The Preparation of Aromatic Aldehydes by Means of the Dinitrogen Tetroxide Reagent.

By B. O. Field and J. Grundy.

[Reprint Order No. 5893.]

A variety of substituted benzyl alcohols has been converted into the corresponding aldehydes by means of dinitrogen tetroxide solutions. The excellent yields and the simplicity of the technique show the reaction to be a valuable general preparative method for aromatic aldehydes.

Cohen and Harrison (*J.*, 1897, **71**, 1057) first observed the conversion of a benzyl alcohol into a benzaldehyde by chloroform solutions of dinitrogen tetroxide. The present work is an investigation of the scope and utility of the reaction. Benzyl alcohols carrying electronically and sterically different substituents have been examined; excellent yields in all cases establish the reaction in its generality as superior to most available preparative methods (see, *e.g.*, Wagner and Zook, " Synthetic Organic Chemistry," Wiley and Sons, Inc., New York, p. 279). For instance, Stephen's synthesis gives reduced yields when *ortho*-substituents are present, and the promising elaboration of the Sommelet reaction has been found of diminished value because of the adverse effect of electron-attracting substituents (Angyal, Morris, Tetaz, and Wilson, *J.*, 1950, 2141).

When a solution of dinitrogen tetroxide in chloroform or carbon tetrachloride and a solution of a benzyl alcohol are mixed, each at 0°, the initially homogeneous and brown mixture, when kept at room temperature, becomes opaque owing to separation of water. After a further period the mixture becomes green owing to formation of dinitrogen trioxide, and the colour deepens as the reaction proceeds. It is therefore suggested that the reaction proceeds by homolytic attack of $\cdot NO_2$ radicals on the α-methylene group of the benzyl alcohol, the nitro-alcohol then decomposing to the aldehyde :

$$C_6H_5\cdot CH_2\cdot OH + 2NO_2\cdot \longrightarrow C_6H_5\cdot CH(OH)\cdot NO_2 + HNO_2[H_2O + N_2O_3] \longrightarrow C_6H_5\cdot CHO + HNO_2[H_2O + N_2O_3]$$

The benzyl alcohols were obtained from both the acid chlorides and the methyl esters of the appropriate acids by reduction with excess of lithium aluminium hydride. In a few cases ethyl esters were tried but methyl esters gave better results and were subsequently used. *m*-Nitrobenzyl alcohol was obtained by Lock's method (*Ber.*, 1930, **63**, 855), but in our hands the reaction was by no means as successful as claimed. The techniques of reduction were extensively examined and finally the reductions were done in ether solution, a four-fold excess of hydride being added, as a suspension–solution, with stirring. A recent method of this type (Tadros, Ekladius, and Sakla, *J.*, 1954, 2353) was tried but gave considerable trouble. The use of four-fold excess of solid hydride resulted in caking on the walls of the flask, making the reaction difficult to control and frequently dangerous. The use of dilute (1 : 1) acetic acid was not as effective as that of 5% (w/w) sulphuric acid in dissolving aluminium hydroxide and permitting clean separation of the ether phase. The results of the reductions are given in Table 1.

TABLE 1. *Yields of alcohols.*

R in $R\cdot C_6H_4\cdot CH_2\cdot OH$	Yield (%) : from acid chloride	Yield (%) : from methyl ester	R in $R\cdot C_6H_4\cdot CH_2\cdot OH$	Yield (%) : from acid chloride	Yield (%) : from methyl ester
o-Me	90	97	*m*-Br	92	95
m-Me	92	95	*p*-Cl	96	98
p-Me	94	98	*o*-OMe	93	98
o-Cl	96	98	*p*-OMe	94	98
o-Br	95	97	(α-Naphthylmethanol)	92	96
o-I	90	94			

The acids required were obtained by standard methods, as were the acid chlorides and esters. Several reported methods (*e.g.*, Cattelain, *Bull. Soc. chim.*, 1927, **41**, 1547) claim the preparation of pure *o*-iodobenzoic acid, but this substance could not be obtained colourless by a direct method. Pure white acid was obtained by converting the coloured product into the acid chloride or *via* the acid chloride into the methyl ester, which was then hydrolysed (cf. Cohen and Raper, *J.*, 1904, **85**, 1272).

TABLE 2. *Yields of aldehydes.*

Aldehyde	Yield (%)	Aldehyde	Yield (%)	Aldehyde	Yield (%)
o-Tolualdehyde	95	*o*-Bromobenzaldehyde	94	*o*-Methoxybenzaldehyde	96
m-Tolualdehyde	98	*o*-Iodobenzaldehyde ...	94	*p*-Anisaldehyde	97
p-Tolualdehyde	98	*m*-Bromobenzaldehyde	96	*m*-Nitrobenzaldehyde ...	98
o-Chlorobenzaldehyde	96	*p*-Chlorobenzaldehyde	98	1-Naphthaldehyde	91

TABLE 3. *Derivatives prepared for characterisation.*

R in $R\cdot C_6H_4\cdot CHO$	Derivative	M. p. of deriv.	Formula	N (%) Found	N (%) Calc.
o-Me	2 : 4-Dinitrophenylhydrazone	193—194°	$C_{14}H_{12}O_4N_4$	18·5	18·6
m-Me	,, ,,	211—212	$C_{14}H_{12}O_4N_4$	18·2	18·6
p-Me	,, ,,	233—234	$C_{14}H_{12}O_4N_4$	18·5	18·6
o-Cl	,, ,,	208—209	$C_{13}H_9O_4N_4Cl$	17·8	17·5
o-Br	Semicarbazone	215—216	$C_8H_8ON_3Br$	17·2	17·3
o-I	,,	204—205	$C_8H_8ON_3I$	14·4	14·5
m-Br	,,	204—205	$C_8H_8ON_3Br$	17·1	17·3
p-Cl	*p*-Nitrophenylhydrazone	218—219	$C_{13}H_{10}O_2N_3Cl$	15·4	15·2
o-OMe	,,	204—205	$C_{14}H_{13}O_3N_3$	15·3	15·1
p-OMe	2 : 4-Dinitrophenylhydrazone	254—255	$C_{14}H_{12}O_5N_4$	17·8	17·7
m-NO_2	,,	291—292	$C_{13}H_9O_6N_5$	21·0	21·1
(1-Naphthaldehyde)...	*p*-Nitrophenylhydrazone	234—235	$C_{17}H_{13}O_2N_3$	14·3	14·4

Various derivatives were made for the identification of the aldehydes prepared, but m. p.s were frequently erratic; *e.g.*, even slight impurities in the starting materials gave

2 : 4-dinitrophenylhydrazones whose m. p.s were not sharp, although analyses were always good. Only those 2 : 4-dinitrophenylhydrazones recorded were easily obtained, indicating that these derivatives are not as suitable as generally believed. The derivatives shown in Table **3** were found satisfactory for identification.

EXPERIMENTAL

Preparation of the Dinitrogen Tetroxide Reagent.—(*a*) Bulk dinitrogen tetroxide was obtained as a liquid by Partington and Park's method (*J.*, 1924, **125**, 74). The crude liquid was twice distilled over phosphoric oxide and then dissolved in chloroform or carbon tetrachloride (1 g. per 3 ml. of solvent), this concentration being found best for the oxidation. The solution was stored in glass with a secured stopper, and immediately before use the container was cooled in ice for safety in opening and to avoid losses of dinitrogen tetroxide.

(*b*) For a single oxidation a limited amount of dinitrogen tetroxide was prepared by quantitative thermal decomposition of lead nitrate (Dodd and Robinson, "Experimental Inorganic Chemistry," Elsevier, p. 234). The gas evolved was dissolved in the solvent cooled to $-10°$ to $-20°$. The solution thus obtained was diluted as required.

Preparation of Benzyl Alcohols.—The ester or acid chloride (0·2 mole) was dissolved in pure ether (100 ml.) and kept in a flask fitted with a wide-bore condenser and a stirrer. The solution was cooled to $-10°$, and a suspension–solution of lithium aluminium hydride (0·4 mole) in pure ether (300 ml.) added portionwise *via* the condenser. The mixture was then refluxed on the steam-bath for 2 hr., then cooled to $-10°$, and wet ether (50 ml.) was added with stirring. (This preliminary addition of wet ether seemed to be of value in initiating the decomposition of excess of hydride and making the subsequent decomposition with water smoother). The remaining hydride was decomposed by dropwise addition of water, stirring being continued. There was generally considerable loss of ether during the decomposition, and this was made good when decomposition was complete. The mixture was shaken with a slight excess of 5% (w/w) sulphuric acid, and the ether layer was separated, washed with 10% sodium hydrogen carbonate solution then with water and finally dried (Na_2SO_4). Although the alcohols thus obtained were essentially pure they were distilled or recrystallised as applicable; yields are given in Table 1.

m-*Nitrobenzyl alcohol.* To *m*-nitrobenzaldehyde (15·1 g.) was added 35% (w/w) sodium hydroxide solution (30 g.). The mixture was vigorously shaken until the temperature reached 45°, and then diluted with water and extracted with ether; the product obtained from the ether solution gave, after recrystallisation from ethanol (ice-cooling), 3·2 g. of *m*-nitrobenzyl alcohol, m. p. 26—27°.

Identification of Alcohols.—The alcohols were identified by oxidation to the corresponding acids, these in turn being identified by mixed m. p. The alcohol (1 g.) was added to a solution of potassium permanganate (3 g.) in 5% sodium carbonate solution (75 ml.), and the mixture refluxed for 15—30 min. The acids were isolated in the usual way, in excellent yield. For the oxidation of the methyl and *o*-iodobenzyl alcohols only a slight excess of permanganate was employed.

Preparation of Aldehydes.—The alcohol (0·1 mole) was dissolved in 2—3 times its volume of dry solvent, and the solution cooled to 0°. An ice-cold solution of dinitrogen tetroxide (0·13 mole) was then added, and the mixture left for 15 min. at 0°, and then stored overnight at room temperature in a glass-stoppered flask. The resulting green mixture was finally distilled (oil-bath) under a suitably reduced pressure to remove excess of reagent, solvent, and dinitrogen trioxide. The residue, whether solid or liquid, was taken up in ether and the solution washed with 10% sodium hydrogen carbonate solution, then with water and dried (Na_2SO_4). The aldehydes were isolated from the ether solution in the usual way. The yields are recorded in Table 2.

THE TECHNICAL COLLEGE, BLACKBURN.

[*Received, November* 19*th* **1954.**]