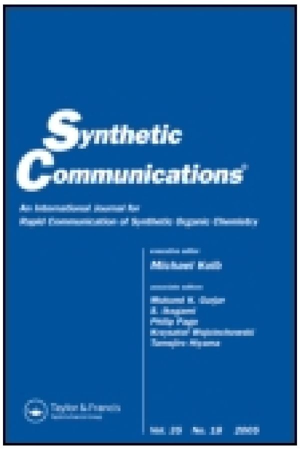

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SIMPLE SYNTHESIS OF N-ALKOXYMETHYL DERIVATIVES OF ANILIDES

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SIMPLE SYNTHESIS OF *N*-ALKOXYMETHYL DERIVATIVES OF ANILIDES

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ABSTRACT

Facile, two-step synthesis of *N*-alkoxymethyl derivatives of anilides consisting of the methoxymethylation of the appropriate anilides with chlomethyl methyl ether followed by heating with an alcohol in the presence of an acid is described.

N-Alkoxymethyl derivatives of anilides (**1**) are compounds of considerable interest due to their herbicidal activity. An important group of them are *N*-(alkoxymethyl)-2-chloroacetanilide derivatives, e.g. Alachlor® (**1**, R^1=CH_2Cl, R^2=CH_3, R^3=R^4=C_2H_5), which are manufactured as commercial herbicides on the large scale.[1–4]

There are a few methods of synthesis of this type of compounds. Usually, they are prepared in several steps starting from the appropriate anilines and aldehydes.[5,6] This type of reactions involves *N*-acyliminium salt intermediate, which is not easy for operating. Another competitive

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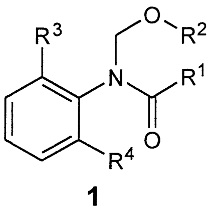

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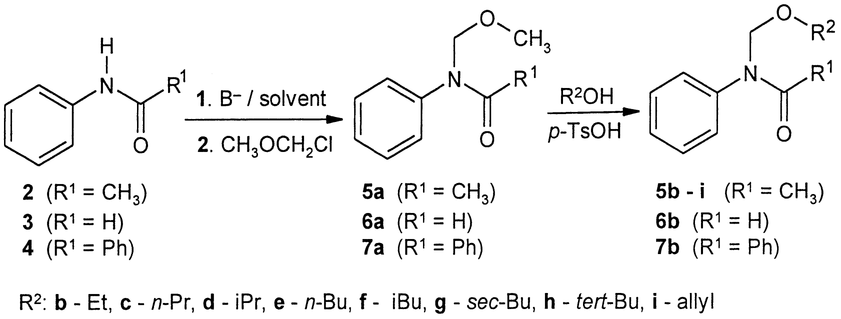
method for the synthesis of these compounds consists of the alkylation with the corresponding alkoxymethyl chlorides.[7] However, preparation of the alkoxymethyl chlorides by the method described by Wedekind is difficult and inconvenient.[8]

In the present paper we would like to report a simple, two step synthesis of *N*-alkoxymethyl derivatives of acetanilide, formanilide and benzanilide. In the first step *N*-(methoxymethyl)anilides are prepared from the corresponding anilides by the action of methoxymethyl chloride under Phase Transfer Catalysis (PTC) conditions in the presence of the solid base and catalytic amount of tetraalkylammonium salt. Alternatively, *tert*-BuOK-THF system can be used for alkylation. The second step consists of the heating up the *N*-(methoxymethyl)-anilides with an excess of the aliphatic alcohols with catalytic amount of *p*-toluenesulfonic acid (Scheme 1).



Scheme 1.

Although the procedure of methoxymethylation of the amidic nitrogen atom with methoxymethyl chloride in the presence of 50% $NaOH_{aq}$ and the appropriate PTC catalyst has been applied many times[7,9] there is no evidence of carrying out such reaction in PTC system with the solid base. In the course of the present work we have checked a few bases and solvents. It turned out that for *N*-methoxymethylation reaction of acetanilide and formanilide powdered KOH in DMSO in the presence of catalytic amount of tetrabutylammonium hydrogensulfate gave the best results. In the case of benzanilide, however, *tert*-BuOK solution in THF appeared to give the highest yield.

N-Methoxymethyl compounds (i.e. *N*,*O*-acetals) are known to produce iminium cations under acidic conditions.[10] In the presence of the nucleophile, generated iminium cation can be trapped to afford many interesting organic compounds, as it was presented in the syntheses of tetrahydroquinolines and julolidines.[11] There are no papers dealing with the reaction of *N*-methoxymethylated amides with alcohols as nucleophiles in acidic conditions. Only Villiger[12] and Muzic[13] during their investigations of the properties of *N*-alkoxymethyl *N*,*N*-dialkylamines stated that the course of discussed transformation is possible, although without any experimental details. It prompted us to study carefully this type of useful reaction especially in relation to compounds **1**. It's clear that this reaction can be applied to other similar compounds e.g. Alachlor® derivatives.

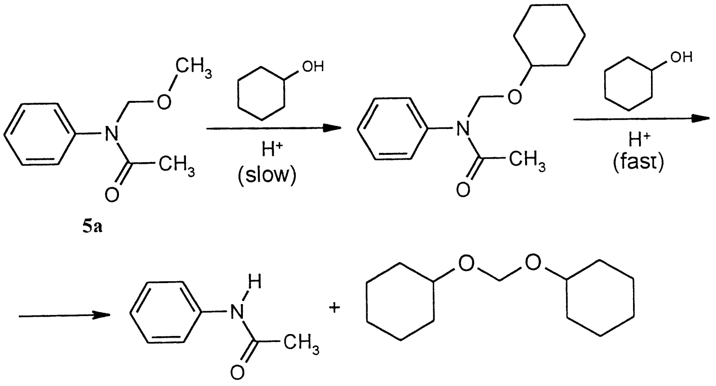
According to our method, *N*-(methoxymethyl)anilides are heated with an excess of the aliphatic alcohol for 1–4 h in the presence of *p*-toluenesulfonic acid to give various *N*-(alkoxymethyl)anilides in good yields (Table 1). It is obvious that the scope of this reaction is much broader and gives an easy access to many interesting compounds.

Surprisingly, we have found that unlike other performed reactions, *N*-(methoxymethyl)acetanilide reacts with cyclohexanol at 60°C in the presence of the catalytic amount of *p*-TsOH to give an equimolar mixture of acetanilide and *bis*(cyclohexyloxy)methane instead of the expected

Table 1. Preparation of *N*-Alkoxymethylanilides from the Appropriate *N*-Methoxymethylanilides

Product	R^1	R^2	T (°C)	t (h)	Yield (%)
5b	Me	Et	78	1.5	92
5c	Me	*n*-Pr	60	1	90
5d	Me	Ipr	82	1.5	83
5e	Me	*n*-Bu	75	3	70
5f	Me	IBu	80	4	74
5g	Me	*sec*-Bu	85	3	90
5h	Me	*tert*-Bu	60	2	60
5i	Me	$CH_2CH{=}CH_2$	r.t.	24	81
6b	H	Et	78	3	67
7b	Ph	Et	78	2.5	93

N-(cyclohexyloxymethyl)acetanilide. This can be rationalized by the following reaction scheme:



The reason for such behaviour of cyclohexanol is not clear.

EXPERIMENTAL

^{1}H and ^{13}C NMR spectra were recorded on a Varian Gemini (200 MHz) instrument in $CDCl_3$ solution with tetramethylsilane as the internal standard. Mass spectra (EI, 70 eV) were obtained on AMD 604 (AMD Intectra GmbH, Germany) instrument. Purity of the prepared samples was checked by GC/MS analysis (HP 5890/5972A from Hewlett-Packard). Anilides **2–4** utilised in the synthesis are commercially available (Aldrich).

Methoxymethylation of Anilides in PTC System. General Procedure

To the suspension of anilide (**2–4**) (30 mmol), powdered KOH (or *tert*-BuOK for **4**) (90 mmol) and tetrabutylammonium hydrogensulfate (0.3 mmol) in DMSO (or THF for **4**) (50 mL) chloromethylmethyl ether (80 mmol) was added dropwise. After 1 h agitation at room temperature the reaction mixture was poured onto water and extracted with ethyl acetate (3 × 15 mL). The organic layer was dried over Na_2SO_4 and then the solvent was evaporated under reduced pressure, yielding the crude product (**5a–7a**) to be purified by column chromatography on silica gel using hexane–ethyl acetate mixture as an eluent.

***N*-(Methoxymethyl)acetanilide (5a).** Yield: 85%. Oil. ^{1}H NMR, δ: 1.90 (s, 3H, $COCH_3$); 3.42 (s, 3H, CH_3); 5.04 (s, 2H, NCH_2O); 7.18–7.48 (m, 5H, Ph). ^{13}C NMR, δ: 22.7 ($CO\underline{C}H_3$); 56.3 (OCH_3); 78.6 (NCH_2O); 128.0 (Ph); 129.5 (Ph); 142.1 (C-1 Ph); 171.5 ($\underline{C}OCH_3$). MS *m*/*z* (%): 179 ($M^{+\bullet}$, 48); 164 (50); 137 (15); 122 (19); 107 (11); 106 (100); 105 (58); 104 (23); 77 (35); 45 (44); 43 (32). HR MS calcd for $C_{10}H_{13}NO_2$: 179.0946, found: 179.0952.

***N*-(Methoxymethyl)formanilide (6a).** Yield: 90%. Oil. ^{1}H NMR, δ: 3.42 (s, 3H, OCH_3); 5.13 (s, 2H, NCH_2O); 7.23–7.50 (m, 5H, Ph); 8.56 (s, 1H, CHO). ^{13}C NMR, δ: 57.2 (OCH_3); 76.3 (NCH_2O); 124.4 (Ph); 127.8 (Ph); 129.7 (Ph); 142.0 (C-1 Ph); 163.7 (CHO). MS *m*/*z* (%): 165 ($M^{+\bullet}$, 29); 150 (24); 134 (10); 106 (46); 105 (30); 104 (29); 77 (42); 51 (13); 45 (100). HR MS calcd for $C_9H_{11}NO_2$: 165.0790, found: 165.0793.

***N*-(Methoxymethyl)benzanilide (7a).** Yield: 73%. Oil. ^{1}H NMR, δ: 3.42 (s, 3H, OCH_3); 5.19 (s, 2H, NCH_2O); 7.02–7.34 (m, 10H, Ph). ^{13}C NMR, δ: 57.2 (OCH_3); 80.7 (NCH_2O); 127.4 (Ph); 127.8 (Ph); 128.3 (Ph); 129.3 (Ph); 129.6 (Ph); 130.6 (Ph); 135.6 (C-1′ Ph); 143.5 (C-1 Ph); 171.9 (CHO). MS *m*/*z* (%): 241 ($M^{+\bullet}$, 31); 226 (30); 181 (10); 180 (12); 106 (16); 105 (100); 104 (17); 77 (71); 45 (30). HR MS calcd for $C_{15}H_{15}NO_2$: 241.1102, found: 241.1099.

Transetherification of *N*-(Methoxymethyl)anilides. General Procedure

Solution of *N*-(methoxymethyl)anilide (**5a–7a**) (20 mmol) and *p*-toluenesulphonic acid (0.2 mmol) in the appropriate aliphatic alcohol (50 mL) was heated during 1–4 h. (Only for compound **5i** the mixture was allowed to stay overnight at room temperature). The cooled reaction mixture was poured into aqueous $NaHCO_3$ solution and extracted with ethyl acetate (3 × 10 mL). The organic layer was dried over Na_2SO_4 and then the solvent was removed under reduced pressure to produce oily product (**5b–i**, **6b**, **7b**) in good yield which, when necessary, can be purified by column chromatography on silica gel.

***N*-(Ethoxymethyl)acetanilide (5b).** Oil. ^{1}H NMR, δ: 1.22 (t, 3H, $J = 7$ Hz, $OCH_2C\underline{H}_3$); 1.88 (s, 3H, $COCH_3$); 3.65 (q, 2H, $J = 7$ Hz, $OC\underline{H}_2CH_3$); 5.08 (s, 2H, NCH_2O); 7.18–7.47 (5H, Ph). ^{13}C NMR, δ: 14.9 ($\underline{C}H_3CH_2O$); 22.7 ($CO\underline{C}H_3$); 64.0 ($O\underline{C}H_2CH_3$); 76.9 (NCH_2O); 127.9 (Ph); 129.5 (Ph); 142 (C-1 Ph); 171.3 (CO). MS *m*/*z* (%): 193 ($M^{+\bullet}$, 3); 164 (73); 122 (40); 107 (13); 106 (100); 105 (57); 104 (31); 93 (51); 77 (52); 59 (25); 43 (35). HR MS calcd for $C_{11}H_{15}NO_2$: 193.1102, found: 193.1100.

_N_-(_n_-Propoxymethyl)acetanilide (5c). Oil. ^{1}H NMR, δ: 0.93 (t, 3H, J = 7.5 Hz, $OCH_2CH_2C\underline{H}_3$); 1.51–1.70 (m, 2H, $OCH_2C\underline{H}_2CH_3$); 1.89 (s, 3H, $COCH_3$); 3.55 (t, 3H, J = 6.8 Hz, $OC\underline{H}_2CH_2CH_3$); 5.09 (s, 2H, NCH_2O); 7.20–7.50 (m, 5H, Ph). ^{13}C NMR, δ: 11.3 ($OCH_2CH_2\underline{C}H_3$); 23.5 ($CO\underline{C}H_3$); 25.9 ($OCH_2\underline{C}H_2CH_3$); 71.2 ($OCH_2CH_2CH_3$); 77.8 ($NCH_2O$); 128.6 (Ph); 130.1 (Ph); 130.1 (Ph); 142.8 (C-1 Ph); 172.0 (CO). MS *m*/*z* (%): 207 ($M^{+\cdot}$, 6); 164 (79); 149 (10); 122 (58); 107 (13); 106 (100); 105 (45); 104 (20); 94 (11); 93 (93); 77 (31); 43 (61). HR MS calcd for $C_{12}H_{17}NO_2$: 207.1259, found: 207.1250.

_N_-(Isopropoxymethyl)acetanilide (5d). Oil. ^{1}H NMR, δ: 1.19 (d, 6H, J = 6.5 Hz, $OCH(C\underline{H}_3)_2$); 1.88 (s, 3H, $COCH_3$); 3.80–3.94 (m, 1H, $OC\underline{H}(CH_3)_2$); 5.10 (s, 2H, NCH_2O); 7.20–7.44 (m, 5H, Ph). ^{13}C NMR, δ: 22.3 ($OCH(\underline{C}H_3)_2$); 22.9 ($CO\underline{C}H_3$); 69.5 ($O\underline{C}H(CH_3)_2$); 75.1 (NCH_2O); 128.0 (Ph); 128.2 (Ph); 129.5 (Ph); 142.4 (C-1 Ph); 171.4 (CO). MS *m*/*z* (%): 207 ($M^{+\cdot}$, 10); 164 (55); 135 (16); 122 (24); 106 (45); 105 (14); 104 (12); 93 (100); 77 (19); 43 (24). HR MS calcd for $C_{12}H_{17}NO_2$: 207.1259, found: 207.1257.

_N_-(_n_-Butoxymethyl)acetanilide (5e). Oil. ^{1}H NMR, δ: 0.91 (t, 3H, J = 7.3 Hz, $OCH_2CH_2CH_2C\underline{H}_3$); 1.21–1.78 (m, 4H, $OCH_2C\underline{H}_2C\underline{H}_2CH_3$); 1.89 (s, 3H, $COCH_3$); 3.58 (t, 2H, J = 6.6 Hz, $OC\underline{H}_2CH_2CH_2CH_3$); 5.08 (s, 2H, NCH_2O); 7.12–7.60 (m, 5H, Ph). ^{13}C NMR, δ: 13.9 ($OCH_2CH_2CH_2C\underline{H}_3$); 19.3 ($OCH_2CH_2\underline{C}H_2CH_3$); 22.9 ($CO\underline{C}H_3$); 31.7 ($OCH_2\underline{C}H_2CH_2CH_3$); 68.7 ($O\underline{C}H_2CH_2CH_2CH_3$); 77.3 ($NCH_2O$); 128.1 (Ph); 128.9 (Ph); 129.5 (Ph); 142.2 (C-1 Ph); 171.5 (CO). MS *m*/*z* (%): 221 ($M^{+\cdot}$, 8); 164 (100); 149 (16); 148 (17); 135 (16); 122 (65); 106 (75); 105 (30); 93 (82); 77 (15); 57 (20); 43 (14). HR MS calcd for $C_{13}H_{19}NO_2$: 221.1416, found: 221.1414.

_N_-(_Iso_-butoxymethyl)acetanilide (5f). Oil. ^{1}H NMR, δ: 0.90 (d, 6H, J = 6.7 Hz, $OCH_2CH(C\underline{H}_3)_2$); 1.72–1.99 (m, 1H, $OCH_2C\underline{H}(CH_3)_2$); 1.89 (s, 3H, $COCH_3$); 3.36 (d, 2H, J = 6.6 Hz, $OC\underline{H}_2CH(CH_3)_2$); 5.09 (s, 2H, NCH_2O); 7.15–7.59 (m, 5H, Ph). ^{13}C NMR, δ: 19.4 ($OCH_2CH(\underline{C}H_3)_2$); 22.9 ($CO\underline{C}H_3$); 28.5 ($OCH_2\underline{C}H(CH_3)_2$); 75.7 ($O\underline{C}H_2CH(CH_3)_2$); 77.4 ($NCH_2O$); 128.1 (Ph); 128.8 (Ph); 129.5 (Ph); 142.2 (C-1 Ph); 171.5 (CO). MS *m*/*z* (%): 221 ($M^{+\cdot}$, 17); 164 (58); 149 (12); 148 (17); 135 (15); 122 (63); 106 (74); 105 (32); 93 (100); 77 (15); 57 (20); 43 (14). HR MS calcd for $C_{13}H_{19}NO_2$: 221.1416, found: 221.1411.

_N_-(_Sec_-butoxymethyl)acetanilide (5g). Oil. ^{1}H NMR, δ: 0.89 (t, 3H, J = 7.3 Hz), $OCH(CH_3)CH_2C\underline{H}_3$); 1.17 (d, 3H, J = 6.1 Hz, $OCH(C\underline{H}_3)CH_2CH_3$); 1.32–1.70 (m, 2H, $OCH(CH_3)C\underline{H}_2CH_3$); 1.88 (s, 3H, $COCH_3$); 3.51–3.78 (m, 1H, $OC\underline{H}(CH_3)CH_2CH_3$); 5.09 (s, 2H, NCH_2O); 7.17–7.58 (m, 5H, Ph). ^{13}C NMR, δ: 9.8 ($OCH(CH_3)CH_2\underline{C}H_3$); 19.4 ($OCH(\underline{C}H_3)CH_2CH_3$); 22.9 ($CO\underline{C}H_3$); 24.6 ($OCH(CH_3)\underline{C}H_2CH_3$); 74.9 ($O\underline{C}H(CH_3)CH_2CH_3$); 75.5 ($NCH_2O$); 128.1 (Ph); 129.0 (Ph); 129.5 (Ph); 141.1 (C-Ph); 170.9 (CO). MS *m*/*z* (%): 221 ($M^{+\cdot}$, 1); 164 (45); 148 (12); 135 (23); 122 (20);

106 (47); 93 (100); 77 (18); 57 (12); 43 (21). HR MS calcd for $C_{13}H_{19}NO_2$: 221.1416, found: 221.1415.

***N*-(*Tert*-butoxymethyl)acetanilide (5h).** Oil. ^{1}H NMR, δ: 1.20 (s, 9H, $OC(CH_3)_3$); 1.85 (s, 3H, $COCH_3$); 5.07 (s, 2H, NCH_2O); 7.22–7.44 (m, 5H, Ph). ^{13}C NMR, δ: 23.1 ($CO\underline{C}H_3$); 27.9 ($OC(\underline{C}H_3)_3$); 71.3 ($O\underline{C}(CH_3)_3$); 73.4 (NCH_2O); 127.9 (Ph); 128.5 (Ph); 129.2 (Ph); 142.5 (C-1 Ph); 170.6 (CO). MS *m*/*z* (%): 221 ($M^{+\bullet}$, 1); 164 (45); 148 (10); 135 (67); 122 (19); 106 (42); 105 (11); 104 (10); 93 (100); 77 (18); 57 (35); 43 (39); 41 (41). HR MS calcd for $C_{13}H_{19}NO_2$: 221.1416, found: 221.1420.

***N*-(*n*-Allyloxymethyl)acetanilide (5i).** Oil. ^{1}H NMR (CD_3OD), δ: 1.87 (s, 3H, $COCH_3$); 4.08 (d, 2H, J = 5.4 Hz, $OC\underline{H_2}CH{=}CH_2$); 5.06 (s, 2H, NCH_2O); 5.10–5.40 (m, 2H, $OCH_2CH{=}C\underline{H_2}$); 5.78–6.02 (m, 1H, $OCH_2C\underline{H}{=}CH_2$); 7.15–7.59 (m, 5H, Ph). ^{13}C NMR (CD_3OD), δ: 22.9 ($CO\underline{C}H_3$); 70.5 ($O\underline{C}H_2CH{=}CH_2$); 77.9 ($NCH_2O$); 117.3 ($OCH_2CH{=}\underline{C}H_2$); 129.3 (Ph); 129.4 (Ph); 130.7 (Ph); 135.4 ($OCH_2\underline{C}H{=}CH_2$); 142.3 (C-1 Ph); 172.0 (CO). MS *m*/*z* (%): 205 ($M^{+\bullet}$, 1); 164 (51); 149 (17); 148 (39); 135 (23); 133 (24); 132 (36); 127 (15); 122 (49); 106 (100); 105 (29); 104 (23); 93 (47); 77 (20), 43 (47); 41 (80). HR MS calcd for $C_{12}H_{15}NO_2$: 205.1103, found: 205.1102.

***N*-(Ethoxymethyl)formanilide (6b).** Oil. ^{1}H NMR, δ: 1.22 (t, 3H, J = 7 Hz, $OCH_2C\underline{H_3}$); 3.64 (q, 2H, J = 7 Hz; $OC\underline{H_2}CH_3$); 5.14 (s, 1H, NCH_2O); 6.82–7.60 (m, 5H, Ph); 8.56 (s, 1H, CHO). ^{13}C NMR, δ: 15.0 ($OCH_2\underline{C}H_3$); 64.5 ($O\underline{C}H_2CH_3$); 75.7 NCH_2O); 125.4 (Ph); 127.1 (Ph); 129.2 (Ph); 144.2 (C-1 Ph); 163.2 (CHO). MS *m*/*z* (%): 179 ($M^{+\bullet}$, 13); 150 (55); 135 (27); 122 (16); 106 (100); 105 (51); 104 (30); 93 (71); 77 (53); 66 (26); 65 (18); 59 (25); HR MS calcd for $C_{10}H_{13}NO_2$: 179.0946, found: 179.0938.

***N*-(Ethoxymethyl)benzanilide (7b).** Oil. ^{1}H NMR, δ: 1.24 (t, 3H, J = 7.6 Hz, $OCH_2C\underline{H_3}$); 3.70 (q, 2H, J = 6.9 Hz, $OC\underline{H_2}CH_3$); 5.30 (s, 2H, NCH_2O); 7.05–7.40 (m, 10H, Ph). ^{13}C NMR, δ: 15.8 (OCH_2CH_3); 65.1 ($O\underline{C}H_2CH_3$); 79.3 (NCH_2O); 127.3 (Ph); 127.9 (Ph); 128.3 (Ph); 129.2 (Ph); 129.6 (Ph); 130.5 (Ph); 136.0 (C-1′ Ph); 143.5 (C-1 Ph); 171.9 (CO). MS *m*/*z* (%): 255 ($M^{+\bullet}$, 6); 226 (27); 105 (100); 77 (36); 59 (6). HR MS calcd for $C_{16}H_{17}NO_2$: 255.1259, found: 255.1258.

REFERENCES

1. Vogl, Ch.; Aebi, R. German Patent (DBP) 2328 340, Ciba-Geigy (1973); C.A. **1974**, *80*, 82440.
2. Vogl, Ch.; Aebi, R. Swiss Patent 576 945, Ciba-Geigy (1976); C.A. **1976**, *85*, 142866; Vogl, Ch.; Aebi, R. Swiss Patent 581 607, Ciba-Geigy (1977); C.A. **1977**, *86*, 8586, 72242.

3. Vogl, Ch.; Aebi, R. US Patent 4 160 660 (1979); C.A. **1979**, *91*, 118677.
4. Kolpin, D.W.; Nations, B.K.; Goolsby, D.A.; Thurman, E.M. Environ. Sci. Technol. **1996**, *30*, 1459.
5. Venkov, A.P.; Minkov, M.M.; Lukanov, L.K. Synth. Commun. **1989**, *19*, 2133.
6. Jacobsen, N.E.; Sanders, M.; Toia, R.F.; Casida, J.E. J. Agric. Food Chem. **1991**, *39*, 1342.
7. Zupancic, B.G.; Sobcic, M. Synthesis **1982**, 942.
8. Wedekind, E. German Patent (DRP) 135310 (1901); Chem. Zentralbl. **1902/II**, *73*, 1164.
9. Chiron, S.; Abian, J.; Ferres, M.; Sanches-Beaza, F.; Messeguer, A.; Barcelo, D. Envirnon. Toxicol. Chem. **1995**, *14*, 1287.
10. Barluenga, J.; Bayon, M.A.; Campos, P.; Asensio, G.; Gonzalez-Nunez, E.; Molina, Y. J. Chem. Soc. Perkin Trans. 1 **1998**, 1631.
11. Shono, T.; Matsumura, Y.; Inoue, K.; Ohmizu, H.; Kashimura, S. J. Am. Chem. Soc. **1982**, *104*, 5753.
12. Villiger, V. Chem. Ber. **1909**, *42*, 3549.
13. Muzic, K.G.; Lapina, R.A. Zh. Obshch. Khim. **1953**, *23*, 1512.

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