384.   *The Oxidation of Alcohols by* 2 : 4-*Dinitrophenylhydrazine.*

By E. A. BRAUDE and W. F. FORBES.

Primary and secondary alcohols containing two or more ethylenic or aromatic substituents conjugated with the carbinol group are oxidised by 2 : 4-dinitrophenylhydrazine in acid solution to the corresponding aldehydes or ketones, which are isolated as the 2 : 4-dinitrophenylhydrazones. The practical and theoretical implications of the reaction, which is analogous to the formation of osazones from α-keto-alcohols, are discussed.

SINCE its introduction by Brady (*Analyst*, 1926, **51**, 77; *J.*, 1931, 756), 2 : 4-dinitrophenyl-hydrazine has been widely employed not only for the characterisation of aldehydes and ketones but also as an analytical reagent for testing for the presence of a carbonyl function. In the course of work with ethylenic compounds, it has been observed by several workers in this laboratory that unsaturated alcohols, even when analytically pure as judged by elemental analysis and active hydrogen determination, frequently gave small amounts of 2 : 4-dinitro-phenylhydrazones when treated with Brady's reagent. These observations were generally ascribed to the presence of traces of ketonic impurities arising from imperfect purification or aerial oxidation and sufficiently small to escape detection by other means. However, a particularly striking case was noted recently with 2-benzylidene*cyclo*pentanol (Braude and Forbes, preceding paper), and in this instance the relatively high yield (20%) of derivative obtained ruled out the assumption that ketonic impurities in the alcohol were responsible. It was therefore decided to investigate the matter more closely. Since Brady's reagent is employed in methanolic or ethanolic solution, and no formaldehyde or acetaldehyde derivative is formed even on prolonged warming of the solution, it appeared highly probable that the occurrence of the reaction was associated with the presence of unsaturation in the carbinol, and this was confirmed by examining a number of examples representing a graded sequence of structural variation.

The results are tabulated below. No 2 : 4-dinitrophenylhydrazone is obtained from saturated alcohols or from crotyl or benzyl alcohol, but primary and secondary alcohols containing two or more ethylenic or phenyl substituents in conjugation with the carbinol group, when warmed with Brady's reagent, afford yields of 5—25% of the derivatives of the corresponding aldehydes or ketones. No attempt was made to compare reactivities of the different alcohols quantitatively, but, as judged by the approximate reaction times and yields

Oxidation of alcohols by 2 : 4-*dinitrophenylhydrazine under standard conditions*
(see Experimental).

Alcohol.	Yield of derivative, %.*	Reaction time.
Crotyl alcohol	Nil	5 hours
Benzyl alcohol	Nil	5 hours
Diphenylmethyl alcohol	4	1 hour
Cinnamyl alcohol	10	1 hour
Sorbyl alcohol	10	5 min.
4-*cyclo*Hex-1'-enylbut-3-en-2-ol	10	5 min.
4-*cyclo*Hept-1'-enylbut-3-en-2-ol	10	5 min.
2-Benzylidene*cyclo*pentanol	20	5 min.[1]
4-Phenylbut-3-en-2-ol	25	5 min.
Vitamin A$_1$	15	5 min.

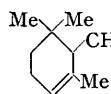* Based on alcohol.   [1] Braude and Forbes, preceding paper.

of 2 : 4-dinitrophenylhydrazones under standard conditions, the ease of oxidation clearly increases with the number of conjugated groups; moreover, an ethylenic substituent appears to have a somewhat greater activating effect than a phenyl substituent, and secondary alcohols are oxidised more readily than primary alcohols. The reaction does not take place in neutral or acetic acid solution, and one of the factors which severely limits the yields of derivatives is undoubtedly the decomposition of the unsaturated alcohols under strongly acid conditions.

In the case of vitamin A$_1$, the 2 : 4-dinitrophenylhydrazone obtained was not identical with that prepared directly from vitamin-A$_1$ aldehyde (Ball, Goodwin, and Morton, *Biochem. J.*, 1948, **42**, 516). The melting points of the two derivatives are very similar (204° and 208°, respectively) but the light-absorption properties differ considerably. Whereas the authentic 2 : 4-dinitrophenylhydrazone exhibits a maximum of 4420 A., close to the wave-length location expected for a pentaene-aldehyde derivative, the 2 : 4-dinitrophenylhydrazone obtained from
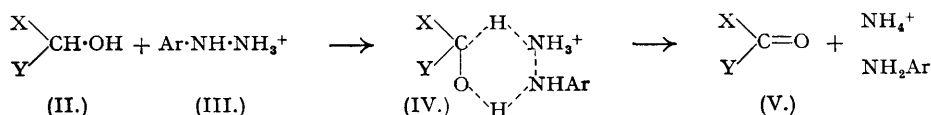
vitamin A_1 has a maximum at 4220 A., which corresponds to four rather than five ethylenic bonds conjugated with the $C\vdots N\cdot NHAr$ grouping (Braude and Jones, *J.*, 1945, 498). The lower-melting derivative may be either a geometrical isomer in which the characteristic maximum has been displaced to shorter wave-length as the result of steric hindrance (cf. Braude, Jones, Koch, Richardson, Sondheimer, and Toogood, *J.*, 1949, 1890) or a prototropic isomer derived from the isomeric vitamin-A aldehyde (I.) in which the cyclic double bond has moved out of conjugation in the course of the oxidation.

$$Me\diagdown_{\diagup}Me$$
$$\diagup\diagdown CH\vdots CH\cdot CMe\vdots CH\cdot CH\vdots CH\cdot CMe\vdots CH\cdot CHO$$
$$\diagdown_{\diagup}Me \qquad (I.)$$

The formation of 2 : 4-dinitrophenylhydrazones from αβ-ethylenic alcohols bears a close resemblance to the formation of osazones from α-keto-alcohols and is of considerable theoretical interest. Both reactions involve the oxidation by an arylhydrazine of the grouping $X\cdot CH\cdot OH$ to $X\cdot CO$, where X is an unsaturated substituent. Both reactions occur only under acid conditions, and it is very probable that in the present reaction, as in osazone formation, one molecule of arylhydrazine acts as a dehydrogenating agent and is converted into the arylamine and ammonia. Moreover, it is known that osazone formation is promoted by electron-attracting and inhibited by electron-donating substituents in the aryl group (cf. Kenner and Knight, *Ber.*, 1936, **69**, 341; Bloink and Pausacker, *J.*, 1950, 1328), so that 2 : 4-dinitrophenylhydrazine represents a highly reactive compound in this type of change. A number of different mechanisms have been proposed for osazone formation (cf. Percival, *Adv. Carbohydrate Chem.*, 1948, **3**, 41), but by far the most plausible is that suggested by Kenner and Knight (*loc. cit.*) according to which the significant step consists of the dehydrogenation of the intermediate hydrazone by the hydrazonium cation (III).* By adopting this point of view, and introducing some modifications concerning the details of the hydrogen-transfer process, the reaction can be represented as follows :

$$\begin{array}{ccc} X\diagdown & & X\diagdown\quad H\diagdown & X\diagdown \\ \diagup CH\cdot OH + Ar\cdot NH\cdot NH_3^+ \longrightarrow & C\quad NH_3^+ \longrightarrow & C{=}O + NH_4^+ \\ Y\diagup & & Y\diagup\quad \diagdown NHAr & Y\diagup \quad NH_2Ar \\ & & O \quad H \end{array}$$

$$(II.) \qquad (III.) \qquad\qquad (IV.) \qquad\qquad (V.)$$

This mechanism, unlike others which have been proposed, introduces a minimum number of assumptions and explains the requirement of acidic conditions as well as of electron-recession at the hydrazono-grouping, since both will weaken the N–N link and facilitate the separation of the ammonium ion. Furthermore, it brings into unison two, at first sight unrelated, sets of observations and explains the much higher reactivity towards arylhydrazines of α-keto-alcohols as compared with other unsaturated alcohols. In the formation of an osazone, (II) represents the α-keto-alcohol monoarylhydrazone (X = $NHAr\cdot N\vdots CH$) and the reaction is assisted by the conjugated side-chain since the conjugation is further increased in the resulting α-diketone monoarylhydrazone (V; X = $NHAr\cdot N\vdots CH$). In the 2 : 4-dinitrophenylhydrazine reaction, (II) represents the α-ethylenic or α-aryl alcohol (X = $CH\vdots CHR$, Ar, etc.); here the transition state (IV) is stabilised to a lesser extent (which, however, increases with increasing conjugated unsaturation in X), and a highly reactive arylhydrazonium cation, such as the 2 : 4-dinitrophenylhydrazonium cation, is required to effect the dehydrogenation.

These observations show that it is necessary to be cautious in using the formation of a 2 : 4-dinitrophenylhydrazone as a functional test for the presence of a carbonyl group. On the other hand, the oxidation of alcohols by 2 : 4-dinitrophenylhydrazine generally gives yields too low to render the reaction of preparative value. The above considerations suggest, however, that the reaction might proceed considerably more readily with a hydrazine derivative, such as 2 : 4 : 6-trinitrophenylhydrazine, more highly substituted with electron-attracting groups. Preliminary experiments have shown that this is indeed the case.

EXPERIMENTAL.

M. p.s are uncorrected.

Reaction of Alcohols with Brady's Reagent.—The reagent was prepared by dissolving 2 : 4-dinitrophenylhydrazine (4 g.) in concentrated sulphuric acid (8 ml.) and adding absolute ethanol (60 ml.) with external cooling. The solution was then heated to the boiling point, filtered, cooled, and diluted with water (20 ml.). For the oxidation reaction, the alcohol was dissolved in a 2—6 molar excess of the

* Kenner and Knight (*loc. cit.*) actually formulate the hydrazonium cation as $Ar\cdot \overset{+}{N}H_2\cdot NH_2$, but there can be little doubt that the extra proton will be preferentially attached to the more basic terminal nitrogen atom and that the structure $Ar\cdot NH\cdot NH_3^+$ will predominate.

reagent, and the mixture was then warmed to about 60° on a steam-bath, in an atmosphere of nitrogen. After cooling, the precipitated 2 : 4-dinitrophenylhydrazones were filtered off, chromatographed on alumina from benzene–chloroform solution, and finally crystallised from ethyl acetate, unless otherwise stated. The reaction times and yields are given in the Table. The physical properties of the alcohols and 2 : 4-dinitrophenylhydrazones, together with other data where necessary, are recorded below.

Diphenylmethyl alcohol m. p. 68°, gave benzophenone 2 : 4-dinitrophenylhydrazone, m. p. and mixed m. p. 236°. Cinnamyl alcohol, m. p. 33°, gave cinnamaldehyde 2 : 4-dinitrophenylhydrazone, m. p. and mixed m. p. 251°. 4-Phenylbut-3-en-2-ol, m. p. 30°, gave benzylideneacetone 2 : 4-dinitrophenylhydrazone, m. p. and mixed m. p. 225° [Light absorption in chloroform : Maxima at 3040 and 3950 A., ε 17,600 and 35,000, respectively]. Sorbyl alcohol, m. p. 30° (Nystrom and Brown, *J. Amer. Chem. Soc.*, 1947, **69**, 2549), gave sorbaldehyde 2 : 4-dinitrophenylhydrazone, m. p. and mixed m. p. 180°. 4-*cyclo*Hexenylbut-3-en-2-ol, b. p. 116°/16 mm. (Braude and Coles, *J.*, 1950, 2014), gave 4-*cyclo*hexenylbut-3-en-2-one 2 : 4-dinitrophenylhydrazone, m. p. and mixed m. p. 195°. 4-*cyclo*Heptenylbut-3-en-2-ol, b. p. 84°/0·4 mm. (Braude and Forbes, unpublished), gave 4-*cyclo*heptenylbut-3-en-2-one 2 : 4-dinitrophenyl-hydrazone, m. p. and mixed m. p. 189°.

Vitamin A_1, m. p. 61° (Isler *et al.*, *Helv. Chim. Acta*, 1947, **30**, 1911), gave a 2 : 4-*dinitrophenylhydrazone* which crystallised from methanol in dark-red needles, m. p. 204° (Found : N, 12·3. $C_{26}H_{32}O_4N_4$ requires N, 12·1%). Light absorption in chloroform : Maximum at 4220 A., ε 42,000, respectively. Under the same conditions, vitamin-A_1 aldehyde (Ball, Goodwin, and Morton, *loc. cit.*) gave a 2 : 4-dinitrophenyl-hydrazone, m. p. 208°, which exhibited a light-absorption maximum at 4450 A., ε 29,000, in chloroform solution (Ball *et al.*, *loc. cit.*, give m. p. 208° ; light-absorption maximum at 4420 A., ε 54,000).

Cinnamyl alcohol did not react with 2 : 4-dinitrophenylhydrazine in neutral ethanolic or in acetic acid solution.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY,
SOUTH KENSINGTON, LONDON, S.W.7.