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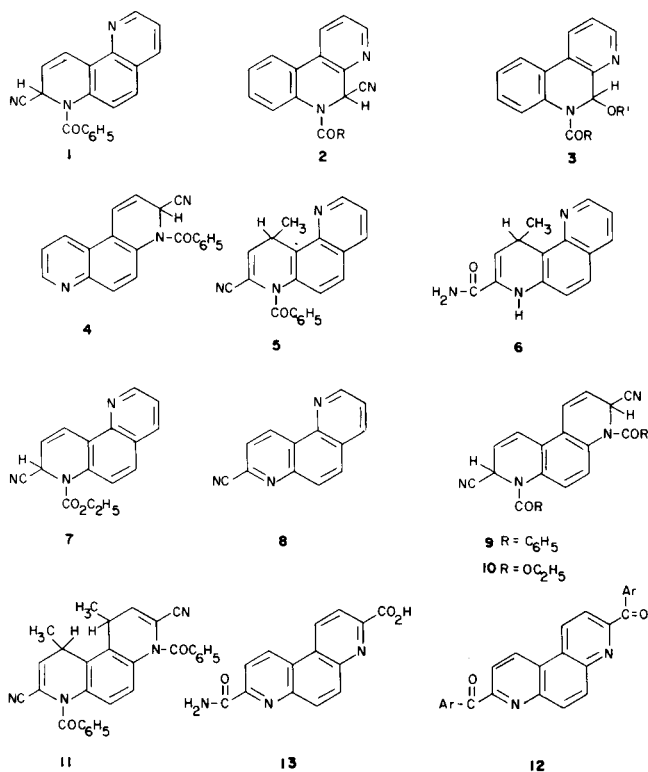
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Reissert compounds have been prepared from 1,7-, 4,6-, and 4,7-phenanthrolines. In the case of 4,7-phenanthroline, both mono- and di-Reissert compounds have been prepared. A number of Reissert analogs have also been prepared in this series. 1,10-Phenanthroline fails to give a Reissert compound.

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Compared with the large volume of work (1) that has been reported in the Reissert compounds of quinoline and isoquinoline, relatively little has appeared on the phenanthrolines. 1,10-Phenanthroline, benzoyl chloride, and potassium cyanide fail to give a Reissert compound in water (2) or in methylene chloride-water (3). 1,7-Phenanthroline under these latter conditions has been reported (3) to give **1**. In methylene chloride-water 4,6-phenanthroline, potassium cyanide, and aliphatic acid chlorides gave low yields of Reissert compounds (2) accompanied by **3** ($R' = H$ or CH_3); while benzoyl chloride gave only **3** ($R = Ph$, $R' = H$) (4). After this work had been completed, it was reported (5) that 4,7-phenanthroline, potassium cyanide, and benzoyl chloride in methylene chloride-water gave **4**.



1,7-Phenanthroline can be converted to 7-benzoyl-8-cyano-7,8-dihydro-1,7-phenanthroline (**1**) by using either the methylene chloride-water method or by reacting 1,7-phenanthroline, benzoyl chloride, and trimethylsilyl cyanide in methylene chloride. Under no conditions could a di-Reissert compound arising from reaction at N_1 be obtained. This is in accord with the observation that 8-substituted quinolines do not form Reissert compounds (1). Also in accord with that fact is our confirmation that 1,10-phenanthroline does not form a Reissert compound with benzoyl chloride in either the methylene chloride-water-potassium cyanide method or in the trimethylsilyl cyanide method.

The Reissert compound (**1**) on treatment with methyl iodide and sodium hydride in dimethylformamide at room temperature gave an alkylation product that has been assigned structure **5**. In the quinoline series alkylation occurs at the 4-position (1). The 1H nmr spectrum of the alkylation product (**5**) revealed a doublet at δ 1.56 (3H, $J = 7.2$ Hz), a multiplet at δ 4.95 (1H), and another doublet at δ 6.77 ($J = 7.2$ Hz). It has been observed by decoupling experiments that the proton that absorbs at δ 4.95 is coupled both to the methyl protons and the proton which appears as a doublet at δ 6.77. This observation clearly suggests that **5** is the correct structure for the alkylation product. It should be noted that this 1,4-dihydro structure is in contrast to the 1,2-dihydro structure assigned to the alkylation product obtained from quinoline (1). In contrast to the hydrolysis of 4-methyl-2-cyano-1-benzoyl-1,2-dihydroquinoline, which because of the 1,2-dihydro structure proceeds with loss of both the benzoyl and cyano groups to give 4-methylquinoline, **5** undergoes base-catalyzed hydrolysis to give **6**. The mass spectrum of **6** does not show a molecular ion but readily aromatizes as shown by M-2 and M-16 peaks. These both then lose $NHCO$.

1,7-Phenanthroline was converted to 7-carbomethoxy-8-cyano-7,8-dihydro-1,7-phenanthroline (**7**) by reaction with ethyl chloroformate and trimethylsilyl cyanide in anhydrous methylene chloride in the presence of a catalytic amount of anhydrous aluminum chloride. When 1,7-phenanthroline was reacted with benzenesulfonyl chloride and potassium cyanide in methylene chloride-

water with a phase transfer catalyst, 8-cyano-1,7-phenanthroline (**8**) was obtained after work-up. In analogy with quinoline (**1**), it is believed that the Reissert analog is first formed and is converted to **8**.

Reaction of 4,7-phenanthroline with benzoyl chloride and potassium cyanide in methylene chloride-water gave **4**. However, treatment of 4,7-phenanthroline with benzoyl chloride and trimethylsilyl cyanide in anhydrous methylene chloride in the presence of a catalytic amount of aluminum chloride afforded 3,8-dicyano-4,7-dibenzoyl-3,4,7,8-tetrahydro-4,7-phenanthroline (**9**). It should be noted that this is the first preparation of a true di-Reissert compound. 4,7-Phenanthroline was similarly converted to 3,8-dicyano-4,5-dicarbethoxy-3,4,7,8-tetrahydro-4,7-phenanthroline (**10**) by using ethyl chloroformate in the above procedure.

The di-Reissert compound (**9**) on reaction with methyl iodide in the presence of sodium hydride in dimethylformamide gave a dialkylated product to which, by analogy with the above work, the structure **11** is assigned. Reaction of **9** with 3,4-dimethoxybenzaldehyde in the presence of sodium hydride gave the diketone **12**. This is the same type of product obtained when this aldehyde is reacted in the isoquinoline (**6**) and phthalazine (**7**) series.

The Reissert compound **1**, **4**, and **9** on hydrolysis with concentrated hydrochloric acid in the presence of 2,4-dinitrophenylhydrazine gave high yields of the 2,4-dinitrophenylhydrazone of benzaldehyde. Hydrolysis of **9** with hydrobromic acid in acetic acid gave the half acid-half amide **13**. The mass spectrum, which shows loss of both CHNO and CO₂ from the molecular ion, confirms this structure.

Reaction of 4,6-phenanthroline with benzoyl chloride and potassium cyanide in methylene chloride-water gave the pseudo base (**3**, R = Ph, R' = H) (**4**) which could be reconverted to 4,6-phenanthroline on treatment with base. By use of the trimethylsilyl cyanide method, however, 4,6-phenanthroline was converted into the Reissert compound (**2**, R = Ph), which could also be obtained by the phase transfer catalyst method.

EXPERIMENTAL

General.

All melting points were determined in a Thomas-Hoover capillary melting point apparatus and are uncorrected. Elemental analyses were performed by Spang Microanalytical Laboratory and mass spectra were obtained from the Midwest Center for Mass Spectrometry at the University of Nebraska. The infrared absorption spectra were determined with a Perkin-Elmer Model 710B spectrometer and ¹H nmr spectra were recorded on a 60 MHz R-24B Hitachi-Perkin-Elmer spectrometer.

7-Benzoyl-8-cyano-7,8-dihydro-1,7-phenanthroline (**1**)

To a well stirred solution of 1.8 g. (0.01 mole) of 1,7-phenanthroline and 1.98 g. (0.02 mole) of trimethylsilyl cyanide in 25 ml. of anhydrous methylene chloride a catalytic amount of anhydrous aluminum chloride was added. After 2 minutes, 2.81 g. (0.02 mole) of benzoyl chloride was

added and the mixture was stirred overnight at room temperature. The solution was then washed with water, 5% hydrochloric acid, water, 5% sodium hydroxide, and water. The methylene chloride solution was dried (sodium sulfate), evaporated and the residue recrystallized from methylene chloride-petroleum ether to give 1.21 g. (39%) of **1**, m.p. 172-173°; ir (potassium bromide): 3065, 2960, 1660, 1595, 1500, 1375, 1325, 1310, 1290 cm⁻¹; nmr (deuteriochloroform): δ 8.85-8.74 (m, 1H), 8.20-7.80 (m, 3H), 7.42-7.26 (m, 6H), 6.73 (d, 1H, J = 8.2 Hz), 6.33-6.12 (m, 2H).

Anal. Calcd. for C₂₀H₁₃N₃O: C, 77.15; H, 4.21; N, 13.50. Found: C, 77.08; H, 4.27; N, 13.44.

This compound (**1**) could also be prepared by the methylene chloride-water method.

7-Benzoyl-8-cyano-10-methyl-7,10-dihydro-1,7-phenanthroline (**5**)

To a stirred solution of 0.8 g. (0.0026 mole) of 7-benzoyl-8-cyano-7,8-dihydro-1,7-phenanthroline (**1**) and 0.37 g. (0.0026 mole) of methyl iodide in 10 ml. of anhydrous dimethylformamide was added 0.13 g. (0.0026 mole) of 50% sodium hydride in oil dispersion. The mixture was stirred at room temperature for two hours, poured into 200 g. of ice and filtered to give 0.68 g. (80.4%) of **5**, m.p. 173-174° from ethanol; ir (potassium bromide): 3075, 2975, 2245, 1665, 1600, 1330, 1295, 1280 cm⁻¹; nmr (deuteriochloroform): δ 8.9-8.8 (m, 1H), 8.09-7.92 (m, 1H), 7.47-7.03 (m, 8H), 6.77 (d, 1H, J = 7.2 Hz), 4.95 (m, 1H, J = 7.2 Hz), 1.56 (d, 3H, J = 7.2 Hz).

Anal. Calcd. for C₂₁H₁₅N₃O: C, 77.52; H, 4.65; N, 12.92. Found: C, 77.48; H, 4.70; N, 12.96.

Hydrolysis of **5**.

A mixture of 0.5 g. (0.0015 mole) of **5**, 15 ml. of ethanol, 5 g. of potassium hydroxide, and 15 ml. of water was refluxed for 3 hours. Addition of water, concentration, and extraction gave after recrystallization 0.15 g. (42%) of **6**, m.p. 271-275°; ir (potassium bromide): 3380, 3310, 3230, 3150-3100, 1660, 1580, 1550, 1385 cm⁻¹; nmr (deuteriochloroform): δ 8.75 (m, 1H), 8.0 (m, 1H), 7.65-7.00 (m, 3H), 6.08 (broad, 1H), 5.70 (d, 1H), 4.50 (m, 1H), 3.32 (s, 2H), 2.74 (broad, water), 1.32 (d, 3H); ms: m/e 237.0900 (C₁₄H₁₁N₃O) (39.09%, M⁺ - 2), 223.0743 (C₁₃H₉N₃O) (61.32, M⁺ - 16), 219 (0.90), 206 (1.14), 205 (2.77), 194 (33.63), 193 (12.54), 192 (9.28), 180 (100), 179 (58.06), 167 (5.46), 153 (32.74), 152 (8.06), 125 (5.94).

Anal. Calcd. for C₁₄H₁₁N₃O · 0.5H₂O: C, 67.72; H, 6.15; N, 16.02. Found: C, 67.30; H, 5.48; N, 16.46.

7-Carbethoxy-8-cyano-7,8-dihydro-1,7-phenanthroline (**7**)

To a stirred solution of 1.8 g. (0.01 mole) of 1,7-phenanthroline and 1.98 g. (0.02 mole) of trimethylsilyl cyanide in 25 ml. of anhydrous methylene chloride, a catalytic amount of aluminum chloride was added. After 2 minutes, 2.17 g. (0.02 mole) of ethyl chloroformate was added and the mixture was stirred at room temperature for 24 hours. Work up in the usual manner gave a gummy solid which was recrystallized from ethanol to give 0.95 g. (34%) of **7**, m.p. 231-232°.

Anal. Calcd. for C₁₆H₁₃N₃O₂: C, 68.80; H, 4.69; N, 15.05. Found: C, 68.73; H, 4.59; N, 14.94.

8-Cyano-1,7-phenanthroline (**8**)

To a stirred mixture of 0.9 g. (0.005 mole) of 1,7-phenanthroline in 15 ml. of methylene chloride, 1.3 g. (0.02 mole) of potassium cyanide in 2 ml. of water, and 0.065 g. of benzyltriethylammonium chloride, was added dropwise 3.53 g. (0.02 mole) of benzenesulfonyl chloride over 30 minutes. The mixture was stirred for 3 hours and worked up as usual to give after recrystallization from ethanol 0.62 g. (60.5%) of **8**, m.p. 213-215°, reported (8) m.p. 217-219°; ir (potassium bromide): 3070, 2240, 1610, 1595, 1570, 1425, 860 cm⁻¹; nmr (deuteriochloroform): δ 9.57 (d, 1H, J = 8.1 Hz), 9.36-9.14 (m, 2H), 8.97 (s, 2H), 8.60-8.23 (m, 2H).

Anal. Calcd. for C₁₃H₇N₃: C, 76.08; H, 3.44; N, 20.48. Found: C, 76.11; H, 3.55; N, 20.39.

4-Benzoyl-3-cyano-3,4-dihydro-4,7-phenanthroline (**4**)

Following the usual procedure 2.0 g. (0.011 mole) of 4,7-phenanthroline in 25 ml. of methylene chloride, and 2.86 g. (0.033 mole) of

potassium cyanide in 4.4 ml. of water was reacted with 4.7 g. (0.044 mole) of benzoyl chloride in the presence of 5% by weight of benzyltriethylammonium chloride. This led to a 30% yield of **4**, m.p. 120-123° from ethanol, reported (5) m.p. 120-123°; ir (potassium bromide): 1660 cm^{-1} ; ms: m/e 285.1032 ($\text{C}_{15}\text{H}_{13}\text{N}_3\text{O}$) (5.80%, $\text{M}^+ - \text{CN}$), 208 (2.1), 181 (14.0), 180 (89.8), 179 (27.2), 178 (1.7), 154 (1.7), 153 (7.9), 152 (9.5), 151 (2.2), 127 (0.9), 125 (2.6), 106 (7.0), 105 (100).

Anal. Calcd. for $\text{C}_{20}\text{H}_{13}\text{N}_3\text{O}$: C, 77.15; H, 4.21; N, 13.50. Found: C, 77.01; H, 4.32; N, 13.67.

3,8-Dicyano-4,7-dibenzoyl-3,4,7,8-tetrahydro-4,7-phenanthroline (**9**).

To a solution of 1.8 g. (0.01 mole) of 4,7-phenanthroline and 2.97 g. (0.03 mole) of trimethylsilyl cyanide in 25 ml. of anhydrous methylene chloride, a catalytic amount of aluminum chloride was added. After 2 minutes, 4.22 g. (0.03 mole) of benzoyl chloride was added and the mixture was stirred at room temperature for 2 days. The product was removed by filtration, washed with methylene chloride and recrystallized from ethanol to give 1.96 g. (44.3%) of **9**, m.p. 196-197°; ir (potassium bromide): 3100, 2975, 1670, 1610, 1585, 1480, 1340, 1295 cm^{-1} ; nmr (deuteriodimethylsulfoxide): δ 7.49-7.04 (m, 12H), 6.51-6.11 (m, 6H).

Anal. Calcd. for $\text{C}_{28}\text{H}_{18}\text{N}_4\text{O}_2$: C, 76.00; H, 4.10; N, 12.66. Found: C, 75.69; H, 4.14; N, 12.46.

3,8-Dicyano-4,7-dicarboethoxy-3,4,7,8-tetrahydro-4,7-phenanthroline (**10**).

Replacement of the benzoyl chloride in the above preparation of **9** by 3.26 g. (0.03 mole) of ethyl chloroformate gave a clear solution that was worked up in the usual manner to give after recrystallization from ethanol 1.39 g. (36.7%) of **10**, m.p. 178-180°; ir (potassium bromide): 3100, 3010, 1715, 1580, 1480, 1405, 1385, 1360, 1300, 1275, 1100 cm^{-1} ; nmr (deuteriochloroform): δ 7.58 (d, 2H), 7.18-6.79 (m, 2H), 6.30-5.99 (m, 4H), 4.31 (q, 4H, J = 7.2 Hz), 1.35 (t, 6H, J = 7.2 Hz).

Anal. Calcd. for $\text{C}_{26}\text{H}_{18}\text{N}_4\text{O}_4$: C, 63.48; H, 4.79; N, 14.81. Found: C, 63.49; H, 4.93; N, 14.64.

Reaction of **9** with Methyl Iodide in the Presence of Sodium Hydride.

To a solution of 0.89 g. (0.002 mole) of **9** and 0.57 g. (0.004 mole) of methyl iodide in 15 ml. of anhydrous dimethylformamide was added in small portions 0.19 g. (0.004 mole) of 50% sodium hydride in oil dispersion. The mixture was stirred at room temperature for 30 minutes and poured into 300 g. of ice. The solid was filtered, washed with water, and recrystallized from ethanol to give 0.70 g. (71.6%) of **11**, m.p. 196-197°; ir (potassium bromide): 3435, 3070, 2980, 2940, 2250, 1660, 1595, 1330, 1315 cm^{-1} ; ms: m/e 470.1721 ($\text{C}_{30}\text{H}_{22}\text{N}_4\text{O}_2$) (12.3%), 455 (2.4), 365 (1.4), 338 (0.1), 324 (1.2), 260 (0.1), 245 (2.1), 234 (0.6), 233 (0.3), 208 (0.2), 131 (0.6), 106 (20.6), 105 (100).

Anal. Calcd. for $\text{C}_{30}\text{H}_{22}\text{N}_4\text{O}_2 \cdot \text{H}_2\text{O}$: C, 73.75; H, 4.95; N, 11.47. Found: C, 73.64; H, 4.99; N, 11.58.

Reaction of **9** with 3,4-Dimethoxybenzaldehyde in the Presence of Sodium Hydride.

Reaction of 0.48 g. (0.0011 mole) of **9**, 0.37 g. (0.0022 mole) of 3,4-dimethoxybenzaldehyde, and 0.0022 mole of 50% sodium hydride in 20 ml. of anhydrous dimethylformamide gave as described above 0.39 g. (69.9%) of **12**, m.p. 171-172°; ir (potassium bromide): 3275, 2850, 2860, 1655, 1595, 1520, 1285, 1140 cm^{-1} ; ms: m/e 508.1636 ($\text{C}_{30}\text{H}_{24}\text{N}_4\text{O}_4$) (57.0%), 507 (7.33), 493 (2.45), 481 (2.08), 480 (9.48), 479 (13.72), 478 (1.77), 477 (5.14), 465 (4.74), 452 (2.78), 451 (5.57), 449 (3.79), 437 (1.37), 343 (1.68), 315 (0.38), 285 (0.14), 178 (1.60), 177 (1.98), 166 (9.31), 165

(100), 151 (0.94).

Anal. Calcd. for $\text{C}_{30}\text{H}_{24}\text{N}_4\text{O}_4$: C, 70.85; H, 4.76. Found: C, 70.97; H, 4.76.

Reaction of Reissert Compounds with Concentrated Acid.

Equimolar quantities of **1** and 2,4-dinitrophenylhydrazine in concentrated hydrochloric acid were heated on the steam bath for 10 minutes and then stirred for 2 hours at room temperature. Filtration and recrystallization from ethanol gave a 76% yield of benzaldehyde 2,4-dinitrophenylhydrazone identical with an authentic sample. Similarly, **4** and **9** gave good yields of benzaldehyde 2,4-dinitrophenylhydrazone.

Hydrolysis of **9** with hydrobromic acid in glacial acetic acid gave **13**, m.p. 261-263° from acetic acid; ir (potassium bromide): 3435, 2950-2800, 1720-1690, 1625, 1400, 1300, 1180, 860 cm^{-1} ; ms: m/e 267.0647 ($\text{C}_{14}\text{H}_9\text{N}_3\text{O}_3$) (20.8%), 224 (64.5), 223 (20.4), 223 (2.2), 180 (100), 179 (51.4), 178 (7.2), 177 (3.8), 153 (20.9), 152 (24.1), 151 (8.7), 125 (6.5).

Anal. Calcd. for $\text{C}_{14}\text{H}_9\text{N}_3\text{O}_3$: C, 62.92; H, 3.39. Found: C, 62.53; H, 3.30.

Hydrolysis of **3** (R = Ph, R' = H).

A mixture of 0.52 g. of the pseudo base **3** (**4**) in a minimum volume of ethanol and 20 ml. of 5% sodium hydroxide solution was heated on the steam bath for 5 minutes and kept overnight. Filtration and recrystallization from ethanol gave 0.28 g. (90%) of 4,6-phenanthroline identical in all respects with an authentic sample.

5-Cyano-6-benzoyl-5,6-dihydro-4,6-phenanthroline (**2**, R = Ph).

To a solution of 0.26 g. (0.0014 mole) of 4,6-phenanthroline and 0.35 g. (0.0035 mole) of trimethylsilyl cyanide in anhydrous methylene chloride was added, as described above, a catalytic amount of aluminum chloride and 0.49 g. (0.0035 mole) of benzoyl chloride. Reaction and work up in the usual manner gave 0.23 g. (53%) of **2** (R = Ph), m.p. 223-225° from ethanol; ir (potassium bromide): 2950, 1645, 1595, 1495, 1450, 1410, 1360, 1330 cm^{-1} .

Anal. Calcd. for $\text{C}_{20}\text{H}_{13}\text{N}_3\text{O}$: C, 77.15; H, 4.21; N, 13.50. Found: C, 77.36; H, 4.24; N, 13.44.

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