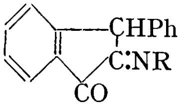
22. *Autoxidation Phenomena and Valency Tautomerism * in the Indone Series.*

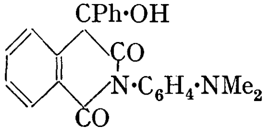
By Alexander Schönberg and Robert Michaelis.

(A) In view of the important part played by autoxidation processes in many branches of chemistry, a recent paper by Pfeiffer and de Waal (*Annalen*, 1935, **520**, 185) attracts special interest on account of the description of an autoxidation process which is without analogy.

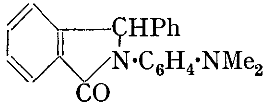
These workers claim that, although the colourless oxime (I) and the corresponding deep blue-violet anil (II) are stable in air, yet the deep blue-violet *p*-dimethylaminoanil (III) (which is stable in the solid state) is oxidised in solution to an *iso*quinoline derivative (IV), which reacts with alkalis to form (V). They point out that the anil (II) is oxidised by hydrogen peroxide to a new compound for which they propose the formula (VI) or (VII).



(I) R = OH
(II) R = Ph
(III) R = $C_6H_4{\cdot}NMe_2$

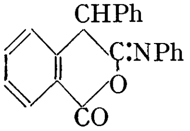


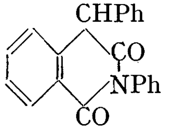
(IV.)



(V.)

(VI.)





(VII.)

In criticism of Pfeiffer and de Waal's conclusions, it may be pointed out that the sensitivity of (III) towards oxygen (which is as great as that of triphenylmethyl) is not in accordance with their formula; and further, that the transformations of (III) ⟶ (IV), (IV) ⟶ (V), and (II) ⟶ (VI) or (VII), under the experimental conditions given, are not supported by evidence from analogous reactions. Moreover, it is highly improbable that the

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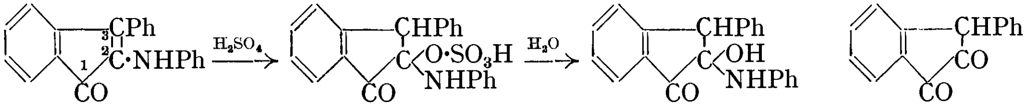
* Compare A. Schönberg, *Ber.*, 1931, **64**, 2323; 1934, **67**, 633; *Annalen*, 1935, **518**, 299; *Trans. Faraday Soc.*, 1936, **32**, 514; *Naturwiss.*, 1936, 620. For the meaning of " valency tautomerism " compare Wieland (*Ber.*, 1920, **53**, 1318; 1922, **55**, 1806).

oxime of a 1 : 2-diketone (in our case IX) should be colourless while the anil of the same diketone is deep blue-violet.

Although each of these difficulties may be overcome with the help of special hypotheses, it appeared to us important, in connexion with the work of one of us (Sch.) on the autoxidation of rubrene, to reinvestigate the phenomena observed by Pfeiffer and de Waal. Although the experimental evidence of their excellent work has been completely confirmed by us (as far as reinvestigated), we have arrived at an essentially different explanation, as a result of further investigation.

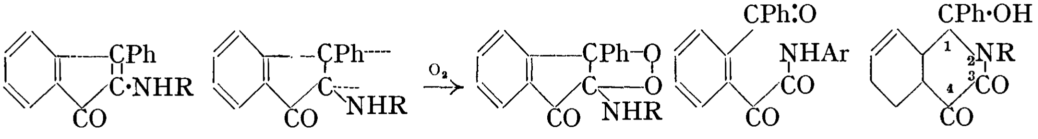
(B) We prefer to formulate the alleged anil (II) (obtained by the action of nitrosobenzene on XIX) as 2-anilino-3-phenylindone (VIII).* This formula completely explains the properties and colour of the compound for the following reasons : (1) the substance is shown to possess one active hydrogen atom by Zerewitinoff analysis. [The result of the Zerewitinoff analysis would also be in accordance with formula (III*a*) (footnote, below), which is, however, excluded by the fact that the substance is not acted upon by diazomethane.] (2) The ease with which (VIII) takes up one atom of oxygen in the presence of hydrogen peroxide is analogous to the behaviour of 2 : 3-diphenylindone and of 3-phenyl-2-ethylindone (Weitz and Scheffer, *Ber.*, 1921, **54**, 2327 ; de Fazi and Pirrone, *Gazzetta*, 1930, **60**, 277, 283). (3) The conversion of (VIII) into (IX), accomplished by Pfeiffer by treatment with concentrated sulphuric acid, followed by hydrolysis, we believe to take place as follows, and to be dependent upon the well-known tendency of the double bond in indones to undergo addition reactions with ease. The phenomenon can also be explained by prototropic change with subsequent ψ-salt formation and hydrolytic splitting. (4) The change from (VIII) to the dioxime of (IX) is formulated in a similar manner. In addition to the reaction between the carbonyl group and hydroxylamine, one molecule of the latter is added at the double bond between C_2 and C_3 and then a molecule of aniline is split off. (5) The blue-violet colour of the compound is in conformity with the formula suggested (VIII) [compare the red colour of 2 : 3-diphenylindone (VIII, with Ph in place of NHPh)].



(VIII.) (IX.)

(C) The blue-violet product of the condensation between 3-phenylindanone (XIX) and *p*-nitrosodimethylaniline we consider to be 2-*p*-dimethylaminoanilino-3-phenylindone (X ; R = $C_6H_4{\cdot}NMe_2$) (according to Pfeiffer and de Waal, it is III).

This compound behaves in a similar fashion to (VIII) towards Zerewitinoff analysis and diazomethane. The above considerations of the relation between colour and constitution also apply to (X). The oxidation of this compound by air, we consider to take place as follows and therefore the oxidation product to be 1-hydroxy-3 : 4-diketo-2-*p*-dimethylaminophenyl-1-phenyl-1 : 2 : 3 : 4-tetrahydro*iso*quinoline (XIII ; R = $C_6H_4{\cdot}NMe_2$) :



(X.) (XI.) (XII.) (XIII.)

R = $C_6H_4{\cdot}NMe_2$

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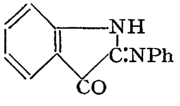
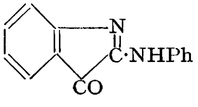
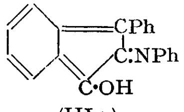
* It is possible that the primary product in the condensation is (II), which could not be isolated, and changed to (VIII). Compare the following change of an anil (I*a*) into an anilino-compound (II*a*) when heated (Pummerer, *Ber.*, 1911, **44**, 339) :



(I*a*.)

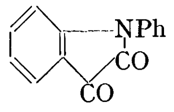


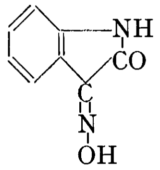
(II*a*.)



(III*a*.)

The formula of (XIII) is based on the following grounds : (1) The orange colour is in conformity with the proposed constitution (*N*-phenylisatin, XIV, is orange). (2) By Zerewitinoff analysis, (XIII) is shown to have one active hydrogen atom (compare Pfeiffer, *loc. cit.*). (3) It yields under mild conditions the oxime (XVI), whose formation is not in accordance with Pfeiffer's formula (IV). (4) The alteration in colour from (XIII) (orange) to (XVI) (yellow) is analogous to the change from isatin (orange) to its β-oxime (XV) (yellow). (5) The transformation (XIII) ⟶ (XVII) by the action of alkalis we consider to be a " benzilic acid rearrangement," followed by elimination of carbon dioxide and water [compare conversion of (XVII) ⟶ (XVIII) (Biltz, Heyn, and Bergius, *Annalen*, 1916, **413**, 68) under the influence of alkalis]. But we do not want to exclude the possibility that the action of alkali on (XIII) can lead to a cleavage of the six-membered ring, followed by ring closure to a five-membered system.


(XIV.)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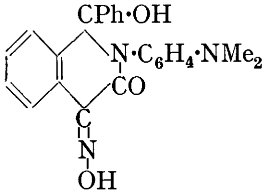
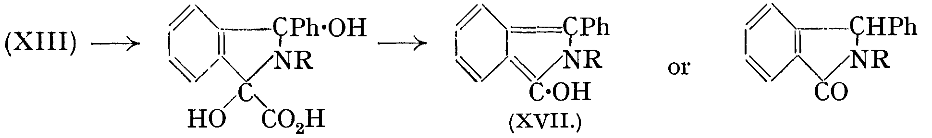
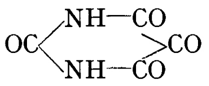
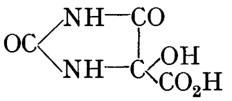
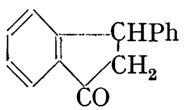

(XVI.)


(XVII.)

R = $C_6H_4{\cdot}NMe_2$


(XVII.)


(XVIII.)


(XIX.)

(D) The abnormal sensitivity of (X) to oxygen (we found it to be as unstable in oxygen as triphenylmethyl even in the dark) cannot be explained by the classical theories of chemical structure. In order to correlate the formula with the chemical properties it may be supposed that (X) in solution can act as its valency-tautomeric form (XI), which adds on oxygen by reason of its two tervalent carbon atoms.

(X) in the solid state is stable towards oxygen. This may be explained by either of the following hypotheses : (1) only the normal form is present in the solid; (2) both forms are present, but a thin oxidised layer is formed on the surface of the crystal, hindering further oxidation.

Whether one can demonstrate by electromagnetic measurements the presence of an equilibrium (X) $\rightleftharpoons$ (XI) will depend on whether the equilibrium is driven so far to the right that the paramagnetic influence of (XI) may be demonstrated, since the limits of error in this type of measurement are large (cf. Sugden, *Trans. Faraday Soc.*, 1934, **30**, 24; Eistert, *Ber.*, 1936, **69**, 2397; Müller, Müller-Rodloff, and v. Bunge, *Annalen*, 1935, **520**, 235; **521**, 89; Schönberg, *Trans. Faraday Soc.*, 1936, **32**, 520). At the present stage of chemical knowledge it is impossible to say why (X; R = $C_6H_4{\cdot}NMe_2$ or $C_6H_4{\cdot}OMe$)* can react in valency-tautomeric forms, whereas (X; R = Ph) so far as is known cannot. A familiar phenomenon occurs in the following case : Tetraphenylhydrazine is only slightly dissociated, but replacement of the phenyl by *p*-dimethylaminophenyl or anisyl groups produces highly dissociated substances (Wieland, *Ber.*, 1915, **48**, 1078). Compare also nitrosobenzene, which is dimeric and colourless, in the solid state, monomeric and green in

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* The blue-violet compound unstable towards oxygen which is described by Pfeiffer and de Waal as (I) is 2-*p*-methoxyanilino-3-phenylindone (X), and the product obtained from it by oxidation in air is (XIII). R = $C_6H_4{\cdot}OMe$ in all three formulæ.

solution, and *p*-nitrosoanisole and *p*-nitrosodimethylaniline, which are green and monomeric in solution *and* in the solid state.

EXPERIMENTAL.

2-*Anilino*-3-*phenylindone* (VIII).—Estimation of active hydrogen by Zerewitinoff's method gives 0·33% ($C_{21}H_{15}ON$ requires for one active hydrogen atom, 0·34%).

Behaviour with diazomethane. The substance (1 mol.), dissolved in ether and added to an ethereal solution of diazomethane (6 mols.), is kept for 2 hours at 0° and for 18 hours at room temperature. It is then recovered unchanged.

2-p-*Dimethylaminoanilino*-3-*phenylindone* (X).—Active-hydrogen estimation (Zerewitinoff's method), found 0·32% ($C_{23}H_{20}ON_2$ requires for one active hydrogen atom, 0·29%).

Importance of light in oxidation by air. The material (0·1 g.) in methyl alcohol (100 c.c.) is boiled for 2 mins. and kept over-night, in the dark. The originally green solution becomes orange and crystals of (XIII) separate. Therefore oxidation by air takes place even when light is excluded.

(X), dissolved in benzene, reacts instantaneously with a benzene solution of bromine with change of colour.

Action of diazomethane on (X). The same experimental conditions are used as above except that in this case air is excluded. After 20 hours, the ether is removed, and the residue dissolved in methyl alcohol and exposed to oxidation by air. (XIII) is formed in such quantity as to show that very little or no reaction takes place with diazomethane.

Action of hydroxylamine. To 0·5 g. of (XIII) in 300 c.c. of warm alcohol is added a solution of hydroxylamine hydrochloride (10 mols.) and sodium acetate in the minimum amount of water. During the addition the orange-coloured solution turns yellow. Sodium chloride soon begins to separate. After 14 hours, the liquid is concentrated to about 20 c.c. and water is added till no more oily material separates. The aqueous alcoholic solution, made alkaline with ammonia, is kept for 1½ hours and the precipitate is then filtered off, washed well with water, and dried in a desiccator (yield, 0·45 g.). The substance is dissolved in ether, and light petroleum (b. p. 80—100°) added till a slight turbidity is produced. After reprecipitation as above, the purified material (XVI) forms light yellow, refractive crystals which redden and sinter at 180° and melt at 192° (Found: C, 71·3; H, 5·4; N, 10·9. $C_{23}H_{21}O_3N_3$ requires C, 71·3; H, 5·4; N, 10·8%).

Action of methyl iodide. To 10 c.c. of methyl iodide boiling in an atmosphere of nitrogen is added 1 g. of (X), which is completely dissolved. After standing for a short time, a precipitate appears. The mixture is then warmed for 2 hours and cooled, and 40 c.c. of boiled absolute ether added. The violet crystals which form are collected after 12 hours, washed with ether, and dried in a vacuum (yield, 1·4 g.). The *substance* is purified by boiling it for 20 minutes with acetone. The now uniformly crystalline material is washed with acetone and dried. It forms deep blue-violet crystals decomposing at 226°. It is much more stable to oxygen than (X), difficultly soluble in cold water, chloroform and acetone, soluble in hot water, and very soluble in warm ethyl alcohol (Found: C, 59·8; H, 4·9; N, 5·9; I, 27·1. $C_{24}H_{23}ON_2I$ requires C, 59·7; H, 4·8; N, 5·8; I, 26·3%).

SUMMARY.

The reaction (III) $\longrightarrow$ (IV) described by Pfeiffer and de Waal is to be replaced by the reaction (X) $\longrightarrow$ (XI) $\longrightarrow$ (XIII). Corresponding corrections in relation to other reactions described by Pfeiffer and de Waal are suggested.

The valency tautomerism between (X) and (XI) is discussed.

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