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# A Convenient Method for the Synthesis of 4,7-Dibromo and Chloro-hydroxy-1,10-Phenanthrolines

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***Abstract:*** *Two rational methods in the field of phenanthroline chemistry are presented. On the one hand the preparation of 4,7-dibromo-1,10-phenanthroline **2** via a transhalogenation reaction of its dichloro analog **1**. On other hand 7-chloro-4-hydroxy-1,10-phenanthroline **3** was synthesized via a selective partial hydrolysis of **1**. Both reactions proceed without the use of expensive catalysts or toxic solvents with an easy work-up procedure.*

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## I. Introduction

Halogenated heterocyclic systems are of great value in organic synthesis for example as starting materials in cross coupling reactions or as substrates for substitution reactions. However, such reactions often require the more reactive bromo substituted compounds rather than the chloro analogs. Since chlorinated compounds are often more readily available and cheaper, transhalogenation reactions are of great value. 1,10-Phenanthroline (phen) in particular is a well-known sub moiety in many different fields of research such as in the preparation of dye sensitized solar cells,[1,2] as a building block in supramolecular chemistry[3]and as ligands in general. Phenanthroline and its metal complexes are also known to be bioactive[4,5]. A convenient preparation of the bromo substituted phen from chloro phen could give access to reactions that fail with chloro substituted phen. Furthermore, unsymmetrically substituted phen are also interesting for the reasons mentioned earlier as well as for the preparation of push-pull-systems. Unfortunately, such systems often require many reaction steps, the use of various protecting groups or expensive reagents for their preparation[6,7].

## II. Material and Methods

The 33% HBr (solution in acetic acid) was purchased from Sigma Aldrich. Other chemicals were used without further purification. Nuclear magnetic resonance spectra ($^{1}$H, $^{13}$C, DEPT 135) were run depending on the compound in either [D6]DMSO or $CDCl_3$ on a Bruker Spectrospin 300 MHz instrument. The high-performance liquid chromatograms and their mass spectra (HLPC-MS) were acquired on a microTOF instrument. The acquisition parameters were as follows: The ions were produced *via* electrospray ionization (ESI), the ion polarity was positive, the capillary was set at 4500 V, the end plate offset was -500 V, the nebulizer was set at 2.5 bar, the dry heater was set at 220 °C and the flow rate of the dry gas was 7.0 l/min.

**Experimental procedure und analytical data:**

*4,7-Dibromo-1,10-phenanthroline* (**2**)

A 250 ml pressure vessel was charged with a stir bar and 249 mg (1 mmol) of 4,7-dichloro-1,10-phenanthroline **1**. The pressure vessel was filled with argon and 5 ml of 33% HBr (wt. %) solution in acetic acid was added. The vessel was closed and put on an oil bath heated to 85 °C. After 3 hours the vessel was cooled to room temperature and 10 ml of distilled water was added. The solution was brought to neutral pH by the addition of sodium bicarbonate and the resulting was filtered, washed with hot distilled water and dried. Recrystallization from ethanol afforded 235 mg of a pale brown mixture of 4,7-dichloro-1,10-phenanthroline **1** and 4,7-dibromo-1,10-phenanthroline **2**. A second run afforded 192 mg of the pale brown mixture with a better dibromo to dichloro ratio (see yield).

Yield 75 % (mixture of 71.5 % 4,7-dibromo-1,10-phenanthroline **2** and 28.5 % 4,7-dichloro-1,10-phenanthroline **1**; judged by $^{1}$H-NMR-Integration), Second run: Yield 78%, Combined Yield of 58% (mixture of 92.1 % 4,7-dibromo-1,10-phenanthroline **2** and 7.9 % 4,7-dichloro-1,10-phenanthroline **1**; judged by $^{1}$H-NMR-Integration). – $^{1}$H-NMR (300 MHz, $CDCl_3$, $\delta$ = 7.26): $\delta$ = 7.78 (d, 2H, Ar-H, $J$ = 5.1 Hz; 4,7-dichloro-1,10-phenanthroline), 7.98 (d, 2H, Ar-H, $J$ = 4.7 Hz; 4,7-dibromo-1,10-phenanthroline), 8.33 (s, 2H, Ar-H; 4,7-dibromo-1,10-phenanthroline), 8.38 (s, 2H, Ar-H; 4,7-dichloro-1,10-phenanthroline), 8.99 (d, 2H, Ar-H, $J$ = 4.7 Hz; 4,7-dibromo-1,10-phenanthroline), 9.11 (d, 2H, Ar-H, $J$ = 4.7 Hz; 4,7-dichloro-1,10-phenanthroline). – MS (HPLC-MS): *m/z* = 338.91 [M+1] (100.0 %), 336.91 (60.0 %), 340.91 (55.3 %), 339.91 (13.8 %), 337.91 (5.8 %), 341.91 (5.6 %).

*7-Chloro-4-hydroxy-1,10-phenanthroline* (**3**)

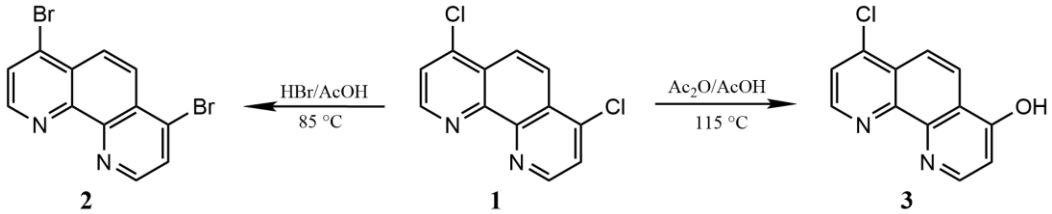
A 250 ml pressure vessel was charged with a stir bar and 249 mg (1 mmol) of 4,7-dichloro-1,10-phenanthroline **1**. The pressure vessel was filled with argon and 2.5 ml of glacial acetic acid and 0.5 ml of acetic anhydride was added. The vessel was closed and put on an oil bath heated to 115 °C. After 4 hours the vessel was cooled to room temperature and 20 ml of distilled water were added. The resulting solid was filtered, washed with DCM, dried. Recrystallization from DMSO afforded 162 mg of 7-chloro-4-hydroxy-1,10-phenanthroline **3** as a beige solid.

Yield 70 %. – $^{1}$H-NMR (300 MHz, [D6]DMSO, δ = 2.5): δ = 6.55 (d, 1H, Ar-H, *J* = 7.3 Hz), 8.66 (m, 2H, Ar-H), 8.27 (m, 2H, Ar-H), 9.01 (d, 2H, Ar-H, *J* = 5.7 Hz), 12.91 (s, 1H, Ar-OH). – $^{13}$C-NMR (300 MHz, [D6]DMSO, δ = 39.5): δ = 112.33, 118.31, 124.17, 124.22, 124.85, 127.08, 137.67, 140.54, 140.56, 142.43, 150.04, 175.73. – DEPT 135 (300 MHz, [D6]DMSO, δ = 39.5): δ = 112.33 (pos.), 118.31 (pos.), 124.17 (pos.), 124.85 (pos.), 140.56 (pos.), 150.04 (pos.). – MS (HPLC-MS): *m/z* = 231.05 [M+1] (100.0 %), 232.05 (19.6 %), 233.04 (15.2 %), 234.04 (4.6 %).

## III. Result

The starting compound 4,7-dichloro-1,10-phenanthroline **1** was prepared according to a procedure by Altman and Buchwald[8]starting from the commercially available meldrum's acid, trimethyl orthoformate and *o*-phenylenediamine. Transhalogenation reactions for other nitrogen containing heterocycles like pyridine have already been described using a constant stream of HBr[9].

We simplified this method significantly by heating **1** with a commercially available solution of of 33% HBr (wt. %) in acetic acid in a pressure tube at 85 °C. This afforded the dibromo analog **2** in good yield (scheme 1). The resulting product is a mixture of **1** and **2** which could be characterized as such by comparison of the $^{1}$H-NMR spectra of both the mixture and the starting compound. If desired, the ratio of **1** to **2** can be further improved in favor of the dibromo analog by conducting a second run under the same conditions, this product is of 92% purity.




**2** **1** **3**

**Scheme 1.** Synthetic transhalogenation and partial hydrolysis approach from the dichloro species **1**.

Treating **1** with a mixture of glacial acetic acid and acetic anhydride (5:1) gave rise to the monohydroxylated analog **3** (scheme 1). This method presents a simple and effective way of synthesizing unsymmetrically substituted 1,10-phenanthrolines **3** that are open for further derivatization. Another advantage is the simple work-up in both cases, precipitation and recrystallization from ethanol and DMSO respectively sufficed for the purification. Working in acetic acid as solvent is also environmentally friendly and nontoxic.

## IV. Conclusion

Chlorophenanthroline**1** could be converted to the corresponding bromo-derivatives**2** or partially hydrolyzed, using a convenient and simple method.

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## References

[1]. Hara K., Sugiara H.,Dye-Sensitized Nanocrystalline $TiO_2$ Solar Cells Based on Ruthenium(II) Phenanthroline Complex Photosensitizers. Langmuir 2001,17(19):5992-5999.DOI: 10.1021/la010343q

[2]. Freys J.C., Gardner J.M.,Ru-based donor–acceptor photosensitizer that retards charge recombination in a p-type dye-sensitized solar cell. Dalton Trans. 2012,41(42):13105-13111.DOI: 10.1039/C2DT30829K

[3]. Murugavel R., Korah R.,Structural Diversity and Supramolecular Aggregation in Calcium, Strontium, and Barium Salicylates Incorporating 1,10-Phenanthroline and 4,4'-Bipyridine: Probing the Softer Side of Group 2 Metal Ions with Pyridinic Ligands, Inorg. Chem. 2007,46(26):11048-11062.DOI: 10.1021/ic700977w

[4]. Sammes P.G., Yahioglu G.,1,10-Phenanthroline: a versatile ligand. Chem. Soc. Rev. 1994, 23, 327-334. DOI: 10.1039/CS9942300327

[5]. Song, Y.M.; Xu J.P. Syntheses, characterization and biological activities of rare earth metal complexes with curcumin and 1,10-phenanthroline-5,6-dione,J. Inorg. Biochem. 2009,103(3):396-400.DOI: 10.1016/j.jinorgbio.2008.12.001

[6]. Ferretti F., Ragaini F.,New Nonsymmetric Phenanthrolines as Very Effective Ligands in the Palladium-Catalyzed Carbonylation of Nitrobenzene,Organometallics 2010,29(6):1465-1471.DOI: 10.1021/om100023x
[7]. Lüdtke C., Haupt A.,Synthesis of fluorine-containing 1,10-phenanthrolines using mild versions of Skraup and Doebner-von Miller reactions, J. Fluor. Chem. 2017,193:98-105.DOI: 10.1016/j.jfluchem.2016.11.016
[8]. Altman R.A., Buchwald S.L.,4,7-Dimethoxy-1,10-phenanthroline: An Excellent Ligand for the Cu-Catalyzed N-Arylation of Imidazoles. Org. Lett. 2006,8(13):2779-2782. DOI: 10.1021/ol0608505
[9]. Mutterer F., Weis C.D., Halogenierte Pyridine V. Fluorierte und bromierte Pyridinverbindungen, Helv. Chim. Acta 1976,59(1):229-235. DOI: 10.1002/hlca.19760590125

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