a*. The other derivatives were partly or fully polymerized under the alkaline conditions of the reaction. The trimethylsilyl group in *5e* is very sensitive to alkaline hydrolysis and is selectively cleaved by aqueous sodium bicarbonate to furnish *5f*, but the latter was poly-



merized when hydrolysis of the sulfonyl group was attempted. It is known that the ease of cleavage of the trimethylsilyl-ethynyl bond is promoted by electron-withdrawing substituents;[9] in *5e* the electron-withdrawing function consists of the π-electron deficient pyrimidine ring which has its electron-withdrawing effect enhanced by its sulfonyl substituent.

Since the 4-ethynyl derivatives, with the exception of the phenylacetylene derivative, were sensitive to alkali, another route for the preparation of *10* was explored where the base treatment after coupling is avoided. The first step involves oxidation of the sulfide *3* to the sulfone *6* which could be effected without iodine liberation by the use of *m*-chloroperbenzoic acid in the cold. Under controlled alkaline conditions the 2-sulfonyl substituent in *6* can be hydrolyzed preferentially although C-2 is less activated than C-4. 5-Chlorouracil, however, was a co-product; compound *7* was selectively precipitated from an acid solution of the mixture and was silylated by means of hexamethyldisilazane (HMDS) and the product *8* subjected to palladium catalyzed coupling reactions. Dry conditions in the coupling reactions were assured by carrying out the reactions in the presence of some HMDS. The coupling reactions proceeded readily, and the silyl group in the products was removed by hydrolysis in aqueous dioxane. In this way *10a* and *10b* became available. The 4-acetylene derivative *10f*, and in part the propargyl alcohol derivative *10c*, were polymerized during the aqueous hydrolysis. The instability of these compounds is attributed to the electron withdrawing properties of the pyrimidine ring.

The pyrimidinones *10a* and *10b* were alkylated selectively on N-1 in the reaction with *p*-chlorophenacyl bromide under alkaline conditions.

Experimental

The ^{1}H NMR spectra were recorded at 60 MHz. The mass spectra under electron impact conditions were recorded at 70 eV ionizing voltage. Isobutane was used for chemical ionization (CI) mass spectra.

4,5-Dichloro-2-methylthiopyrimidine (2). A mixture of 5-chloro-2-methylthio-4(1*H*)-pyrimidinone[10] (50.0 g, 0.28 mol) and phosphorus oxychloride (380 ml) was heated under reflux for 2 h. The excess phosphorus oxychloride was distilled off, the residue triturated with water, extracted

into chloroform and the solution shaken with aqueous sodium bicarbonate, washed and dried ($MgSO_4$) before evaporation of the solvent. The residual material was distilled on a Fischer Spaltrohr column; yield 44.0 g (80 %), b.p. 121–122 C/8 mmHg. Anal. $C_5H_4Cl_2N_2S$: C,H. ^{1}H NMR ($CDCl_3$): δ 2.58 (SMe), 8.50 (H-6). MS: 198/196/194 (13/68/100, M), 195 (32), 193 (36), 159 (17), 150 (37), 149 (17), 148 (56).

5-Chloro-4-iodo-2-methylthiopyrimidine (3). 4,5-Dichloro-2-methylthiopyrimidine (19.0 g, 97.2 mmol) was added to hydroiodic acid (57 %, 180 ml) and the mixture stirred at ambient temperature for 60 h. The solid precipitate was collected and added to water (50 ml). The resultant slurry was neutralized by slow addition of solid potassium carbonate and extracted with chloroform. The chloroform solution was shaken with aqueous sodium sulfite, dried ($MgSO_4$) and evaporated. The residue was crystallized from light petroleum; yield 25.5 g (92 %), m.p. 106 °C. Anal. $C_5H_4ClIN_2S$: C,H. ^{1}H NMR ($CDCl_3$): δ 2.48 (MeS), 8.10 (H-6). MS: 288/286 (36/100, M), 161 (11), 159 (32), 146 (6), 144 (16).

General procedures for the preparation of 4-alkynyl-5-chloro-2-methylthiopyrimidines (4). 5-chloro-4-iodo-2-methylthiopyrimidine (10 mmol) and the alkyne (12 mmol) were dissolved in triethylamine (60 ml) at 0 °C to which had been added bis(triphenylphosphine)palladium dichloride (0.1 mmol) and cuprous iodide (0.05 mmol). The mixture was allowed to reach ambient temperature and stirred for 20 h. The triethylamine was removed at reduced pressure, water (100 ml) added and the mixture extracted with chloroform. The washed and dried ($MgSO_4$) chloroform solution was evaporated. The crude product was further purified either by chromatography or by crystallizations.

5-Chloro-2-methylthio-4-(phenylethynyl)pyrimidine (4a). This was obtained as above from phenylacetylene. The crude product was crystallized from light petroleum; yield 83 %, m.p. 80 °C. Anal $C_{13}H_9ClN_2S$: C,H. ^{1}H NMR ($CDCl_3$): σ 2.55 (MeS), 7.1–7.6 (Ph), 8.37 (H-6). MS: 262/260 (35/100, M), 216 (6), 214 (17), 179 (43), 152 (10).

5-Chloro-4(hex-1-yn-1-yl)-2-methylthiopyrimidine (4b). This was obtained from 1-hexyne. The crude product was purified by flash chromatography on silica gel; eluant dichloromethane – light petroleum, ratio 1:1. The product was non-crystalline; yield 80 %, b.p. 128–130 °C/0.1 mmHg. Anal. $C_{11}H_{13}ClN_2S$: C,H. ^{1}H NMR ($CDCl_3$): δ 0.95/1.4–1.9/2.3–2.8 (Bu-C≡), 2.57 (SMe), 8.45 (H-6). MS: 243/241 (5/15), 242/240 (34/100, M), 198 (10), 197 (9), 194 (14), 165 (8).

5-Chloro-2-methylthio-4-(tetrahydropyran-2-yloxymethylethynyl)pyrimidine (4c). This was prepared as above from the *O*-tetrahydropyran-2-yl derivative[11a] of propargyl alcohol. During the work-up of the reaction mixture the chloroform solution was dried by potassium carbonate instead of magnesium sulfate.[11b] The crude product was purified by flash chromatography on silica gel; eluant 1.5 % ethyl acetate in dichloromethane; yield 74 %, m.p. 63–64 °C. Anal. $C_{13}H_{15}ClN_2O_2S$: C,H. ^{1}H NMR ($CDCl_3$): δ 1.4–2.0/3.3–4.2/4.9 (THP), 2.55 (SMe), 4.58 (CH_2O, s), 8.48 (H-6). MS: 300/298 (2/6, M), 216/214 (9/28), 200/198 (30/100), 199 (13), 197 (18), 196 (18).

5-Chloro-4-(hydroxymethylethynyl)-2-methylthiopyrimidine (4d). This was prepared as above from propargyl alcohol. The crude product was purified by crystallization from toluene; yield 70 %, m.p. 114–116 °C. Anal. $C_8H_7ClN_2OS$: C,H. ^{1}H NMR ($CDCl_3$): δ 2.49 (MeS), 2.88 (OH), 4.52 (CH_2), 8.32 (H-6). MS: 216/214 (35/100, M), 196 (26), 185 (18), 168 (17), 150 (16).

5-Chloro-2-methylthio-4-(trimethylsilylethynyl)-pyrimidine (4e). This was obtained as above from trimethylsilylacetylene.[8] The crude product was purified by flash chromatography on silica gel; eluant ligh petroleum – dichloromethane, ratio 3:2; yield 86 %, m.p. 38–39 °C (sublimation). Anal. $C_{10}H_{13}ClN_2SSi$: C,H. ^{1}H NMR ($CDCl_3$): δ 0.31 (Me_3Si), 2.51 (SMe), 8.32 (H-6). MS: 258/256 (41/100, M), 257 (18), 243 (27), 242 (11), 241 (68).

General procedures for the preparation of 4-alkynyl-5-chloro-2-methylsulfonylpyrimidines (5). m-Chloroperbenzoic acid (30 mmol) was added to a solution of the 4-alkynyl-5-chloro-2-methylthiopyrimidine (10 mmol) in dichloromethane (250 ml) at 0 °C. The reaction mixture was stirred at 4 °C for 20 h. The resultant solution was

shaken with sodium sulfite, with aqueous sodium bicarbonate and water. The dried ($MgSO_4$) solution was evaporated, and the crude product was purified further by crystallizations.

5-Chloro-2-methylsulfonyl-4-(phenylethynyl)pyrimidine (5a). This was obtained as above from the sulfide *4a* and was purified by crystallization from 2-propanol; yield 90%, m.p. 174°C. Anal. $C_{13}H_9ClN_2O_2S$: C,H. ^1H NMR ($CDCl_3$): δ 3.36 ($MeSO_2$), 7.2–7.7 (Ph), 8.80 (H-6). MS: 294/292 (37/100, M), 215/213 (26/79), 186 (24), 161 (23), 151 (38).

5-Chloro-4(hex-1-yn-1-yl)-2-methylsulfonylpyrimidine (5b). This was prepared as above from the sulfide *4b* and was purified by crystallization from 2-propanol; yield 74%, m.p. 61°C. Anal. $C_{11}H_{13}ClN_2O_2S$: C,H. ^1H NMR ($CDCl_3$): δ 0.97/1.4–1.9/2.4–2.8 (Bu-C≡), 3.37 ($MeSO_2$), 8.87 (H-6). MS: 274/272 (3/13, M), 232 (30), 230 (85), 195 (23), 193 (75).

5-Chloro-2-methylsulfonyl-4-(tetrahydropyran-2-yloxymethylethynyl)pyrimidine (5c). This was prepared as above from the sulfide *4c*. Potassium carbonate was used for drying the solution of the product instead of magnesium sulfate as specified in the general procedure. *4c* Was purified by crystallization from ethanol; yield 43%, m.p. 71°C. Anal. $C_{13}H_{15}ClN_2O_4S$: C,H. ^1H NMR ($CDCl_3$): δ 1.4–2.0/3.3–4.2/4.9 (THP), 3.37 ($MeSO_2$), 8.88 (H-6). MS: 277/275 (23/61), 233/230 (39/100), 231 (34), 229 (57). MS(CI): 333/331 (38/100, M+H).

5-Chloro-2-methylsulfonyl-4-(trimethylsilylethynyl)pyrimidine (5e). This was obtained as above from the sulfide *4e* and was purified by crystallization from 2-propanol; yield 83%, m.p. 99°C. Anal. $C_{10}H_{13}ClN_2O_2SSi$: C,H. ^1H NMR ($CDCl_3$): δ 0.35 (Me_3Si), 3.38 ($MeSO_2$), 8.92 (H-6). MS: 275/273 (39/100), 274 (16), 225 (13), MS(CI): 291/289 (42/100, M+H).

5-Chloro-4-ethynyl-2-methylsulfonylpyrimidine (5f). Aqueous, saturated sodium bicarbonate (10 ml) was added to a solution of 5-chloro-2-methylsulfonyl-4-(trimethylsilylethynyl)pyrimidine (0.50 g, 1.7 mmol) in tetrahydrofuran (30 ml) and the mixture stirred at ambient temperature for 30 min. Water (50 ml) was added and the resultant mixture extracted (×4) with diethyl ether. The ether extracts were washed with aqueous sodium chloride, dried ($MgSO_4$) and evaporated, and the residual material crystallized from 2-propanol; yield 76%, m.p. 123°C. Anal. $C_7H_5ClN_2O_2S$: C,H. ^1H NMR ($CDCl_3$): σ 3.38 ($MeSO_2$), 3.95 (≡CH), 8.93 (H-6). MS: 218/216 (5/15, M), 154 (42), 152 (21), 139 (32), 137 (100), 126 (23).

5-Chloro-4-iodo-2-methylsulfonylpyrimidine (6). *m*-Chloroperbenzoic acid (11.0 g, 63.0 mmol) was added to a solution of 5-chloro-4-iodo-2-methylthiopyrimidine (6.0 g, 21.0 mmol) in dichloromethane (600 ml) at 0°C, and the mixture stirred at 4°C for 20 h. The resultant solution was shaken with saturated aqueous sodium sulfite, then with saturated aqueous sodium bicarbonate and the dried ($MgSO_4$) solution evaporated. The residual material was crystallized from 2-propanol; yield 5.8 g (87%), m.p. 136–138°C. Anal. $C_5H_4ClIN_2O_2S$: C,H. ^1H NMR ($CDCl_3$): δ 3.33 ($MeSO_2$) 8.53 (H-6). MS: 320/318 (12/33, M), 256 (17), 254 (18), 241 (12), 239 (36), 127 (50), 63 (100).

5-Chloro-4-iodo-2(1H)-pyrimidinone (7). 5-Chloro-4-iodo-2-methylsulfonylpyrimidine (9.4 g, 29.4 mmol) was suspended in 0.1 M NaOH (1.0 l) and the mixture stirred at 4°C for 16 h. The mixture was filtered and the filtrate neutralized by 1 M sulfuric acid. The white solid precipitate was collected, washed with water and dried (N_2); yield 5.3 g (70%). The product turns purple on storage and was therefore used in the subsequent reaction without further purification. ^1H NMR (DMSO-d_6): δ 8.30 (H-6), 13.1 (NH). MS: 258/256 (30/95, M), 131 (30), 130 (32), 129 (88), 128 (100).

5-Chloro-4-iodo-2-(trimethylsilyloxy)pyrimidine (8). 5-Chloro-4-iodo-2(1*H*)-pyrimidinone (5.3 g, 20.7 mmol) was added to HMDS (100 ml) and the mixture heated under reflux (N_2) for 2 h when a clear solution was obtained. The solution was evaporated to dryness and the residue crystallized from HMDS; yield 3.4 g (50%). The product was stored under N_2. ^1H NMR ($CDCl_3$): δ 0.39 (Me_3Si), 8.29 (H-6). MS: 330/328 (7/22, M), 315/313, (16/49), 276/274 (11/31), 254 (19), 203/201 (13/36), 185 (100).

General procedures for the preparation of 4-alkynyl-5-chloro-2-(trimethylsilyloxy)pyrimidine (9). 5-Chloro-4-iodo-2-(trimethylsilyloxy)pyrimidine (6 mmol) and the ethynyl derivative (7 mmol) were dissolved in dry triethylamine (40 ml) at 0 °C to which had been added 2–5 % HMDS, bis(triphenylphosphine)palladium dichloride (0.06 mmol) and cuprous iodide (0.03 mmol). The mixture was stirred at room temperature for 20 h, passed through a dry, sintered glass filter and the filtrate evaporated. The crude product thus obtained was a non-crystalline material.

5-Chloro-4-phenylethynyl-2-(trimethylsilyloxy)-pyrimidine (9a). This was prepared as above from phenylacetylene in 83 % yield. ^{1}H NMR ($CDCl_3$): δ 0.35 (Me_3Si), 7.2–7.7 (Ph), 8.42 (H-6). MS: 302 (0.4, M), 287 (0.5), 179 (2), 108 (4), 95/93 (36/100).

5-Chloro-4-(hex-1-yn-1-yl)-2-(trimethylsilyloxy)-pyrimidine (9b). This was prepared as above from 1-hexyne in 80 % yield. ^{1}H NMR ($CDCl_3$): δ 0.40 (Me_3Si), 1.0/1.3–1.9/2.3–2.7 (Bu-C≡), 8.40 (H-6). MS: 284/282 (15/40, M), 269/267 (39/100), 270 (16), 268 (19).

5-Chloro-4-(tetrahydropyran-2-yloxymethylethynyl)-2-(trimethylsilyloxy)pyrimidine (9c). This was obtained as above from the *O*-tetrahydropyran-2-yl derivative of propargyl alcohol;[11] yield 85 %. ^{1}H NMR ($CDCl_3$): δ 0.35 (Me_3Si), 1.3–2.0/3.3–4.2/4.9 (THP), 4.57 (CH_2O), 8.50 (H-6). MS: 342/340 (0.5/1.5, M), 327/325 (4/12), 269 (10), 258 (10), 256 (29), 242 (43), 241 (79), 240 (100).

5-Chloro-4-trimethylsilylethynyl-2-trimethylsilyloxy)pyrimidine (9e). This was obtained as above from trimethylsilylacetylene[8] in 80 % yield. ^{1}H NMR ($CDCl_3$): δ 0.39 (2 Me_3Si), 8.32 (H-6). MS: 300/298 (17/41,M), 285 (39), 284 (23), 282 (100), 155 (12).

4-Alkynyl-5-chloro-2(1H)-pyrimidinone 10 by hydrolysis of 5. 5-chloro-4-phenylethynyl-2(1-H)-pyrimidinone (10a). This was prepared from 5-chloro-2-methylsulfonyl-4-phenylethynylpyrimidine (4.63 g, 15.83 mmol) which was added to 1 M NaOH (300 ml) and the mixture stirred at 40° for 3 d. The cold reaction mixture was filtered and the filtrate neutralized by 3 M HCl. The precipitate was collected and washed with water and a little ethanol; yield 2.30 g (63 %), m.p. 180 °C (decomp.). ^{1}H NMR (DMSO-d_6): δ 5.4 (NH), 7.60 (Ph), 8.35 (H-6). MS: 232/230 (33/100, M), 202 (42), 140 (21), 128 (37).

4-Alkynyl-5-chloro-2(1H)-pyrimidinone 10 by hydrolysis of (9). The 4-alkynyl-5-chloro-2-(trimethylsilyloxy)pyrimidine (10 mmol) was dissolved in dioxane (15 ml) and water (30 ml) added. The mixture was stirred at ambient temperature for 30 min and then freeze-dried to yield the product.

5-Chloro-4-phenylethynyl-2(1H)-pyrimidinone (10a). This was obtained as above in 90 % yield; physical data as above.

5-Chloro-4-(hex-1-yn-1-yl)-2(1H)-pyrimidinone (10b). This was obtained as above in 77 % yield; m.p. 123 °C. Anal. $C_{10}H_{11}ClN_2O$; C,H. ^{1}H NMR ($CDCl^3$): δ 0.95/1.3–1.9/2.3–2.8 (Bu-C≡), 8.32 (H-6). MS: 212/210 (20/62, M), 211 (11), 209 (14), 195 (26), 183 (29), 170 (31), 168 (100).

5-Chloro-1-(4-chlorophenacyl)-4-phenylethynyl-2(1H)-pyrimidinone (11a). 4-Chlorophenacyl bromide (2.43 g, 10.4 mmol) in dichloromethane (50 ml) was added with stirring to a solution from triethylamine (1.2 ml, 8.7 mmol) and 5-chloro-4-phenylethynyl-2(1*H*)-pyrimidinone (2.00 g, 8.7 mmol) in dichloromethane (250 ml) at 0 °C. The mixture was stirred at ambient temperature for 20 h before the precipitate was collected by filtration and washed with diethyl ether; yield 1.91 g (58 %), m.p. 218 °C (decomp.). Anal. $C_{20}C_{12}Cl_2N_2O_2$: C,H. ^{1}H NMR (TFA): δ 5.88 (CH_2), 7.4–8.2 (2 Ar), 8.90 (H-6). MS: 386/384/382 (2/9/13, M), 385 (3), 383 (4), 243 (13), 141/139 (31/100).

5-Chloro-1-(4-chlorophenacyl)-4-(hex-1-yn-2-yl)-2(1H)-pyrimidinone (11b) was prepared as above from 5-chloro-4-(hex-1-yn-1-yl)-2(1*H*)-pyrimidinone, except that the stirring at ambient temperature lasted 5 h. The solution was then extracted with water, the dried ($MgSO_4$) solution reduced to *ca.* 30 ml and cooled to −20 °C when the product crystallized out; yield 41 %; m.p. 188 °C (decomp., EtOAc). Anal. $C_{18}H_{16}Cl_2N_2O_2$: C,H. ^{1}H NMR ($CDCl_3$): δ 0.95/1.4–1.8/2.3–2.7 (Bu-

C≡), 5.29 (CH_2), 7.3–8.0 (2 Ar), 7.71 (H-6). MS: 366/364/362 (5/24/37, M), 365 (5), 363 (8), 337 (5), 335 (25), 333 (37), 209 (49), 141 (31), 139 (100).

Acknowledgement. We gratefully acknowledge financial support (J.S.) for this work from the Royal Norwegian Council for Scientific and Industrial Research.

References

1. Rise, F., Rømming, C. and Undheim, K. *Acta Chem. Scand. B39* (1985) 459.
2. (a) Elmoghayar, M. R. H. and Undheim, K. *Acta Chem. Scand. B37* (1983) 160; (b) Rise, F., Ongstad, L., Gacek, M. and Undheim, K. *Acta Chem. Scand. B37* (1983) 613; (c) Rasmussen, A., Rise, F. and Undheim, K. *Acta Chem. Scand. B39* (1985) 235; (d) Rise, F. and Undheim, K. *Acta Chem. Scand. B39* (1985) 195; (e) Katoh, A., Omote, Y. and Kashima, C. *J. Heterocycl. Chem. 21* (1984) 53; (f) Kauffmann, T. *Angew. Chem. 91* (1979) 1.
3. (a) Kashima, C., Katoh, A., Yokota, Y. and Omote, Y. *J. Chem. Soc. Perkin Trans 1* (1981) 489; (b) Coppola, G. M., Fraser, J. D., Hardtmann, G. E., Huegi, B. S. and Kathawala, F. G. *J. Heterocycl. Chem. 16* (1979) 545; (c) Hardtmann, G. E. and Ott, H. *U.S. Patent* 3663, 698 (1972); (d) Bredereck, H., Gompper, R. and Herlinger, H., *Chem. Ber. 91* (1958) 2832; (e) van der Stoel, R. E., van der Plas, H. C., Jongejan, H. and Hoeve, L. *Recl. Trans. Chim. Pays-Bas 99* (1980) 234.
4. Rise, F. and Undheim, K. *J. Chem. Soc. Perkin Trans. 1* (1985) 1997.
5. Gacek, M., Undheim, K., Oftebro, R. and Laland, S. G. *FEBS. Lett. 98* (1979) 355.
6. Rise, F. and Undheim, K. *J. Organomet. Chem. 291* (1985) 139.
7. (a) Sonogashira, K., Tohda, Y. and Hagihara, N. *Tetrahedron Lett.* (1975) 4467; (b) Edo, K., Yamanaka, H. and Sakamoto, T. *Heterocycles 9* (1978) 271; (c) Edo, K., Sakamoto, T. and Yamanaka, H. *Chem. Pharm. Bull. Jpn. 26* (1978) 3843; (d) Sakamoto, T., Kondo, Y. and Yamanaka, H. *Chem. Pharm. Bull. Jpn. 30* (1982) 2410, 2417; (e) Abe, Y., Ohsawa, A., Arai, H. and Igeta, H. *Heterocycles 9* (1978) 1397; (f) Koyama, S., Kumazawa, Z. and Kashimura, N. *Nucleic Acids Research* (1982) 41.
8. West, R. and Quass, L. C. *J. Organomet. Chem. 18* (1969) 55.
9. Chvalovsky, V. In: Becker, E. I. and Tsutsui, M., eds. *Organometallic Reactions*, Wiley-Interscience, New York 1972, Vol. 3, p. 191.
10. West, R. A. and Barrett, H. W. *J. Am. Chem. Soc. 76* (1954) 3146.
11. (a) Henbest, H. B., Jones, E. R. H. and Walls, I. M. S. *J. Chem. Soc.* (1950) 3646; (b) Robertson, D. N. *J. Org. Chem. 25* (1960) 931.

Received November 26, 1985.