Quinolizines and Indolizines. Part 16 [1]. Synthesis of Pyrrolo[3,2,1-*ij*]quinolin-4-ones with Potential Fungicidal Activity

C. Oliver Kappe and Thomas Kappe*

Institut für Organische Chemie, Universität Graz, Heinrichstr. 28, A-8010 Graz, Austria

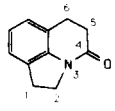
Received March 1, 1989

The synthesis of some derivatives of 1,2,5,6-tetrahydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (pyroquilon) having potential fungicidal activity has been accomplished starting with readily available 6-hydroxy-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-ones **3**, **7**. Functionalization in 6- or 5-position gave rise to the corresponding 6-and 5-substituted derivatives **8-12**, **17** and **13-16**, **20**, **21** respectively. The formation of pyrrolo[3,2,1-*ij*]-pyrano[3,2-*c*]quinolines (**5**, **22**, **23**) and their degradation to acyl-substituted derivatives of **7** was studied.

J. Heterocyclic Chem., **26**, 1555 (1989).

The activity of tricyclic amides against rice blast disease (RBD, [2]) has been established in 1975 [3] and these findings led to the preparation and biological evaluation of several pyrido[3,2,1-*ij*]- and pyrrolo[3,2,1-*ij*]quinolinones with potential fungicidal activity [4]. Representative of the compounds in this series is one of the simplest derivatives, 1,2,5,6-tetrahydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (common name pyroquilon) which is currently marketed as a systemic blast fungicide in rice [5]. Although pyroquilon displays the highest activity in this series, some activity is

Chart



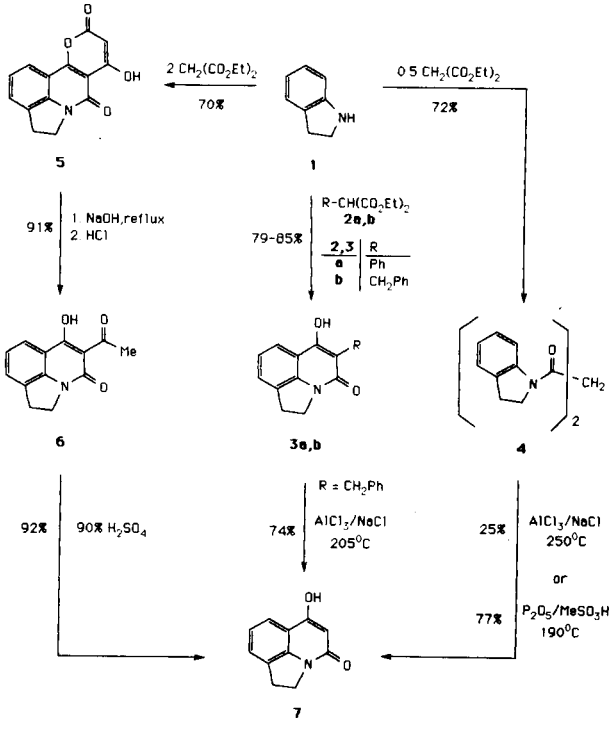
Pyroquilon

retained by substitution as well as unsaturation of the pyridine ring [4]. Furthermore, several derivatives of 1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one bearing perfluorinated alkyl substituents on the aromatic ring were reported for their antihypertensive activity [6,7].

This prompted us to carry on some earlier unpublished work regarding the synthesis and chemistry of 6-hydroxy-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-ones [8]. These compounds represent the general class of "malonylheterocycles" on which much research has been performed in our laboratories [9,10].

The three general methods for the preparation of 6-hydroxy-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**7**) are outlined in Scheme 1. Thus, if indoline **1** was reacted with substituted diethylmalonates **2a,b** the corresponding 5-substituted pyrroloquinolones **3a,b** were obtained in good yields [8]. Debenzylation of **3b** with aluminum chloride afforded the 5-unsubstituted pyrroloquinolone **7**. Reaction of indoline **1** with diethylmalonate in a molar ratio of 2:1 yielded malonic acid diindolinide **4**. Under more vigorous conditions - using a two molar excess

Scheme 1

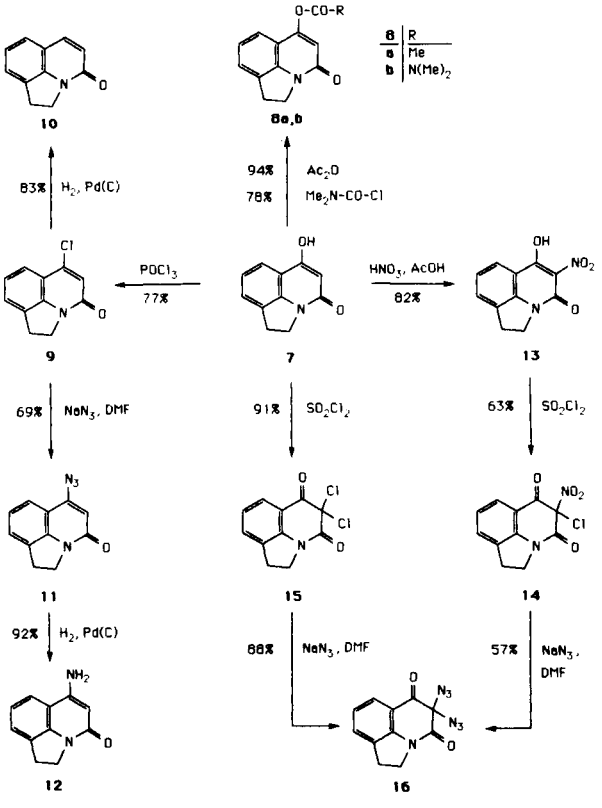


of diethylmalonate - pyronoquinolone **5** was formed. The synthesis of **7** was achieved by intramolecular cyclization of **4** using either an aluminum chloride melting [11] or - with higher yields - phosphorus pentoxide in methanesulfonic acid [10] as cyclization agents. Alternatively **7** was prepared in a two-step reaction [12,13] from pyronoquinolone **5**. Thus, treatment of **5** with aqueous sodium hydroxide led to acetyl-derivative **6**, which was deacetylated with 90% sulfuric acid to give **7** in an overall acceptable yield.

The various reactions of hydroxyquinolone **7** are shown in Scheme 2. Derivatization of the hydroxy group led to 6-acylated-pyrroloquinolones **8**, of which the dimethylcarbamoyl derivative **8b** was of particular interest because of the known insecticidal activity of such carbamates [14a-b].

Reaction of **7** with phosphorus oxychloride gave the corresponding chloro compound **9**. Catalytic reduction of **9** led

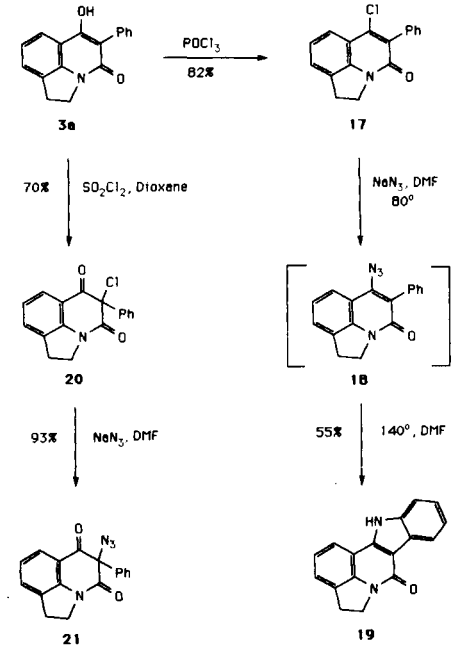
Scheme 2



to 1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**10**) which had been synthesized previously using different methods of preparation [4,15]. In order to introduce the amino group in 6-position the chloroquinolone **9** was reacted with sodium azide in dimethylformamide to give the corresponding azido-derivative **11** [16], which was reduced catalytically to the desired aminoquinolone **12**. The synthesis of dichloro compound **15** and chloronitro compound **14** was accomplished following standard procedures [17, 18]. The formation of geminal diazides from dichloromalonyl compounds has been reported earlier [19-21]; however, **16** was also obtained by reaction of chloronitro compound **14** with sodium azide in dimethylformamide in acceptable yield [22].

Some reactions of 6-hydroxy-5-phenyl-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**3a**) are shown in Scheme 3. The action of phosphorus oxychloride on **3a** led to chloroquinolone **17**, which was reacted with sodium azide to give the corresponding azidoquinolone **18**. Since this reaction requires relatively high temperatures (80°), simultaneous cyclization to indole derivative **19** occurred and therefore we obtained indolo[3,2-*c*]pyrrolo[3,2,1-*ij*]quinolone **19** without isolation of the intermediate azidoquinolone **18**

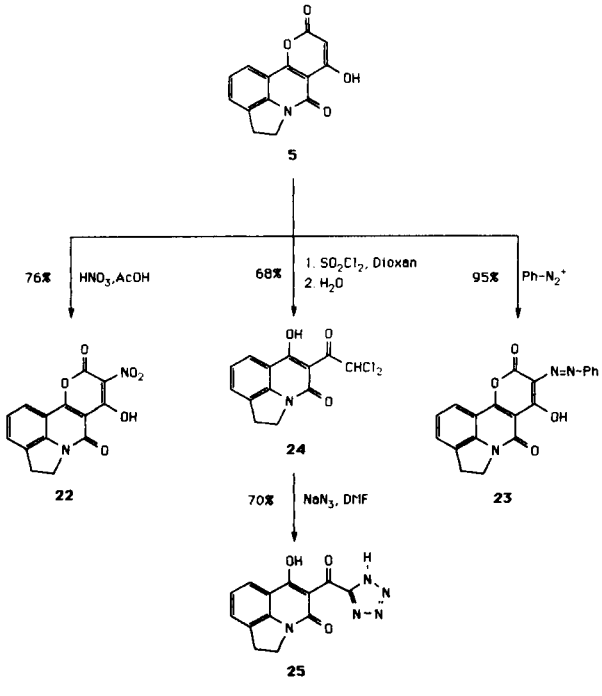
Scheme 3



[23]. Chlorination of **3a** with sulfuryl chloride led to 5-chloro-5-phenylquinolone **20**; the chloro atom in this compound was easily exchanged against the azido group to give compound **21**.

In recent years the various reactions of pyronoquinolones of type **5** have been extensively studied in our labor-

Scheme 4



atories [24,25]. As an example a few of these ractions were applied to pyronoquinolone **5** (Scheme 4). Thus, reaction of **5** with electrophiles such as nitric acid or benzenediazonium chloride led to the corresponding substituted pyrono-quinolones **22** and **23**, respectively. In the case of sulfuryl chloride the reaction proceeded differently. After hydrolytic ring opening of the dichloro-pyrone ring system and decarboxylation the dichloroacetyl derivative **24** was obtained [26]. The action of sodium azide in dimethylformamide at room temperature yielded the tetrazole **25** [26].

EXPERIMENTAL

The melting points were determined with a Gallenkamp Melting Point Apparatus Model MFB-595 and are uncorrected. The ir spectra were recorded on a Perkin-Elmer 298 spectrophotometer using samples in potassium bromide disks. The ^{1}H-nmr spectra were obtained on a Varian EM 360 at 60 MHz or XL-200 at 200 MHz in hexadeuteriodimethyl sulfoxide unless otherwise indicated. Chemical shifts (δ) are expressed in ppm downfield from TMS used as internal standard. Mass spectra were obtained on a Finnigan mass spectrometer 4500 at 70 eV (EI) using a direct inlet system. Microanalyses were performed on a C,H,N-automat Carlo Erba 1106.

6-Hydroxy-5-phenyl-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**3a**) [3,8].

A mixture of indoline **1** (59.6 g, 0.5 mole) and diethyl phenylmalonate (118.1 g, 0.5 mole) (**2a**) was heated in an oil bath in a distillation apparatus. At about 160° liberation of ethanol took place and the temperature was increased to about 240°, where it was kept until no more ethanol was formed. The crude precipitated product was digested with hot methanol and filtered to yield 104 g (79%) of **3a**, mp 291-293° (dimethylformamide); ir: 3300-2500, 1630, 1600, 1585, 1570 cm^{-1}; ^{1}H-nmr: δ = 3.35 (t, J = 7.8 Hz, 2H on C-1), 4.30 (t, J = 7.8 Hz, 2H on C-2), 7.07-7.90 (m, 8H, Ar).

Anal. Calcd. for $C_{17}H_{13}NO_2$: C, 77.55; H, 4.98; N, 5.32. Found: C, 77.45; H, 5.03; N, 5.31.

5-Benzyl-6-hydroxy-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**3b**) [8].

This compound was prepared according to the method described above using indoline **1** (59.6 g, 0.5 mole) and diethyl benzylmalonate (**2b**) (125.1 g, 0.5 mole) as starting materials to give 117.9 g (85%) of **3b**, mp 262-264° (dimethylformamide); ir: 3200-2800, 1630, 1590, 1550 cm^{-1}; ^{1}H-nmr: δ = 3.35 (t, J = 7.8 Hz, 2H on C-1), 3.99 (s, 2H, benzyl-CH$_2$), 4.30 (t, J = 7.8 Hz, 2H on C-2), 7.07-7.78 (m, 8H, Ar).

Anal. Calcd. for $C_{18}H_{15}NO_2$: C, 77.95; H, 5.45; N, 5.05. Found: C, 78.05; H, 5.25; N, 5.05.

Malonic Acid Diindolinide (**4**) [8].

A mixture of indoline **1** (13.0 g, 0.11 mole) and diethylmalonate (8.0 g, 0.05 mole) was heated in an oil bath to about 200° for one hour while liberated ethanol was distilled off. The crude material was treated with methanol and filtered to yield 11 g (72%) of **4**, mp 254-257° (dimethylformamide); ir: 3060-3030, 2970-2840, 1650, 1595 cm^{-1}.

Anal. Calcd. for $C_{19}H_{18}N_2O_2$: C, 74.49; H, 5.92; N, 9.14. Found: C, 74.46; H, 5.94; N, 9.09.

8-Hydroxy-4,5-dihydro-7*H*-pyrrolo[3,2,1-*ij*]pyrano[3,2-*c*]quinoline-7,10-dione (**5**).

A mixture of indoline **1** (59.6 g, 0.50 mole, 56 ml) and diethyl malonate (192.6 g, 1.2 moles, 182 ml) was heated in an oil bath in a distillation apparatus. At about 160° liberation of ethanol took place and the temperature was increased slowly to about 220°, where it was kept until no more ethanol was formed. Then the mixture was heated at 240° for an additional 3 hours until unreacted diethyl malonate was completely distilled off. The hot reaction mixture was allowed to cool to about 80°, before it was treated with methanol and filtered to give a crude product which was recrystallized from dimethylformamide to remove side products, mainly **4**. The yield of **5** was about 90 g (70%), mp 289-290° (acetic acid); ir: 3080, 1760, 1745-1725, 1670, 1570 cm^{-1}; ^{1}H-nmr (trifluoroacetic acid): δ = 3.61 (t, J = 7.8 Hz, 2H on C-4), 4.67 (t, J = 7.8 Hz, 2H on C-5), 5.94 (s, 1H on C-9), 7.39-8.14 (m, 3H, Ar).

Anal. Calcd. for $C_{14}H_9NO_4$: C, 65.88; H, 3.55; N, 5.49. Found: C, 66.02; H, 3.45; N, 5.49.

5-Acetyl-6-hydroxy-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**6**).

A suspension of **5** (5.10 g, 0.02 mole) in 400 ml of 2.5*N* sodium hydroxide solution was refluxed for 12 hours. After filtration the solution was acidified with concentrated hydrochloric acid to yield 4.17 g (91%) of **6**, mp 190° (acetic acid); ir: 3080, 2980, 1660, 1635-1620, 1560 cm^{-1}; ^{1}H-nmr (trifluoroacetic acid): δ = 2.95 (s, 3H, acetyl CH$_3$), 3.62 (t, J = 7.8 Hz, 2H on C-1), 4.64 (t, J = 7.8 Hz, 2H on C-2), 7.32-8.19 (m, 3H, Ar).

Anal. Calcd. for $C_{13}H_{11}NO_3$: C, 68.11; H, 4.84; N, 6.11. Found: C, 67.90; H, 4.92; N, 6.18.

6-Hydroxy-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**7**).

Method A [8].

To a melting of aluminum chloride (5.0 g, 0.037 mole) and sodium chloride (1.7 g, 0.029 mole), **4** (3.1 g, 0.01 mole) was added at 150°. The mixture was heated to 250° for 20 minutes and was treated with concentrated hydrochloric acid after cooling to room temperature. Purification of the precipitated product was accomplished by dissolution in 1*N* sodium hydroxide and reprecipitation with 1*N* hydrochloric acid to yield 0.47 g (25%) of **7**.

Method B.

A suspension of **4** (36.7 g, 0.12 mole) in 50 ml of methanesulfonic acid containing 10% of phosphorus pentoxide [27] was heated in an oil bath to 190° for about 30 minutes. The hot reaction mixture was allowed to cool to about 40°, before it was poured into 1000 ml of water. The crude reaction product was separated by filtration then dissolved in 1*N* sodium hydroxide and reprecipitated with 1*N* hydrochloric acid to yield 17.4 g (77%) of **7**.

Method C [8].

A mixture of **3b** (4.0 g, 0.014 mole), aluminum chloride (10.0 g, 0.075 mole) and sodium chloride (3.0 g, 0.05 mole) was heated in an oil bath at 205° for 10 minutes. Work-up as described above (Method A) gives 1.9 g (74%) of **7**.

Method D.

A mixture of **6** (6.87 g, 0.03 mole) and 25 ml of 90% sulfuric acid was heated at 140° for 10 minutes. After the mixture was allowed to cool to room temperature it was poured into 500 ml of ice-water to yield 5.16 g (92%) of **7**, mp 310° dec (dimethylformamide); ir: 3300-2500, 1635, 1620, 1590, 1570 cm^{-1}; ^{1}H-nmr [28]: δ = 3.30 (t, J = 7.8 Hz, 2H on C-1), 4.16 (t, J = 7.8 Hz, 2H on C-2), 5.74 (s, 1H on C-5), 6.83-7.53 (m, 3H, Ar).

Anal. Calcd. for $C_{11}H_9NO_2$: C, 70.58; H, 4.84; N, 7.48. Found: C, 70.59; H, 4.81; N, 7.29.

6-Acetoxy-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**8a**).

A suspension of **7** (5.61 g, 0.03 mole) in 30 ml of acetic anhydride was refluxed for 2 hours. After standing at room temperature for several hours the precipitated product was filtered to give 6.46 g (94%) of **8a**, mp 183-185° (ethanol); ir: 2975, 2935, 1770, 1655, 1615 cm^{-1}; ^{1}H-nmr: δ = 2.48 (s, 3H, acetyl CH_3), 3.41 (t, J = 7.8 Hz, 2H on C-1), 4.32 (t, J = 7.8 Hz, 2H on C-2), 6.45 (s, 1H on C-5), 7.07-7.60 (m, 3H, Ar).

Anal. Calcd. for $C_{13}H_{11}NO_3$: C, 68.11; H, 4.80; N, 6.11. Found: C, 68.09; H, 4.80; N, 6.02.

6-(*N,N*-Dimethylcarbamoyloxy)-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]-quinolin-4-one (**8b**).

A suspension of **7** (5.61 g, 0.03 mole), dimethylcarbamoylchloride (3.44 g, 0.032 mole) and 4-(*N,N*-dimethylamino)pyridine (50 mg) in 50 ml of pyridine was stirred for 24 hours at room temperature. Then the resulting mixture was filtered and taken to dryness *in vacuo*. The resulting material was extracted several times with boiling ethyl acetate and the combined organic layers were evaporated. The resulting oil was treated with cyclohexane and after crystallization the solid was filtered to yield 6.04 g (78%) of **8b**, mp 114-116° (benzene/cyclohexane); ir: 2930, 1735, 1645, 1615 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ = 3.08 (s, 3H, NCH_3), 3.21 (s, 3H, NCH_3), 3.42 (t, J = 7.8 Hz, 2H on C-1), 4.43 (t, J = 7.8 Hz, 2H on C-2), 6.62 (s, 1H on C-5), 7.03-7.54 (m, 3H, Ar).

Anal. Calcd. for $C_{14}H_{14}N_2O_3$: C, 65.11; H, 5.46; N, 10.85. Found: C, 64.89; H, 5.38; N, 10.65.

6-Chloro-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**9**).

This compound was prepared by refluxing a mixture of **7** (5.61 g, 0.03 mole) with 20 ml of phosphorus oxychloride for 30 minutes. The resulting solution was poured into ice-water (200 ml), and then the *p*H was adjusted with 2*N* sodium hydroxide to 7-8. The aqueous layer was extracted twice with ethyl acetate. After drying the organic phase was evaporated to give 4.75 g (77%) of **9**, mp 168-170° (ethanol); ir: 2940, 1640, 1610, 1555 cm^{-1}; ^{1}H-nmr: δ = 3.35 (t, J = 7.8 Hz, 2H on C-1), 4.20 (t, J = 7.8 Hz, 2H on C-2), 6.77 (s, 1H on C-5), 7.15-7.67 (m, 3H, Ar).

Anal. Calcd. for $C_{11}H_8ClNO$: C, 64.25; H, 3.92; N, 6.81. Found: C, 64.25; H, 3.93; N, 6.70.

1,2-Dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**10**).

A solution of **9** (2.06 g, 0.01 mole) in 30 ml of 1-propanol containing sodium acetate (1.64 g, 0.02 mole) was hydrogenated at 50-60° under atmospheric pressure for 4-6 hours in the presence of 0.3 g of palladium on charcoal (10%). The hot solution was filtered from the catalyst and evaporated *in vacuo*; the residue obtained was treated with water and ethyl acetate. The organic layer was separated and evaporated *in vacuo* to give 1.42 g (83%) of **10**, mp 157-158° (benzene) (157-158° [4,15]); ir: 3080-3020, 2970, 2935, 1650, 1610 cm^{-1}; ^{1}H-nmr: δ = 3.26 (t, J = 7.8 Hz, 2H on C-1), 4.25 (t, J = 7.8 Hz, 2H on C-2), 6.48 (d, J = 9.4 Hz, 1H on C-5), 6.95-7.57 (m, 3H, Ar), 7.81 (d, J = 9.4 Hz, 1H on C-6).

6-Azido-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**11**).

A suspension of **9** (2.06 g, 0.01 mole) and sodium azide (3.25 g, 0.05 mole) in 25 ml of dimethylformamide was heated to 85-90° for 72 hours, then was allowed to cool to room temperature and poured into 200 ml of ice-water to yield 1.46 g (69%) of **11**, mp 186° dec (ethanol); ir: 2930, 2180, 2120, 1645, 1615 cm^{-1}; ^{1}H-nmr: δ = 3.28 (t, J = 7.8 Hz, 2H on C-1), 4.21 (t, J = 7.8 Hz, 2H on C-2), 6.30 (s, 1H on C-5), 7.08-7.55 (m, 3H, Ar).

Anal. Calcd. for $C_{11}H_8N_4O$: C, 62.26; H, 3.80; N, 26.40. Found: C, 62.29; H, 3.91; N, 26.17.

6-Amino-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**12**).

The reduction of the azide **11** (1.11 g, 0.005 mole) in 30 ml of acetic acid was accomplished by hydrogenation at room temperature in the presence of 0.1 g of palladium on charcoal (10%) for 2 hours. The resulting suspension was heated to boiling and filtered. After evaporation of the solvent the residue was treated with ethanol to yield 0.86 g (92%) of **12**, mp 290° dec (acetic acid); ir: 3350, 3190, 1670, 1635, 1595-1570 cm^{-1}; ^{1}H-nmr: δ = 3.26 (t, J = 7.8 Hz, 2H on C-1), 4.16 (t, J = 7.8 Hz, 2H on C-2), 5.12 (s, 2H, NH_2), 6.48 (s, 1H on C-5), 6.85-7.62 (m, 3H, Ar).

Anal. Calcd. for $C_{11}H_{10}N_2O$: C, 70.95; H, 5.41; N, 15.04. Found: C, 70.60; H, 5.20; N, 14.87.

6-Hydroxy-5-nitro-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**13**).

To a mixture of 10 ml of acetic acid and 5 ml of nitric acid, **7** (1.87 g, 0.01 mole) was added portionwise keeping the temperature at about 50-60° until dissolution of the starting material. Then the solution was heated at 95° for 3 minutes. After cooling the separated product was filtered to give 1.90 g (82%) of **13**, mp 225° dec (acetic acid); ir: 3200-2850, 1640, 1605, 1570, 1525 cm^{-1}; ^{1}H-nmr: δ = 3.27 (t, J = 7.8 Hz, 2H on C-1), 4.18 (t, J = 7.8 Hz, 2H on C-2), 6.94-7.85 (m, 3H, Ar), 11.13 (b, 1H, OH).

Anal. Calcd. for $C_{11}H_8N_2O_4$: C, 56.90; H, 3.47; N, 12.06. Found: C, 56.77; H, 3.46; N, 12.02.

5-Chloro-5-nitro-1,2,5,6-tetrahydro-4*H*-pyrrolo[3,2,1-*ij*]quinoline-4,6-dione (**14**).

To a boiling solution of the nitro derivative **13** (2.32 g, 0.01 mole) in 20 ml of dioxane sulfurylchloride (4.05 g, 0.03 mole) was added portionwise. After the reaction was completed the mixture was poured into 200 ml of ice-water to give 1.68 g of **14**, mp 120° dec (ethanol); ir: 1730-1715, 1685, 1615, 1600, 1580 cm^{-1}; ^{1}H-nmr: 3.30 (t, J = 7.8 Hz, 2H on C-1), 4.18 (t, J = 7.8 Hz, 2H on C-2), 7.09-7.83 (m, 3H, Ar).

Anal. Calcd. for $C_{11}H_7ClN_2O_4$: C, 49.55; H, 2.65; N, 10.51. Found: C, 49.59; H, 2.52; N, 10.61.

5,5-Dichloro-1,2,5,6-tetrahydro-4*H*-pyrrolo[3,2,1-*ij*]quinoline-4,6-dione (**15**).

To a suspension of **7** (18.72 g, 0.10 mole) in 100 ml of dioxane sulfuryl chloride (25 ml, 0.31 mole) was added portionwise while the temperature should be kept between 50 and 70°. After the addition was completed the solution was quickly heated to 85° and poured into 1000 ml of ice-water to yield 23.3 g of **15**, mp 146-148° (ethanol); ir: 1725, 1695, 1635, 1605, 1500 cm^{-1}; ^{1}H-nmr:

δ = 3.31 (t, J = 7.8 Hz, 2H on C-1), 4.17 (t, J = 7.8 Hz, 2H on C-2), 6.98-7.72 (m, 3H, Ar).

Anal. Calcd. for $C_{11}H_7Cl_2NO_2$: C, 51.59; H, 2.76; N, 5.47. Found: C, 51.31; H, 2.81; N, 5.37.

5,5-Diazido-1,2,5,6-tetrahydro-4*H*-pyrrolo[3,2,1-*ij*]quinoline-4,6-dione (**16**).

Method A (from **15**).

To a solution of dichloro derivative **15** (2.5 g, 0.01 mole) in 30 ml of dimethylformamide sodium azide (1.95 g, 0.03 mole) was added in small portions, keeping the temperature below 10°. After the addition was completed the mixture was stirred at room temperature for 3 hours and then was poured into 300 ml of ice-water to give 2.37 g (88%) of **16**.

Method B (from **14**).

The diazido derivative **16** was prepared in the same way as described above (Method A), using the chloronitro derivative **14** (2.66 g, 0.01 mole) as the starting material. The yield of **16** was 1.53 g (57%), mp 129-131° dec (ethanol); ir: 2120, 1715, 1680, 1630, 1600, 1500 cm^{-1}; ^1H-nmr: δ = 3.30 (t, J = 7.8 Hz, 2H on C-1), 4.18 (t, J = 7.8 Hz, 2H on C-2), 7.05-7.75 (m, 3H, Ar); ms: m/e (relative intensity) 269 (M+ 24), 241 (17), 212 (22), 199 (49), 172 (46), 153 (12), 143 (50), 128 (32), 116 (100).

Anal. Calcd. for $C_{11}H_7N_7O_2$: C, 49.08; H, 2.62; N, 36.42. Found: C, 49.28; H, 2.58; N, 36.80.

6-Chloro-5-phenyl-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**17**).

This compound was prepared by refluxing a mixture of **3a** (26.33) g, 0.10 mole) with 30 ml of phosphorus oxychloride for 90 minutes. The resulting solution was poured into ice-water (1000 ml) and was allowed to stand for 12 hours. Then it was filtered and by bringing the *p*H to about 8 with 2*N* sodium hydroxide the precipitated product was filtered to give 23.1 g (82%) of **17**, mp 207-209° (ethanol); ir: 3050, 2985, 1645, 1625, 1615 cm^{-1}; ^1H-nmr (trifluoroacetic acid): δ = 3.75 (t, J = 7.8 Hz, 2H on C-1), 4.95 (t, J = 7.8 Hz, 2H on C-2), 7.21-8.18 (m, 3H, Ar).

Anal. Calcd. for $C_{17}H_{12}ClNO$: C, 72.47; H, 4.29; N, 4.97. Found: C, 72.20; H, 4.25; N, 4.90.

4,5-Dihydro-7*H*,12*H*-indolo[3,2-*c*]pyrrolo[3,2,1-*ij*]quinolin-7-one (**19**).

A mixture of **17** (8.44 g, 0.03 mole), sodium azide (6.5 g, 0.10 mole) and 100 ml of dimethylformamide was stirred at 80° for 48 hours, while the course of the reaction was followed by thin-layer chromatography. After almost all of the starting material had reacted the mixture was heated at 140° for 2 hours, before it was poured into 1000 ml of ice-water. The crude product was filtered and recrystallized from dimethylformamide to yield 4.29 g (55%) of **19**, mp >350° (dimethylformamide); ir: 3240-2800, 1630, 1620, 1595, 1580, 1550 cm^{-1}; ^1H-nmr: δ = 3.42 (t, J = 7.8 Hz, 2H on C-4), 4.39 (t, J = 7.8 Hz, 2H on C-5), 7.19-7.46 (m, 4H, Ar), 7.61 (d, J = 8.0 Hz, 1H, Ar), 7.93 (d, J = 8.0 Hz, 1H, Ar), 8.24 (d, J = 8.0 Hz, 1H, Ar).

Anal. Calcd. for $C_{17}H_{12}N_2O$: C, 78.44; H, 4.64; N, 10.76. Found: C, 78.70; H, 4.75; N, 10.85.

5-Chloro-5-phenyl-1,2,5,6-tetrahydro-4*H*-pyrrolo[3,2,1-*ij*]quinoline-4,6-dione (**20**).

To a suspension of **3a** (13.15 g, 0.05 mole) in 70 ml of dioxane sulfuryl chloride (10 ml, 0.12 mole) was added in small portions. After stirring at room temperature for 30 minutes the reaction mixture was poured into 700 ml of ice-water; after complete crystallization the product was removed by filtration and was recrystallized from ethanol to yield 10.41 g (70%) of **20**, mp 110-112° (ethanol); ir: 3060, 2960-2900, 1715, 1680, 1620, 1595 cm^{-1}; ^1H-nmr: δ = 3.28 (t, J = 7.8 Hz, 2H on C-1), 4.10 (t, J = 7.8 Hz, 2H on C-2), 6.95-7.74 (m, 3H, Ar), 7.43 (s, 5H, Ph).

Anal. Calcd. for $C_{17}H_{12}ClNO_2$: C, 68.58; H, 4.06; N, 4.70. Found: C, 68.25; H, 4.04; N, 4.62.

5-Azido-5-phenyl-1,2,5,6-tetrahydro-4*H*-pyrrolo[3,2,1-*ij*]quinoline-4,6,-dione (**21**).

To a solution of **20** (2.97 g, 0.01 mole) in 10 ml of dimethylformamide sodium azide (0.78 g, 0.012 mole) was added and the resulting mixture was stirred for 45 minutes at room temperature. Then it was poured into 200 ml of ice-water and after one hour the product was filtered to give 2.83 g (93%) of **21**, mp 148° dec (methanol); ir: 3030, 2120, 1715, 1675, 1625, 1595 cm^{-1}; ^1H-nmr: δ = 3.18 (t, J = 7.8 Hz, 2H on C-1), 4.16 (t, J = 7.8 Hz, 2H on C-2), 6.88-7.65 (m, 3H, Ar), 7.43 (s, 5H, Ph).

Anal. Calcd. for $C_{17}H_{12}N_4O_2$: C, 67.10; H, 3.97; N, 18.41. Found: C, 66.78; H, 3.90; N, 18.29.

8-Hydroxy-9-nitro-4,5-dihydro-7*H*-pyrrolo[3,2,1-*ij*]pyrano[3,2-*c*]-quinoline-7,10-dione (**22**).

To a suspension of **5** (2.55 g, 0.01 mole) in 20 ml of acetic acid concentrated nitric acid (5 ml) was added portionwise keeping the temperature below 50°. After the addition was completed, the solution was heated at 80° for 3 minutes and then poured into ice-water to give 2.28 g (76%) of **22**, mp 244-245° (acetic acid); ir: 1755, 1675, 1630, 1570, 1515 cm^{-1}; ^1H-nmr (trifluoroacetic acid): δ = 3.72 (t, J = 7.8 Hz, 2H on C-4), 4.77 (t, J = 7.8 Hz, 2H on C-5), 7.54-8.18 (m, 3H, Ar).

Anal. Calcd. for $C_{14}H_8N_2O_6$: C, 56.01; H, 2.69; N, 9.33. Found: C, 56.27; H, 2.67; N, 9.33.

8-Hydroxy-9-phenylazo-4,5-dihydro-7*H*-pyrrolo[3,2,1-*ij*]pyrano-[3,2-*c*]quinoline-7,10-dione (**23**).

To a solution of **5** (1.28 g, 0.005 mole) in 50 ml of 2*N* sodium hydroxide a solution of benzenediazonium chloride [prepared from aniline (0.47 g, 0.005 mole) and sodium nitrite (0.35 g, 0.005 mole) in 10 ml of 6*N* hydrochloric acid] was added dropwise at a temperature of about 5° to yield 1.63 g (95%) of a yellow-orange colored dye, mp 278° dec (acetic acid): ir [29]: 3180, 1775, 1720, 1675, 1620, 1560 cm^{-1}; ^1H-nmr [29] (trifluoroacetic acid): δ = 2.24 (s, 3H, acetyl CH_3), 3.82 (t, J = 7.8 Hz, 2H on C-4), 4.95 (t, J = 7.8 Hz, 2H on C-5), 7.48-8.38 (m, 8H, Ar).

Anal. Calcd. for $C_{22}H_{17}N_3O_6$ [29]: C, 63.01; H, 4.09; N, 10.02. Found: C, 62.96; H, 3.94; N, 9.90.

5-Dichloroacetyl-6-hydroxy-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-4-one (**24**).

To a suspension of **5** (5.10 g, 0.02 mole) in 50 ml of dioxane sulfuryl chloride (10 ml, 0.12 mole) was added portionwise, while the temperature was not allowed to rise above 50°, where it was then kept for an additional 10 minutes. The mixture was quickly heated to the boil and poured into 500 ml of ice-water to yield 4.05 g of **24**, mp 229-230° (acetic acid); ir: 3035, 1645, 1635, 1620, 1555 cm^{-1}; ^1H-nmr (trifluoroacetic acid): δ = 3.51 (t, J = 7.8 Hz, 2H on C-1), 4.56 (t, J = 7.8 Hz, 2H on C-2), 7.38-8.04 (m, 3H, Ar), 7.78 (s, 1H, $CHCl_2$).

Anal. Calcd. for $C_{13}H_9Cl_2NO_3$: C, 52.38; H, 3.04; N, 4.70. Found: C, 52.46; H, 3.15; N, 4.63.

(6-Hydroxy-4-oxo-1,2-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-5-yl) (tetrazol-5-yl) ketone (**25**).

To a solution of 2.98 g of **24** (0.01 mole) in 50 ml of dimethylformamide, sodium azide (2.60 g, 0.04 mole) was added. The mixture was stirred at room temperature for 24 hours and then diluted with 500 ml of ice-water. After filtration the product was precipitated by addition of 2*N* hydrochloric acid until the *p*H was about 4 to yield 1.98 g (70%) of **25**, mp 228° dec (acetic acid); ir: 3050, 1640, 1600, 1545 cm^{-1}; ^{1}H-nmr: δ = 3.41 (t, J = 7.8 Hz, 2H on C-1), 4.26 (t, J = 7.8 Hz, 2H on C-2), 7.11-7.84 (m, 3H, Ar).

Anal. Calcd. for $C_{13}H_9N_5O_3$: C, 55.13; H, 3.20; N, 24.73. Found: C, 55.24; H, 3.27; N, 24.53.

REFERENCES AND NOTES

[1] Part **15**: G. Dannhardt, W. Meindl, S. Gussmann, S. Ajili and Th. Kappe, *Eur. J. Med. Chem.*, **22**, 505 (1987).

[2] S. H. Ou and P. R. Jennings, *Annu. Rev. Phytopathol.*, **77**, 383 (1969).

[3] R. J. Bass, R. C. Koch, H. C. Richards and J. E. Thorpe (Pfizer Ltd.), British Patent 1,394,373 (1975); *Chem. Abstr.*, **83**, 114237b (1975).

[4] R. J. Bass, R. C. Koch, H. C. Richards and J. E. Thorpe, *J. Agric. Food Chem.*, **29**, 576 (1981).

[5] M. Nakamura, *Japan Pestic. Inf.*, **48**, 27 (1986); *Chem. Abstr.*, **105**, 185742w (1986).

[6] P. E. Aldrich and G. H. Berezin (E. I. du Pont de Nemours and Co.), Belgian Patent 872,311 (1979); *Chem. Abstr.*, **91**, 175218h (1979).

[7] P. E. Aldrich and G. H. Berezin (E. I. du Pont de Nemours and Co.), U. S. Patent 4,218,448 (1980); *Chem. Abstr.*, **93**, 239264w (1980).

[8] H. Schmidt, Ph. D. Thesis, University of Graz, 1971; See also Th. Kappe and H. Schmidt, *Org. Prep. Proced. Int.*, **4**, 233 (1972).

[9] Th. Kappe, S. Ajili and W. Stadlbauer, *J. Heterocyclic Chem.*, **25**, 463 (1988) and literature cited therein.

[10] Th. Kappe, A. S. Karem and W. Stadlbauer, *J. Heterocyclic Chem.*, **25**, 857 (1988) and literature cited therein.

[11] E. Ziegler, R. Wolf and Th. Kappe, *Monatsh. Chem.*, **96**, 418 (1965).

[12] R. E. Bowman, A. Campbell and E. Tanner, *J. Chem. Soc.*, 444 (1959).

[13] J. A. Bosson, M. Rasmussen, E. Ritchie, A. V. Robertson and W. C. Taylor, *Aust. J. Chem.*, **16**, 480 (1963).

[14a] R. J. Kuhr and H. W. Dorough in "Carbamate Insecticides: Chemistry, Biochemistry and Toxicology", CRC Press, Cleveland, Ohio, 1976; [b] W. Draber, in "Chemistry of Pesticides", K. H. Büchel, ed, John Wiley and Sons, Inc., New York, NY, 1983.

[15] L. G. S. Brooker and D. W. Heseltine, U. S. Patent 2,646,430 (1953); *Chem. Abstr.*, **48**, 1184i (1954).

[16] General methods for the preparation of 4-azido-2(1*H*)-quinolones: W. Stadlbauer, *Monatsh. Chem.*, **117**, 1305 (1986).

[17] E. Ziegler and Th. Kappe, *Monatsh. Chem.*, **94**, 447 (1963).

[18] E. Ziegler and Th. Kappe, *Monatsh. Chem.*, **95**, 59 (1964).

[19] G. Landen and H. W. Moore, *Tetrahedron Letters*, 2513 (1976).

[20] Th. Kappe, G. Lang and E. Pongratz, *J. Chem. Soc., Chem. Commun.*, 338 (1984).

[21] G. Weber, G. Mann, H. Wilde and S. Hauptmann, *Z. Chem.*, **20**, 437 (1980).

[22] For reactions of bromonitroalkanes with sodium azide and discussion of mechanism see S. I. Al-Khalil, W. R. Bowman and M. C. R. Symons, *J. Chem. Soc. Perkin Trans. I*, 555 (1986).

[23] W. Stadlbauer, A. S. Karem and Th. Kappe, *Monatsh. Chem.*, **118**, 81 (1987).

[24] Ph. D. Theses, Unversity of Graz: O. Schmut (1971), Th. Witoszynskyj (1972), Th. Wolf (1974), H. Stückler (1981) and K. Faber (1982).

[25] Diploma Theses, University of Graz: A. Pfaffenschlager (1985), P. Hohengassner (1987) and P. Roschger (1988).

[26] K. Faber and Th. Kappe, *J. Heterocyclic Chem.*, **21**, 1881 (1984).

[27] Commercially available from Merck and Co. (Art. 818182).

[28] See also H. Sterk and H. Holzer, *Org. Magn. Reson.*, **6**, 133 (1974).

[29] The spectra and analysis of compound **23** were obtained from material containing one equivalent of acetic acid.