

The Interaction between Halogen Acids and Nitro-amines*

II. Investigation of the Reaction Mechanism

L. SIHLBOM

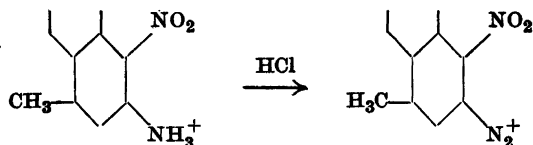
Institute of Organic Chemistry and Biochemistry, University of Stockholm, Sweden

The reaction between 4,9-dinitro-3-aminoretene and halogen acids has been described in a previous paper¹. It was shown that this amine, and also some other *o*-nitro-amines were quantitatively transformed into a chlorodiazonium chloride when dissolved in glacial acetic acid and treated with concentrated hydrochloric acid. The reaction with excess of hydrochloric acid at 90–100° C was completed very rapidly, and in the case of the retene derivative mentioned above the reaction time was as short as 15–30 seconds under suitable conditions. Owing to the rapidity of this unexpected reaction it was assumed provisionally to be an intramolecular transformation (*i.e.* the direct reaction of the nitro-group with the amino-group in the *o*-position) though no experiments which supported this hypothesis had been carried out in that investigation. The present paper concerns the mechanism of this reaction.

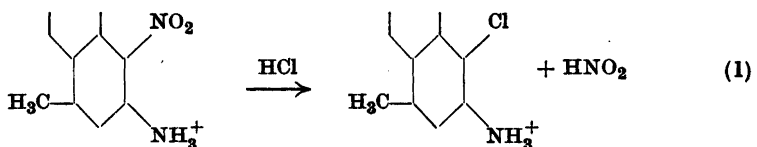
Two alternative mechanisms, one intramolecular (A) and one intermolecular (B) may be suggested (see p. 791) and the experiments described below have been performed in order to decide which actually occurs.

When 4,9-dinitro-3-aminoretene was treated as described above, but in the presence of an equimolecular amount of *p*-chloroaniline, the reaction was considerably retarded, and after 2 minutes a large proportion of the starting material remained unchanged. For complete consumption of the nitro-amine a reaction time of about 5 minutes was required. Before the reaction products were investigated the diazonium salts which had been formed were decomposed by reduction with hypophosphorous acid or by a Sandmeyer reaction (cuprous chloride), and then worked up.

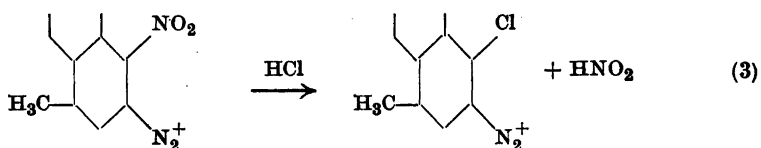
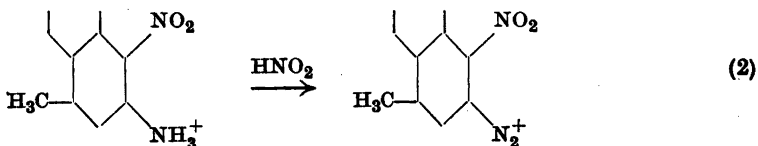
* The previous paper of this series appeared in *Acta Chem. Scand.* 5 (1951) 872 and was entitled "Intramolecular Diazotisation of *o*-Nitroamines".

A. Intramolecular mechanism

B. Intermolecular mechanism

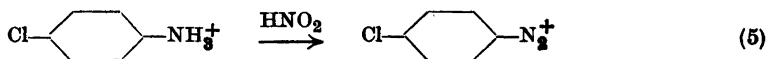
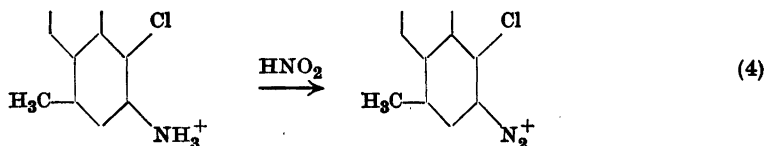
Initiation:



Propagation:



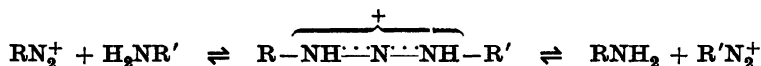
Termination:


Reaction scheme

After reduction with hypophosphorous acid two amines, 4-chloro-9-nitro-3-aminoretene and 9-nitro-3-aminoretene and a neutral substance, 4-chloro-9-nitroretene were isolated in about 8 % yield each, and after the Sandmeyer reaction *p*-dichlorobenzene and 3,4-dichloro-9-nitroretene were isolated in yields of about 10 % and 16 % respectively.

These results strongly support the intermolecular mechanism (B). The diazotisation of the *p*-chloroaniline demonstrates that a diazotising agent (indicated in the reaction scheme by HNO_2) must be formed from dinitroaminoretene. The fact that the addition of *p*-chloroaniline decreases the rate of the reaction indicates that it proceeds by a chain mechanism — initiation (reaction 1), propagation (reactions 2 and 3), and termination (reaction 4). By addition of an easily diazotable amine a new termination reaction, the diazotisation of the amine (reaction 5), occurs, and the total velocity is decreased. On the other hand the velocity should be increased by the addition of a small amount of nitrous acid and this was also demonstrated: a suspension of 4,9-dinitro-3-etylamine hydrochloride in a mixture of glacial acetic and concentrated hydrochloric acids was perfectly stable at room temperature (*cf.* part I¹) but when one tenth of the equivalent amount of nitrite was added, the amine was transformed quantitatively into 4-chloro-9-nitroretene-3-diazonium chloride within 3 minutes. It is to be expected that the presence of a diazonium-group will facilitate the elimination of the nitro-group (reaction 3) to a greater extent than will the ammonium ion (reaction 1), for the diazonium-group is the more powerful electron attracting substituent.

The possibility that the *p*-chloroaniline was diazotised by 4-chloro-9-nitroretene-3-diazonium chloride, formed by intramolecular diazotisation, *via* the diazoaminocompound,



is rather improbable, as the reactions are carried out in an extremely acid medium, but the point has nevertheless been investigated: *p*-chloroaniline was added to a hot (90° C) solution of 4-chloro-9-nitroretene-3-diazonium chloride in a mixture of glacial acetic and concentrated hydrochloric acids, the proportions of the components being the same as in the experiment described above, and after 5 minutes the mixture was treated with cuprous chloride. From the resulting mixture no *p*-dichlorobenzene could be obtained, indicating that the postulated mechanism does not operate.

As mentioned above 9-nitro-3-aminoretene was isolated when the reaction mixture from 4,9-dinitro-3-aminoretene, *p*-chloroaniline and hydrochloric acid in acetic acid was reduced by hypophosphorous acid; it was also formed on treatment of the reaction mixture with cuprous chloride or by heating only.

A possible source for this product could be 4-chloro-9-nitro-3-aminoretene which can be dechlorinated by cuprous chloride. In agreement with this fact 9-nitro-3-aminoretene was obtained in good yield (*ca.* 70 %) when 4,9-dinitro-3-aminoretene was heated with excess of cuprous chloride in a

mixture of glacial acetic and concentrated hydrochloric acids. This reductive dechlorination, however, could not be effected with hypophosphorous acid, nor did it take place when 4-chloro-9-nitro-3-aminoretene was added to a solution of 4-chloro-9-nitroretene-3-diazonium chloride, *p*-chloroaniline, *p*-chlorobenzene diazonium chloride and hydrochloric acid in acetic acid (proportions approximately the same as in the experiment that yielded 9-nitro-3-aminoretene), and the diazonium salts were decomposed by heating. The intention with the latter experiment was to find out if products formed in the reaction mixture could have effected the dechlorination, but this was obviously not the case. A possible explanation for the formation of 9-nitro-3-aminoretene is that 4,9-dinitro-3-aminoretene may undergo denitration, just as sulphonic acids can be desulphonated; this remains to be investigated further. Though not quite comparable, a reaction applicable to certain nitrohalobenzenes may be mentioned. These compounds on treatment with potassium cyanide in alcoholic solution exchange the nitro-group with hydrogen and at the same time a cyano-group is introduced in the ortho-position to the eliminated nitro-group (the von Richter reaction, recently investigated and discussed by Bunnett, Cormack, and McKay²). A reaction discovered by Kohn³ may also be mentioned. He found that *m*-dinitrobenzene and 2,4-dinitrotoluene on treatment with aqueous hydroxylamine exchange a nitro-group with hydrogen yielding nitrobenzene and *o*-nitrotoluene respectively.

Since the first paper¹ on this subject was published, Dey, Krishna Maller, and Pai⁴ have reported an analogous reaction. They found that on heating in a mixture of glacial acetic and concentrated hydrochloric acids to 100° C 3-chloro-4,6-dinitroaniline loses its nitro-groups. The present author has investigated the six isomeric dinitroanilines with respect to this reaction and the results will be published in a forthcoming paper.

EXPERIMENTAL

The interaction between hydrochloric acid and 4,9-dinitro-3-aminoretene in the presence of *p*-chloroaniline

A hot mixture of glacial acetic acid (10 ml) and conc. hydrochloric acid (14 ml) containing *p*-chloroaniline (0.50 g; 0.004 mole) was added to a hot (*ca.* 90° C) well-stirred solution of 4,9-dinitro-3-aminoretene (1.35 g; 0.004 mole) in glacial acetic acid (50 ml). After five minutes at *ca.* 90° C the reaction solution was divided into two equal parts. One part was reduced with hypophosphorous acid (20 ml 50 % acid were added) and the other was decomposed by the Sandmeyer reaction (cuprous chloride in hot conc. hydrochloric acid).

The former was mixed with hypophosphorous acid and kept at room temperature for five hours, then diluted, made alkaline, and extracted with ether. After washing with

water and drying over sodium sulphate the ether solution was saturated with hydrogen chloride whereupon the amines present were precipitated as their hydrochlorides. These were collected, converted into the corresponding amines (yield 0.14 g), dissolved in benzene and adsorbed on a column of alumina ($10 \text{ cm}^2 \times 20 \text{ cm}$). On development with benzene many zones appeared. The lowest, orange-coloured zone contained a compound (0.05 g, 8 %) which crystallized from ethanol in orange-yellow needles, m.p. $129-130^\circ \text{C}^*$. By its conversion to 9-nitro-3-aminoretene and 3,4-dichloro-9-nitroretene it was shown to be 4-chloro-9-nitro-3-aminoretene (these experiments are described below). [Calc. for $\text{C}_{18}\text{H}_{17}\text{O}_2\text{N}_2\text{Cl}$ (328.8): C 65.8; H 5.21. Found: C 65.8; H 5.30.]

An acetyl-derivative of this amine is described below.

Another compound was collected from an orange-red zone, separated from the lowest one by a violet zone which was not investigated. Reddish-yellow needles (0.05 g, 8 %), m.p. $156-157^\circ \text{C}$, undepressed on admixture with 9-nitro-3-aminoretene ** were obtained.

The acetyl-derivative, prepared as described for 9-nitro-3-acetylaminoretene ⁵, crystallized from glacial acetic acid as scales, m.p. $290-291^\circ \text{C}$, undepressed on admixture with 9-nitro-3-acetylaminoretene.

About the same amount of 9-nitro-3-aminoretene has been obtained in another experiment where the diazonium salts were decomposed by heating only.

The ether filtrate saturated with hydrogen chloride was washed with water and dried. The residue obtained after evaporation of the ether was adsorbed, from a benzene solution, on a column of alumina ($10 \text{ cm}^2 \times 20 \text{ cm}$). A yellow zone could be seen among those which appeared on development with a mixture of benzene (1 vol.) and petroleum ether (10 vol., b.p. $40-50^\circ \text{C}$). This yielded on elution a yellow well-crystalline compound (0.05 g, 8 %), m.p. $130-131^\circ \text{C}$. Crystallized from glacial acetic acid it was obtained as yellow flat needles, m.p. $133-134^\circ \text{C}$, undepressed on admixture with 4-chloro-9-nitroretene.

The second part of the reaction mixture, in which the diazonium salts were decomposed by the Sandmeyer reaction, was diluted with water and extracted with ether which then was repeatedly washed with dilute sodium hydroxide until the water-phase was nearly colourless. The ether solution was washed with water, dried over sodium sulphate and saturated with hydrogen chloride. The precipitate formed was collected and the filtrate washed with water and dried. After evaporation of the ether the residue was steam distilled and gave colourless crystals, m.p. $51.5-53^\circ \text{C}$, undepressed when mixed with *p*-dichlorobenzene. Yield 0.03 g, ca. 10 %. [Calc. for $\text{C}_6\text{H}_4\text{Cl}_2$ (147.0): C 49.0; H 2.74. Found: C 49.6; H 2.84.]

The residue from the steam distillation was dissolved in benzene and adsorbed on a column of alumina ($10 \text{ cm}^2 \times 20 \text{ cm}$). Development with benzene caused many zones to separate. Only the compound from the most quickly moving, light-yellow zone was collected, yield 0.14 g, m.p. $146-148^\circ \text{C}$. The product was again chromatographed but now, a mixture of benzene (1 vol.) and petroleum ether (10 vol., b.p. $40-50^\circ \text{C}$) was used. Two yellow zones appeared. The lower zone containing the main product yielded 0.11 g (16 %), m.p. $155-156^\circ \text{C}$. Crystallized from glacial acetic acid the compound was obtained as light-yellow needles, m.p. $158-159^\circ \text{C}$, undepressed on admixture with 3,4-dichloro-9-nitroretene.

* All melting points are corrected.

** In a previous paper ⁵ the m.p. is incorrectly reported to be $152-153^\circ \text{C}$.

Experiments giving information about the rate of the reactions

I. A hot (80 °C) mixture of glacial acetic acid (4 ml) and conc. hydrochloric acid (3 ml) was added to a hot (80 °C) solution of 4,9-dinitro-3-aminoretene (0.20 g) in glacial acetic acid (10 ml). A small amount of the amine hydrochloride separated but was consumed within 20 seconds when a clear solution was obtained. The amine hydrochloride is slightly soluble in this mixture even at 80° C and therefore, no greater amount of it can be present in the clear solution.

II. Experiment (I) was repeated in the presence of *p*-chloroaniline (0.20 g) which was dissolved in the mixture of glacial acetic and conc. hydrochloric acids before the solutions were mixed. Within 10 seconds a large amount of the amine hydrochloride precipitated. The reaction mixture was kept at 80 °C for 2 minutes with stirring, and the amine hydrochloride still present was collected from the hot suspension, washed with a mixture of glacial acetic acid (5 ml) and conc. hydrochloric acid (2 ml), dried and suspended in ether. When ammonia was passed through the suspension a light-yellow coloured solution was obtained. On evaporation of the ether unchanged 4,9-dinitro-3-aminoretene (0.16 g, 80 %), m.p. 208–209 °C, undepressed on admixture with an authentic sample, was obtained.

III. Experiment (II) was repeated with a reaction time of 5 minutes. In this case 0.07 g (35 %) of unchanged 4,9-dinitro-3-aminoretene was recovered.

IV. Experiment (II) was allowed to proceed until all 4,9-dinitro-3-aminoretene was consumed (no crystals of the amine hydrochloride was present in the reaction solution). A reaction time of 12–14 minutes was required.

V. 4,9-Dinitro-3-aminoretene (0.34 g, 0.001 mole) was dissolved in glacial acetic acid (20 ml) at 30 °C. Conc. hydrochloric acid (4 ml) was added and the resultant suspension (a large amount of the amine hydrochloride separated as colourless needles) was cooled to room temperature (22 °C). A solution of sodium nitrite (*ca.* 0.0001 mole) was added to the mixture with stirring. After 3 minutes a clear solution was obtained, indicating that all 4,9-dinitro-3-aminoretene had been diazotised. The diazonium salt was decomposed by the Sandmeyer reaction (cuprous chloride). By chromatographic purification (Al_2O_3 , benzene-petroleum ether) of the reaction product, rather pure 3,4-dichloro-9-nitroretene was obtained, (yield 0.28 g, 80 %, m.p. 157–158 °C). Crystallized from glacial acetic acid it melted at 159–160 °C, undepressed on admixture with an authentic sample of 3,4-dichloro-9-nitroretene.

Derivatives prepared from 4-chloro-9-nitro-3-aminoretene

4-Chloro-9-nitro-3-acetylaminoretene was obtained by adding acetic anhydride to a solution of 4-chloro-9-nitro-3-aminoretene in benzene. The solution was kept at room temperature for 8 hours when light-yellow needles appeared in the reaction mixture. Petroleum ether was added to cause complete precipitation. Crystallized from ethanol the acetyl-derivative melted at 211–212 °C. [Calc. for $\text{C}_{20}\text{H}_{19}\text{O}_3\text{N}_2\text{Cl}$ (370.8): C 64.8; H 5.16. Found: C 65.6; H 5.31.]

3,4-Dichloro-9-nitroretene. 4-Chloro-9-nitro-3-aminoretene (0.10 g) was dissolved in glacial acetic acid (2 ml). The amine hydrochloride, precipitated by the addition of conc.

hydrochloric acid (0.5 ml), was diazotised at room temperature with sodium nitrite (0.03 g) dissolved in a small amount of water. After 5 minutes the clear diazonium salt solution, thus obtained, was added to a hot solution of cuprous chloride (1 g) in conc. hydrochloric acid (10 ml). The reaction mixture was diluted with water and the precipitate collected (yield 0.10 g, m.p. 152–154 °C). After purification by chromatography and crystallization from glacial acetic acid the compound melted at 159–160 °C, undepressed on admixture with 3,4-dichloro-9-nitroretene.

9-Nitro-3-aminoretene. A hot (90 °C) solution of 4-chloro-9-nitro-3-aminoretene (50 mg) in glacial acetic acid (15 ml) was mixed with a hot solution consisting of glacial acetic acid (3 ml), conc. hydrochloric acid (4 ml), and cuprous chloride (0.3 g). The reaction mixture was shaken at 90 °C for 7 minutes, then cooled and diluted with hydrochloric acid to ensure complete separation of the reaction product. The colourless crystals, thus obtained, were collected, washed with hydrochloric acid and suspended in ethanol. On the addition of sodium acetate a red solution was obtained, from which the reaction product was precipitated by dilution with water (yield 40 mg, m.p. 154–155 °C). Crystallized from ethanol it was obtained as reddish-yellow needle-shaped crystals, m.p. 156–157 °C, undepressed on admixture with 9-nitro-3-aminoretene.

In another experiment a solution of 4-chloro-9-nitro-3-aminoretene (50 mg) in glacial acetic acid (15 ml) was mixed with a mixture of 50 % hypophosphorous acid (10 ml) and conc. hydrochloric acid (3 ml). On heating the suspension to 65 °C a clear solution was formed. After 5 minutes at 65 °C the solution was allowed to cool and was kept at room temperature for 10 hours. From the reaction mixture pure 4-chloro-9-nitro-3-aminoretene was obtained quantitatively.

The interaction between hydrochloric acid and 4,9-dinitro-3-aminoretene in the presence of excess of cuprous chloride

4,9-Dinitro-3-aminoretene (0.68 g) was dissolved in hot glacial acetic acid (30 ml). A solution of cuprous chloride (1.2 g) in a mixture of glacial acetic acid (5 ml) and conc. hydrochloric acid (7 ml) was added at 90 °C and the reaction mixture was kept at this temperature for 10 minutes with stirring. At the end of this time a large amount of the reaction product had precipitated as colourless needles giving the reaction mixture a pulpy appearance. After the addition of dilute hydrochloric acid (200 ml) the reaction product was collected, washed with dilute hydrochloric acid, suspended in ether and washed with aqueous alkali. Evaporation of the ether yielded a reddish-brown product (0.60 g) which was dissolved in benzene and adsorbed on a column of alumina (10 cm² × 20 cm). From the orange-red zone which appeared on development with benzene, 9-nitro-3-aminoretene (0.40 g, 68 %) was obtained. Crystallized from ethanol it melted at 156–157 °C, undepressed on admixture with an authentic sample.}

SUMMARY

In a previous paper¹ on this subject it was reported that certain nitroamines are converted to chlorine substituted diazonium salts by treatment with a halogen acid alone. This reaction, conjectured as an intramolecular

diazotisation, has now been investigated more closely. On the basis of the experimental evidence a probable mechanism representing the reaction as intermolecular is put forward and discussed.

REFERENCES

1. Sihlbom, L. *Acta Chem. Scand.* **5** (1951) 872.
2. Bunnett, J. F., Cormack, J. F., and McKay, F. C. *J. Org. Chem.* **15** (1950) 481.
3. Kohn, M. *Monatsh.* **30** (1909) 397; **31** (1910) 745.
4. Dey, B. B., Krishna Maller, R., and Pai, B. R. *J. Sci. Ind. Research (India)* **10 B** (1951) 140.
5. Sihlbom, L. *Acta Chem. Scand.* **2** (1948) 486.

Received February 11, 1953.