854. *The Reaction of Dimethyl Acetylenedicarboxylate with Quinaldine.*

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The main product from the reaction of dimethyl acetylenedicarboxylate and quinaldine is formulated as a tricyclic " ylide " (VI) comprising a quinolinium ring with a fused seven-membered cyclic carbanion. The reactions and structure of the tetrabromo-addition product of (VI) are discussed. The other product from the initial quinaldine reaction contains an angular methyl group and is a neutral quinolizine (IV) which shows no tendency to rearrange.

The addition of pyridine or related compounds to dimethyl acetylenedicarboxylate [1-4] is an example of nucleophilic addition of the basic nitrogen atom to the activated triple bond, and a closely related example is the addition [5] of triphenylphosphine to the acetylenic ester. The adducts from the pyridines and dimethyl acetylenedicarboxylate undergo rapid cyclisation at the unsubstituted α-carbon atom of the pyridine ring to form the crystalline 9a*H*-quinolizines (I) which usually rearrange readily to the 4*H*-quinolizines (II).[2]

Continuing our study of these reactions, we have examined the reaction of dimethyl acetylenedicarboxylate with quinaldine, which contains no unsubstituted α-position. A similar reaction with 2,6-lutidine had failed to yield a stable product but quinaldine readily yielded two crystalline adducts, one yellow and one red. This reaction had already been studied by Diels and his co-workers [1,6,7] who described three adducts, but we have not observed their third, colourless adduct. The yellow compound was formulated as (III) by Diels *et al.*, but by analogy with the revised structures for the pyridine adducts, we reformulated it as (IV), a conclusion which had already been reached by van Tamelen, Aldrich, Bender, and Miller [3] on the basis of its nuclear magnetic resonance spectrum (see below). With the presence of the angular methyl group in (IV) there is no tendency for

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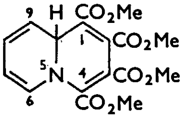
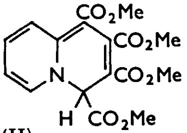
[1] Diels, Alder, Kashimoto, Friedrichsen, Eckardt, and Klare, *Annalen*, 1932, **498**, 16.
[2] Jackman, Johnson, and Tebby, *J.*, 1960, 1579.
[3] van Tamelen, Aldrich, Bender, and Miller, *Proc. Chem. Soc.*, 1959, 309.
[4] Acheson and Taylor, *J.*, 1960, 1691.
[5] Johnson and Tebby, *J.*, 1961, 2126.
[6] Diels, Alder, Friedrichsen, Petersen, Brodersen, and Kech, *Annalen*, 1934, **510**, 87.
[7] Diels and Kech, *Annalen*, 1935, **519**, 140.

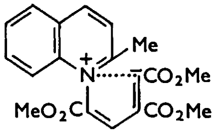
prototropic rearrangement as with the pyridine adducts, and this compound (IV) is stable to moderate treatment with acid. Diels *et al.* observed, however, that vigorous treatment of it with hydrochloric acid gave a tricarboxylic acid which decomposed to give quinaldine on fusion with lime; we have obtained quinaldine directly from this compound by heating it with hydrochloric acid in acetic acid. The observed nuclear magnetic resonance spectrum is in accord with the assigned structure (IV). In addition to four singlets (τ 6·24, 6·31, 6·39, and 6·44) arising from the four ester groups, the spectrum contains singlets at 8·53 (3 protons), 3·65 (2 protons), and 3·01 (broad; 4 protons). The singlet at 8·53 clearly arises from a methyl group attached to a fully substituted saturated carbon atom. The singlet at 3·65 is assigned to the two olefinic protons of the heterocyclic ring B, and the remaining absorption (3·01) arises from the four aromatic protons (ring A).



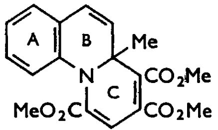
(I)



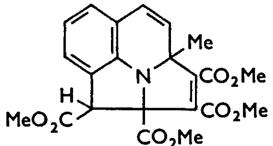
(II)



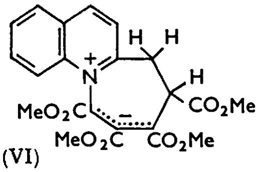
(III)



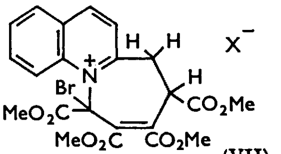
(IV)



(V)



(VI)



(VII)

The red, second adduct, which was the main product of the reaction, was originally formulated by Diels *et al.* as (IV), but later[7] on the grounds of spectra and the fact that the compound could not be obtained by acid treatment of the yellow adduct, the structure was amended to (V). An examination of the nuclear magnetic resonance spectrum of this red adduct has shown that no *C*-methyl group is present and consequently structures (IV) and (V) cannot be upheld. Further, the absence of absorption in the region between 6·00 and 3·00 indicates the absence of olefinic protons. The absorptions of the two protons of the heterocyclic ring B now appear as doublets (J = 10·0 c./sec.) at 2·172 and 2·36, thus establishing the aromatic nature of the ring. There is absorption equivalent to four other aromatic protons in the same region. A double doublet equivalent to one proton is observed at 7·42. The separation of the outer components of this multiplet is 29·8 c./sec., so that the proton responsible for this band is strongly coupled to two other protons, the absorption of which is, in fact, centred near 6·4 and is partially obscured by the signals of the ester-methyl groups. The separation of the outer components represents the sum of the two coupling constants, so that the minimum value of the largest is 15 c./sec. To accommodate such a value, it is necessary to assign the double doublet to one proton of a methylene group and the grouping $-CH_2{\cdot}CH\!<$ is, therefore, present. These features are accommodated in structure (VI). The band at 7·42 can be assigned to one proton of the methylene group which is out of the plane of the aromatic ring in the preferred conformation of the seven-membered ring. The other proton of the methylene group will be in the plane of the aromatic system and hence deshielded. These results suggest that the molecule, unlike (IV) and (V), contains a fully aromatic quinolinium ring system to which is attached the grouping $-CH_2{\cdot}CH\!<$. Structure (VI) is an "ylide," the anion presumably existing as a mesomeric system involving three carbon atoms, and a species (III) is regarded as an intermediate (cf. ref. 2) in the formation of both compounds (IV) and (VI). In the latter case, a proton is transferred from the active methyl group of (III) to the anionic side-chain which acts as an internal base, and the product then cyclises to (VI).

Some support for the zwitterionic structure (VI) is provided by its dipole moment, 3·55 D, determined on a benzene solution at 25° (we are grateful to Dr. J. Chatt, F.R.S., for this measurement). With bromine, the adduct (VI) formed a tetrabromide, in which three of the bromine atoms were present as an ionic perbromide. The tetrabromide which is regarded as (VII; $X = Br_3$) was readily reconverted into the original adduct (VI) by zinc and water [6] or aqueous silver nitrate. With perchloric acid the adduct gave a monoperchlorate monobromide (VII; $X = ClO_4$) which was also obtained by prolonged action of perchloric and hydrobromic acid on the original adduct, some of the hydrobromic acid presumably being oxidised to bromine which then reacted with the carbanion. The monobromo-monoperchlorate re-formed compound (VI) when treated with aqueous sodium hydrogen carbonate, and the ease with which the bromine substituent is removed in these reactions suggests that it has a " positive " character. Reaction of the tetrabromo-compound with hot methanol gave a mixture of mono- and di-bromo-compounds, each of which possessed an absorption spectrum resembling that of the parent zwitterion (VI), and in which consequently the bromine is probably present as a substituent of the methylene group. In an attempt to obtain these bromo-derivatives directly, the adduct (VI) was treated with *N*-bromosuccinimide, but the crystalline product was derived by addition of the two components and it is formulated as (VII; $X = C_4H_4NO_2$) on the basis of the similarity of the absorption spectrum to that of the tribromide (VII; $X = Br_3$). On attempted vacuum-sublimation, the adduct decomposed and gave succinimide.

The nitro-compounds obtained by Diels *et al.* by treating the adduct (VI) with either nitrous or nitric acid have not been re-investigated, but it seems probable that some of them are also addition complexes of the type described above.

EXPERIMENTAL

M. p.s are determined on a Kofler block. Ultraviolet absorption spectra refer to ethanolic solutions except where otherwise stated.

Reaction of Dimethyl Acetylenedicarboxylate and Quinaldine.—Quinaldine (20 c.c.) in ether (20 c.c.) was added dropwise to dimethyl acetylenedicarboxylate (40 c.c.) in ether (200 c.c.) at 0° with shaking during 15 min. and the mixture was left at 0° for 24 hr. and then at room temperature for 36 hr. The dark red solution was decanted to leave a dark red solid tar which was triturated with ether (3 × 200 c.c.); the residual solid crystallised from methanol (450 c.c.) as orange needles (7·5 g.), m. p. 195°, which after repeated crystallisation from methanol gave the quinaldine adduct (VI) as orange needles (6·0 g.), m. p. 202—203° (lit.,[1] 204°) (Found: C, 62·1; H, 4·9; N, 3·1. Calc. for $C_{22}H_{21}NO_8$: C, 61·8; H, 4·9; N, 3·3%), $\lambda_{max.}$ 220, 278, 298, 309, 323, 429, and 455 mμ (log ε 4·40, 4·22, 4·29, 4·31, 4·15, 4·03, and 4·00, respectively), λ_{infl} 256, 270, and 483 mμ (log ε 3·99, 4·15, and 4·69, respectively).

The methanolic mother-liquors from the first crystallisation were evaporated to 50 c.c., brought on to alumina [18″ × 2″ of Spence's alumina (type H)], and eluted with 3 : 17 chloroform–light petroleum (b. p. 60—80°). The reddish-yellow band eluted first gave the quinaldine adduct (IV) (1·0 g.) which formed yellow needles, m. p. 167° (lit.,[1] 174—175°), from methanol (Found: C, 61·6; H, 4·9; N, 3·4. Calc. for $C_{22}H_{21}NO_8$: C, 61·8; H, 4·9; N, 3·3%), $\lambda_{max.}$ 242 and 398 mμ (log ε 4·29 and 3·74, respectively), unchanged on addition of perchloric acid.

Reaction of the Adduct (IV) *with Hydrochloric Acid and Acetic Acid.*—The adduct (0·1 g.) was heated under reflux for 1·5 hr. in 10% hydrochloric acid (5 c.c.) and acetic acid (3 c.c.). The solution was poured into water (20 c.c.), made alkaline by sodium carbonate, and steam-distilled, and the distillate was mixed with saturated aqueous picric acid. The precipitated picrate (50 mg.) crystallised from methanol as yellow needles, m. p. 193—195° (lit.,[6] 190°), not depressed on admixture with authentic quinaldine picrate.

The Tetrabromo-compound (VII; $X = Br_3$) *from the Orange Adduct.*—The adduct (1 g.) in acetic acid (10 c.c.) was treated with bromine (0·25 c.c.) in acetic acid (3 c.c.), and the resultant oil solidified as pale yellow needles (1·6 g.), m. p. 143—145° (lit.,[6] 145—147°) (from acetic acid) (Found: C, 35·3; H, 3·0; N, 2·1; Br, 44·8. Calc. for $C_{22}H_{21}Br_4NO_8$: C, 35·3; H, 2·8; N, 1·9; Br, 42·8%), $\lambda_{max.}$ 256, 302, and 362 mμ (log ε 4·28, 3·93, and 4·08, respectively).

The Monobromo-perchlorate (VII; $X = ClO_4$) *from the Orange Adduct.*—(i) The tetrabromo compound (0·5 g.) was heated on a steam-bath with 60% perchloric acid (4 c.c.) and water (3 c.c.). Bromine was evolved. The residue (0·3 g.) formed colourless needles, m. p. 216° (lit.,[6] 217°) from methanol, and had $\lambda_{max.}$ 252 and 341 mμ (log ε 4·40 and 3·97, respectively).

(ii) The quinaldine stable adduct (0·5 g.) in methanol (25 c.c.) was heated on the steam-bath with hydrobromic acid (10 c.c. of a 48% solution in acetic acid) and 60% aqueous perchloric acid (10 c.c.) for 20 min. and then kept at room temperature for a week. Colourless needles (50 mg.) were precipitated and after crystallisation from methanol had m. p. 212° and an infrared spectrum identical with that of the monobromo-perchlorate prepared from the tetrabromo-compound.

Reaction of the Monobromo-perchlorate with Alkali.—The monobromo-perchlorate (350 mg.), m. p. 216°, in acetone (20 c.c.), was shaken with solid sodium hydrogen carbonate (0·5 g.) for three hr. The yellow solution was filtered and evaporated, to give an orange solid (0·1 g.) which crystallised from methanol as orange needles, m. p. 202°, not depressed on admixture with the orange quinaldine adduct. The infrared spectra of the two specimens were identical.

Reaction of the Tetrabromo-compound with Silver Nitrate.—The tetrabromo-compound (1·56 g.) in acetone (20 c.c.) was treated with aqueous silver nitrate until no further precipitate was formed. The precipitated silver bromide (0·8 g., 50%) was separated and washed with acetone (2 × 10 c.c.), and the washings were combined with the filtrate. Some bromination of the acetone occurred (lachrymator) and accounts for the low yield of silver bromide. The filtrate and washings were combined and evaporated to give a yellow solid (0·9 g.) which from methanol formed orange needles, m. p. 200—202°, not depressed on admixture with compound (VI).

Reaction of the Tetrabromide with Methanol.—The tetrabromo-compound (1·6 g.) was heated on the steam-bath in methanol (50 c.c.) until dissolution was complete and no further evolution of bromine was observed. On evaporation of the solution and cooling, a *dibromo-compound* was precipitated (0·1 g.) which formed yellow prisms, m. p. 216—218°, from methanol (Found: C, 44·5; H, 3·8; N, 2·15; Br, 28·4; OMe, 22·5. $C_{22}H_{19}Br_2NO_8$ requires C, 45·1; H, 3·3; N, 2·4; Br, 27·3; 4OMe, 21·4%); it had $\lambda_{max.}$ 203, 224, 261, 313, 362, 439, and 463 mμ (log ε 4·56, 4·33, 4·37, 4·21, 4·37, 4·64, and 4·58, respectively) with an inflection at 336 mμ (log ε 4·22).

The methanolic mother-liquors were evaporated to dryness and left an orange solid (0·4 g.) which formed orange needles of a *monobromo-compound*, m. p. 228—230°, from aqueous methanol (2 : 3) (Found: C, 52·7; H, 4·1; N, 2·7; Br, 16·8; OMe, 24·5. $C_{22}H_{20}BrNO_8$ requires C, 52·2; H, 4·0; N, 2·8; Br, 15·8; 4OMe, 24·6%). This had $\lambda_{max.}$ 206, 224, 275, 306, 316, 330, 441, and 465 mμ (log ε 4·26, 4·41, 4·26, 4·33, 4·36, 4·24, 4·03, and 4·37, respectively), λ_{infl} 203 and 285 mμ (log ε 4·21 and 4·26, respectively).

Reaction of the Orange Adduct with N-*Bromosuccinimide.*—The stable adduct (1·0 g.) in carbon tetrachloride (10 c.c.) with *N*-bromosuccinimide (0·35 g.) was heated under reflux on a lamp-bath for 1 hr. The precipitate (1·2 g.) was separated, washed with a little carbon tetrachloride, and crystallised by dissolving it in chloroform (50 c.c.), adding methanol (100 c.c.), and then evaporating the chloroform with addition of methanol to keep the volume of solution at about 150 c.c. The *product* (VII; $X = C_4H_4O_2N$) was thus obtained as prisms, m. p. 228—230° (Found: C, 51·5; H, 4·15; N, 4·7. $C_{26}H_{25}BrN_2O_{10}$ requires C, 51·5; H, 4·15; N, 4·6%), $\lambda_{max.}$ 256, 301, 325, and 358 mμ (log ε 3·86, 3·75, 3·74, and 3·92, respectively).

The product (0·1 g.) was sublimed in a tube overnight at 200°/0·01 mm. The sublimate separated into two bands: (i) colourless needles, m. p. 125°, not depressed on admixture with authentic succinimide and having an infrared spectrum identical with that of succinimide; and (ii) an orange unidentified " glass " that was probably a mixture of bromo-derivatives of (VI).

We thank the Directors of Imperial Chemical Industries Limited, Dyestuffs Division, for granting leave of absence (to A. C.).

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[*Received, June 12th, 1962.*]