

90. *The Determination of the Nitro-group in Organic Compounds.*

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The stannous chloride method for the determination of nitro-compounds, originated by Limpricht and modified by subsequent workers, has been thoroughly re-examined. The various possible sources of error have been investigated, and a general procedure has been devised which enables accurate determinations to be made of the nitro-group in a wide variety of aromatic nitro-compounds.

A QUANTITATIVE determination of the nitro-group in an organic compound, in which stannous chloride is employed as the reducing agent, was first devised by Limpricht (*Ber.*, 1878, **11**, 35), who, by means of a standard iodine solution in presence of Rochelle salt, determined the amounts of stannous chloride before and after reduction of the nitro-compound. The method has been adapted by many workers for particular purposes, but, in spite of the various modifications introduced to eliminate apparent sources of error (Young and Swain, *J. Amer. Chem. Soc.*, 1897, **19**, 812; Altman, *J. pr. Chem.*, 1901, **63**, 370; Berry and Colwell, *Chem. News*, 1915, **112**, 1; Druce, *ibid.*, 1919, **118**, 133; Colver and Prideaux, *J. Soc. Chem. Ind.*, 1917, **36**, 480; Sachs, *ibid.*, p. 915; Desvergnès, *Ann. Chim. analyt.*, 1920, **2**, 141; Florentin and Vanderberghe, *Bull. Soc. chim.*, 1920, **27**, 158), generally satisfactory results have not been obtained even in the restricted field of compounds hitherto examined (see Table I), and it would seem that in several cases the elimination of one error has introduced others.

TABLE I.

% Purity of Nitro-compounds as Determined by Various Modifications of the Stannous Chloride Reduction Method.

Authors.	Ph·NO ₂ .	C ₆ H ₄ Me·NO ₂ .		<i>m</i> -		C ₆ H ₄ (OH)·NO ₂ .		2:4-		Picric acid.
		<i>o</i> -	<i>p</i> -	C ₆ H ₄ (NO ₂) ₂ .	C ₆ H ₃ Me(NO ₂) ₂ .	<i>o</i> -	<i>p</i> -	C ₆ H ₃ (OH)(NO ₂) ₂ .		
L.	96·30 99·44 96·97	—	99·3	99·8	—	99·55 §	—	—	—	—
A.	—	—	—	99·8	—	99·55 §	—	64·6 75·0 92·3	Reduction failed	—
Y. & S.	—	—	—	100·3 99·5	—	—	—	—	—	—
C. & P.	—	95·0 †	—	96·8	95·2	—	—	—	—	—
S.	92·2 * 96·0 * 99·9	—	—	99·8 100·0	—	—	—	—	—	—
B. & C.	—	—	—	—	—	—	98·7 101·6	—	—	98·6
Druce	99·65 99·50	101·4 101·1	—	99·55 99·89	99·9	—	—	—	—	—
D. ‡	—	—	—	99·5	—	104·6	76·2	88·4	—	99·7
F. & V.	99·30 99·7	90·3 92·5	97·1 96·3	98·9 99·0	99·1 99·3	—	—	—	—	98·2 98·6

Other results: trinitrotoluene, 95·1 (C. & P.), 100·8 (F. & V.); *o*-nitroaniline, 101·3 (D.); *m*-nitroaniline, 99·4 (L.).

* In open flask on water-bath. † Mononitrotoluene mixture. § Titration with permanganate.
‡ D. = Desvergnès.

Previous workers, except Desvergnès (*loc. cit.*), have apparently employed stannous chloride solution prepared by dissolving metallic tin in concentrated hydrochloric acid, but dissolution is only facile when the tin contains small quantities of impurities, such as lead or antimony, and although these impurities may have little or no influence on the actual reduction stage, their presence has a marked influence on the final titration of the stannous chloride solution by iodine (see Table II) (Altman, *loc. cit.*, records that platinum produces similar discrepancies).

TABLE II.

Effect of Impurity in the Tin on the Determination.

SnCl ₂ soltn.	% Purity of nitro- <i>o</i> -xylene.
1. Prepared from Sn containing 0.3% of Sb.....	93.30, 95.60
2. Prepared from Sn containing 0.2% of Pb.....	101.50, 100.90, 99.50

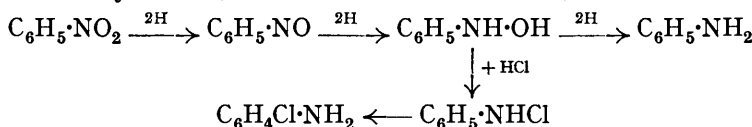
The majority of previous workers apparently assumed that the stannous chloride solution is not oxidised by the air during the long heating, and, except Colver and Prideaux (*loc. cit.*), they did not perform a concurrent blank experiment. This omission has been one of the principal sources of error in all recorded determinations, since even at room temperature stannous chloride solutions decrease in strength owing to aerial oxidation. All results of determinations in which concurrent blank experiments have not been performed will be too high. It is probable that this is the real cause of the so-called "over reduction."

Passage of an inert gas, such as carbon dioxide or nitrogen (Young and Swain; Berry and Colwell; Desvergnès, *loc. cit.*), through the solution during reduction, while eliminating the possibility of aerial oxidation, may introduce a new source of error by the removal of some of the volatile nitro-compound from the reaction mixture. This has been confirmed by duplicate experiments on nitrobenzene, in which the flow of carbon dioxide was relatively two and five bubbles per second; the mean values obtained for the purity were 99.85 and 95.3% respectively. The immiscibility of the nitro-compound with the reducing solution also introduces errors, for not only will there be a greater tendency for incomplete reduction unless the reaction be carried out for a considerable time, but also the possibility for aerial oxidation is greatly increased. Furthermore the longer reaction period necessary increases the possibility of loss of the nitro-compound by volatilisation. The concentration of the reducing solution is also a matter of importance, since when it is dilute reduction may be incomplete, unless the reaction is prolonged, in which case aerial oxidation is facilitated. The difficulties inherent in the immiscibility of the nitro-compound were realised by several workers, who sought to overcome them by employing alcohol as a solvent for the nitro-compound during reduction (Young and Swain; Colver and Prideaux; Druce; Desvergnès: *loc. cit.*). Although this may eliminate the error due to volatilisation and incomplete reduction of the nitro-compound, it not only introduces a new error in the final titration with iodine unless the alcohol is free from aldehyde, but also increases very considerably the tendency for nuclear chlorination (compare Blanskma, *Proc. K. Akad. Wetensch. Amsterdam*, 1906, **8**, 680). The use of *ca.* 93% alcohol solution (compare Sampey, *J. Amer. Chem. Soc.*, 1930, **52**, 88) is unsatisfactory for mixtures of nitro- and halogeno-nitro-benzenes (Bird and Ingold, *J.*, 1938, 919).

Many cases have been recorded in which nuclear chlorination has occurred during the reduction of nitro-compounds with stannous chloride (Fittig, *Ber.*, 1875, **8**, 15; Siedler, *ibid.*, 1878, **11**, 1201; Kock, *ibid.*, 1887, **20**, 1568; Bamberger, *ibid.*, 1895, **28**, 251; Blanskma, *Rec. Trav. chim.*, 1907, **25**, 365; Hurst and Thorpe, *J.*, 1915, **107**, 934). In some cases, especially in the presence of alcohol, it has been shown that the sole product consists of chloroamines (Gabriel and Stephens, *Ber.*, 1896, **29**, 305; Blanskma, *loc. cit.*). The generally accepted view of the formation of the chlorinated compound is based on the primary reduction of the nitro-group to the hydroxylamine derivative through the nitroso-stage. On further reduction, this hydroxylamine compound gives rise to the amine, but in presence of a large excess of hydrochloric acid, it may yield the chloroamine, which readily undergoes migration from the side chain into the nucleus (see p. 405).

For complete chlorination, the reduction does not proceed beyond the hydroxylamine

stage, *i.e.*, only four atoms of hydrogen are required, whereas for complete reduction to amine six atoms are necessary. Thus, whenever chlorination occurs, the final result for the nitro-



group will be low. This chlorination may be almost eliminated by using only the minimum quantity of free hydrochloric acid necessary to keep the stannous chloride in solution. The replacement of hydrochloric acid by sulphuric acid should also prevent simultaneous chlorination during reduction, and it has been found that, although reduction in presence of excess of sulphuric acid proceeds slowly, chlorination is entirely eliminated even in the presence of alcohol (compare Table III).

TABLE III.

The Influence of Alcohol and of Sulphuric Acid.

% Purity of the nitro-compound when reduced with hydrochloric acid solution of stannous chloride in presence of :

	(a) EtOH.		(b) EtOH and H ₂ SO ₄ .	
<i>p</i> -Nitroaniline	99.5	99.6	100.0	100.0
Nitrobenzene	95.0	95.2	99.9	99.85
<i>o</i> -Nitrotoluene.....	93.2	94.0	99.85	99.9
Nitro- <i>o</i> -xylene.....	93.0	93.2	99.9	99.95
Nitronaphthalene	88.0	78.5	99.5	99.0
<i>o</i> -Nitroanisole	76.0	77.5	98.0	98.4

In spite of the various errors with which the method seems beset, it can readily be made to yield concordant and accurate results, since most of the errors can be eliminated by employing pure materials and by performing a concurrent blank experiment under identical conditions. The two serious errors calling for special attention, *viz.*, loss of the nitro-compound and nuclear chlorination, can be avoided by employing a solvent such as purified alcohol and by replacing the greater portion of the hydrochloric acid by sulphuric acid. Furthermore, the use of alcohol is only required when the nitro-compound is insoluble in the reducing solution. The method, when performed as described below, has been found to yield concordant and excellent results for a large variety of nitro-compounds (compare Table IV), including *p*-nitrophenol and *p*-nitrotoluene, which are the least easily reduced of the compounds examined by Sampey (*loc. cit.*).

TABLE IV.

Results obtained with Typical Nitro-compounds.

Compound.	Purity, %.	Compound.	Purity, %.
<i>Nitrohydrocarbons.</i>		<i>Nitro-amines.</i>	
Nitrobenzene	99.85, 99.70	<i>p</i> -Nitroaniline	100.0, 100.0
<i>o</i> -Nitrotoluene.....	99.50, 99.50	<i>m</i> -Nitroaniline	100.0, 99.9
<i>p</i> -Nitrotoluene	99.5, 99.7	<i>o</i> -Nitroaniline.....	99.85, 99.8
Nitro- <i>o</i> -xylenes (mixed) ...	99.6, 99.9	<i>o</i> -Nitro- <i>p</i> -toluidine	99.85, 100.0
3-Nitro- <i>o</i> -xylene	99.8, 99.7	5-Nitro- <i>o</i> -3-xylydine	99.89, 100.0
4-Nitro- <i>o</i> -xylene	99.55, 99.84	3 : 5-Dinitro- <i>o</i> -4-xylydine	99.9, 100.0
4-Nitro- <i>m</i> -xylene	99.7, 99.8	Picramide	99.75
α -Nitronaphthalene	99.0, 99.5	<i>p</i> -Nitroacetanilide	99.85, 99.9
<i>Dinitrohydrocarbons.</i>		5 : 6-Dinitro- <i>o</i> -4-acetoxylidide	99.85, 99.95
2 : 4-Dinitrotoluene	99.95, 100.0	<i>p</i> -Nitrophenylhydrazine	99.0, 99.2
3 : 4-Dinitro- <i>o</i> -xylene.....	99.63, 100.0	<i>Nitrophenols.</i>	
4 : 5-Dinitro- <i>o</i> -xylene.....	99.65, 99.70	<i>o</i> -Nitrophenol.....	100.0, 100.0
<i>Trinitrohydrocarbons.</i>		<i>p</i> -Nitrophenol	100.0, 100.0
3 : 4 : 5-Trinitro- <i>o</i> -xylene ...	99.7, 100.0	5-Nitro- <i>o</i> -3-xylenol	99.0, 100.0
3 : 4 : 6-Trinitro- <i>o</i> -xylene ...	99.5	Dinitro- <i>o</i> -cresol	99.95, 99.7
Trinitrotoluene	99.65, 99.7	4 : 6-Dinitro- <i>o</i> -3-xylenol	99.8, 100.0
<i>Nitrobenzaldehydes.</i>		Picric acid	99.95, 99.95
<i>o</i> -Nitrobenzaldehyde	99.6, 100.0	<i>Nitro-acids.</i>	
<i>m</i> -Nitrobenzaldehyde	100.0, 100.0	Nitrobenzoic	99.75, 99.80
<i>p</i> -Nitrobenzaldehyde	99.85, 99.9	Nitrobenzenesulphonic (Na salt)	100.0, 100.0

EXPERIMENTAL.

Apparatus and Materials.—The apparatus consisted of a 300-c.c. round-bottomed flask fitted to a straight Liebig condenser by means of a ground glass joint. A narrow glass delivery tube reaching to the centre of the flask for admission of carbon dioxide passed through the condenser.

Reduction Solution.—283 G. of A.R. stannous chloride were dissolved in 300 c.c. of hydrochloric acid (d 1.16), and the solution was made up to 1 l. with water saturated with carbon dioxide. This solution approximates to 2.5N-stannous chloride in 3N-hydrochloric acid, the acid being somewhat in excess of that required for the conversion of stannous into stannic chloride.

Method.—The nitro-compound (0.1—0.2 g.) and, if necessary, 5—6 c.c. of alcohol (purified by refluxing in a rapid stream of carbon dioxide for several hours in order to remove aldehyde) were introduced into the reaction flask, from which the air had been previously displaced by carbon dioxide. After the nitro-compound had dissolved (by gentle warming if necessary), 10 c.c. of dilute sulphuric acid (1 : 1 by vol.) were added, followed by 10 c.c. of the standard stannous chloride solution. A slow stream of carbon dioxide (two bubbles per second) was led into the flask through a bubbler throughout the reduction. The mixture was gradually heated to 100° on the water-bath. If the nitro-compound was insoluble and volatile, the inside of the condenser tube was washed down by the addition of 2 c.c. of alcohol after $\frac{1}{2}$ hour and again after another $\frac{1}{2}$ hour. After 1 $\frac{1}{2}$ hours' heating, when reduction was complete, the contents of the flask were rapidly cooled, diluted with 200 c.c. of water saturated with carbon dioxide, and rapidly titrated with a standard solution of iodine (approx. 0.6N), starch solution being the indicator.

A concurrent blank experiment must be performed under identical conditions.

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