

THE IMPROVED SYNTHESIS OF 5-NITRO-1,10-PHENANTHROLINE

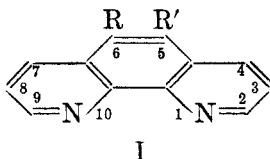
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The application of the ferrous complex of 5-nitro-1,10-phenanthroline as a high potential oxidation-reduction indicator (oxidation potential 1.25 volts) to newly developed procedures in cerate oxidimetry (1, 2), has increased the demand for this indicator. Since the starting material used in its preparation, 1,10-phenanthroline, is itself a somewhat expensive preparation (3), it has heretofore been a distinct disadvantage that the yield of 5-nitro-1,10-phenanthroline prepared from it by the best known method (4) has been relatively low, (60%).

A report is now being given of the successfully attempted development of a new procedure for the preparation of the dye base for preparation of the indicator nitro-ferroin¹ in yields of 90% or better. A study has also been made of the simultaneous formation, in small yield, of a new compound identified as 1,10-phenanthroline-5,6-quinone.

The preparation of most other 1,10-phenanthrolines substituted in the 5 or 5,6 positions of structural formula I where R and R' are CH₃ and NO₂ respectively or when R is hydrogen and R' is either CH₃, NO₂, Cl, or Br, follows procedures involving (5) a Skraup synthesis employing the properly substituted 8-aminoquinoline (6, 7). The preparation of 1,10-phenanthroline for the present work involved two successive Skraup reactions starting with ortho-nitroaniline with intermediate reduction of 8-nitroquinoline to the amino derivative (3).



The 5-nitro-1,10-phenanthroline may, however, as an exception to the usual case, be prepared by direct nitration of 1,10-phenanthroline or its monohydrate. This nitration as originally described (4) results in the formation of the mononitro derivative in a yield of 60% based upon the 1,10-phenanthroline used. Further investigation into the possible formation of a 5,6-dinitro derivative by this reaction was unsuccessful (8).

In distinction from the previously described nitration of 1,10-phenanthroline (4), the influence of two modifications of the usual procedure was predicted to be possibly beneficial. The use of 95% sulfuric acid was altered by substituting 15-25% oleum, and the temperature of the reaction was increased from 120° to 170°. Nitration under these conditions using concentrated nitric acid (sp. gr. 1.42) could be reasonably expected both to increase the yield of finished product

¹ Nitro-ferroin is the trivial name for the ferrous complex of 5-nitro-1,10-phenanthroline. This compound is red. The corresponding ferric compound, nitro-ferrin, is faintly blue.

and decrease the required reaction time. The well established resistance of the phenanthrolines to destructive decomposition by strong acids in contact with strong oxidants justified the innovations applied.

THE NITRATION OF 1,10-PHENANTHROLINE

The directions for the improved nitration of 1,10-phenanthroline, applying the newly developed procedure, are as follows:

Dissolve 30 g. of 1,10-phenanthroline monohydrate in 150 ml. of oleum (25% sulfur trioxide). Add 80 ml. of conc'd HNO_3 (sp. gr. 1.42) with stirring and at such a rate that the temperature approaches but does not exceed 170°. After the addition of nitric acid continue stirring during a 30-min. period.

Carefully pour the reaction mixture thus prepared over 2000 g. of crushed ice. Treat the strongly acid solution, after the ice has melted, with sufficient 30% sodium hydroxide solution to give a reaction mixture neutral to litmus. Add just sufficient dilute nitric

TABLE I
THE NITRATION OF 1,10-PHENANTHROLINE AND ITS CONVERSION
TO 5-NITRO-1,10-PHENANTHROLINE

1,10-PHENANTHROLINE MONOHYDRATE, G.	TEMPERATURE OF NITRATION, °C	YIELD, %
3	173	69.4
3	168	72.2
6	168	78.7
30	168	75.2
30	161	81.0
30	165	87.4
30	165	90.1

acid to reverse the color of the indicator, litmus paper, and filter the insoluble 5-nitro-1,10-phenanthroline, using a 6-inch Büchner funnel, and moderately reduced pressure. Wash the product with cold water to remove soluble products of the reaction.

The 5-nitro-1,10-phenanthroline is a light yellow crystalline compound (m.p. 197-198°). It may be air-dried either at ordinary temperatures or at 60°, or, preferably, in a spacious desiccator over an ample supply of anhydron to accelerate the removal of adsorbed water.

Data obtained for a series of applications of the described procedure are given in Table I.

By examination of the data of Table I it is seen that the optimum conditions involve heating to 165° during nitration. Best yields are obtained employing moderate amounts of 1,10-phenanthroline. Even better yields (approximately 95%) are attained in nitration of 300-g. portions of starting material.

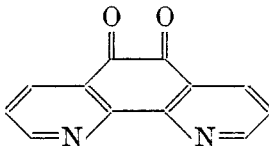
INVESTIGATION OF SECONDARY OXIDATION PRODUCTS OF NITRATION REACTION

The filtrate from the nitration of 30 g. of 1,10-phenanthroline monohydrate was orange-red in color and upon storage during 15 days (with slight evaporation) deposited a small amount of an orange-colored crystalline material. This was found to melt with decomposition at 248-253°. It was recrystallized twice from 95% ethanol, giving 0.7 g. of small, yellow, plate-like crystals having the melting point 256-257°.

Anal. Calc'd for $\text{C}_{12}\text{H}_8\text{N}_2\text{O}_2$: C, 68.6; H, 2.88; N, 13.3.

Found: C, 68.3; H, 2.72; N, 13.3.

From the nature of its synthesis and as a result of analysis, the compound $C_{12}H_6N_2O_2$ was postulated to have the structural formula.



It seems unlikely that the keto oxygen would be found on the extremely inert heterocyclic rings. The material was found to be insoluble in water and to form no hydrate under the described conditions of preparation. It gave no colored complex compound with the ferrous ion, in contrast to the parent substance.

Further substantiation for the structural formula assumed was found by confirmatory test reactions. The compound reacts with 2,4-dinitrophenylhydrazine to give in rather poor yield a red hydrazone of m.p. above 300° . This material can be recrystallized from pyridine, in which it is slightly soluble at the boiling point, and almost insoluble at room temperature. The 2,4-dinitrophenylhydrazone is almost insoluble in boiling ethyl acetate and only very slightly soluble in boiling benzene. A sample recrystallized twice from pyridine was used for microanalysis and found to be the mono substituted derivative.

Anal. Calc'd for $C_{12}H_6N_2O_2$: C, 55.39; H, 2.58; N, 21.53.

Found: C, 55.29; H, 2.62; N, 20.81.

The agreement of the nitrogen in the analysis leaves something to be desired, but considering the nature of the material and difficulty of purification by crystallization, it was felt that the results were satisfactory.

The compound also reacts with ethylenediamine exothermally to give a product of very high m.p. and wide fusion range. The substance gives the test described by Feigl (9) for a 1,2-diketone. An additional amount of (about 0.5 g.) of this 1,10-phenanthroline-5,6-quinone can be obtained by evaporation of the filtrate from the first batch recovery until sodium sulfate begins to separate.

Attempts to prepare this compound by oxidation of 1,10-phenanthroline employing acidified dichromate, neutral, acid, or alkaline peroxide, acidified vanadate or periodate, all failed. This is in agreement with a recent report (10) of the attempted oxidation of 1,7- and 4,7-phenanthrolines to form ortho-quinones.

The fact that this compound does not form a colored complex with ferrous iron (the ferroin reaction) may be due to the lack of possible resonance in the benzene nucleus of the molecule.

ACKNOWLEDGMENT

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RÉSUMÉ

Directions have been given for the improved synthesis of 5-nitro-1,10-phenanthroline by direct nitration of 1,10-phenanthroline. Former optimum yields (following previously described directions for nitration) of 60% have been improved to 90% yield of finished product.

The isolation of a by-product, 1,10-phenanthroline-5,6-quinone, in small yield has been described.

URBANA, ILL.

LITERATURE CITED

- (1) SALOMON, GABRIO, AND SMITH, *Arch. Biochem.*, **11**, 433 (1946).
- (2) SMITH, AND GETZ, *Ind. Eng. Chem., Anal. Ed.*, **10**, 304 (1938).
- (3) SMITH AND GETZ, *Chem. Rev.*, **16**, 113 (1935).
- (4) HAMMETT, WALDEN, AND EDMONDS, *J. Am. Chem. Soc.*, **56**, 1092 (1934).
- (5) RICHTER AND SMITH, *J. Am. Chem. Soc.*, **66**, 396 (1944).
- (6) SMITH AND RICHTER, "Phenanthroline and Substituted Phenanthroline Indicators," Columbus, Ohio, The G. Frederick Smith Chemical Co., 1944.
- (7) SMITH AND RICHTER, *Ind. Eng. Chem., Anal. Ed.*, **16**, 580 (1944).
- (8) MARVEL AND PEPPLER, private communication.
- (9) FEIGL, (Trans., J. W. Mathews), "Qualitative Analysis by Spot Tests," New York, Nordemann Publishing Company, Inc., 1939, Ed. 2, pp. 304-7.
- (10) LINSKER AND EVANS, *J. Am. Chem. Soc.*, **68**, 403 (1946).