513. *Addition Reactions of Heterocyclic Compounds. Part XVIII.* The Structures and Reactions of Adducts from Pyridines, Dimethyl Acetylenedicarboxylate, and Carbon Dioxide at Low Temperatures.*

By R. M. Acheson and A. O. Plunkett.

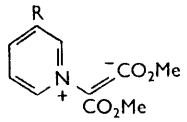
Pyridine, some alkylpyridines and isoquinoline combine with dimethyl acetylenedicarboxylate and carbon dioxide at −60° yielding 1 : 1 : 1 molar adducts which, in chloroform at 0° lose carbon dioxide rapidly, with perchloric acid yield corresponding salts, and on hydrogenation give back the original heterocycle. Only the pyridine adduct, 1-protopyridinium 1-(1,2-dimethoxycarbonylvinyl)-β-carboxylate, was obtained in both *cis*- and *trans*-forms. The stereochemistry was deduced from the infrared absorption spectra of the corresponding perchlorates, one of which possessed a strong intramolecular hydrogen bond. Both perchlorates decarboxylated on heating and gave the same 1-(1,2-dimethoxycarbonylvinyl)pyridinium perchlorate.

Pyridines react with dimethyl acetylenedicarboxylate at room temperature, yielding, in the first instance, 9a*H*-quinolizines (*e.g.*, IV). The reaction is thought [1] to involve the successive addition of two moles of the ester to the base, leading to zwitterionic intermediates (*e.g.*, II and III, respectively) and subsequent cyclisation. Jackman, Johnson, and Tebby [2] obtained very unstable cream-coloured products on pouring pyridine or 3-methylpyridine into ethereal dimethyl acetylenedicarboxylate at −50° and tentatively formulated these products as " ylids " (*e.g.*, III). Analysis of the product from 3-methylpyridine corresponded approximately to that of a 1 : 2 molar adduct, and it decomposed at room temperature, giving very low yields (total about 3%) of tetramethyl 7-methyl-4*H*-quinolizine-1,2,3,4-tetracarboxylate and the isomer (IV), one mole of carbon dioxide, and some dimethyl fumarate, 3-methylpyridine, and an unidentified ester. The " ylid " structure suggested for the cream products seemed very unlikely, to us, because it accounts for neither the carbon dioxide nor the low yield of cyclic products; many carbanions [3] readily attack 1-substituted pyridinium derivatives at position 2. Subsequently, on direct analogy with the structure of a 1 : 1 : 1 molar adduct obtained from triphenylphosphine, dimethyl acetylenedicarboxylate, and carbon dioxide, and without further experimental data, Johnson and Tebby [4] suggested that the adduct from pyridine had the structure

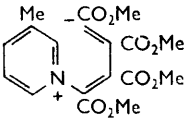
* Part XVII, *J.*, 1964, 526.

[1] Acheson, *Adv. Heterocyclic Chem.* (ed. Katritzky), 1963, **1**, 125.
[2] Jackman, Johnson, and Tebby, *J.*, 1960, 1579.
[3] *E.g.*, McEwen and Cobb, *Chem. Rev.*, 1955, **55**, 511; Agawa and Miller, *J. Amer. Chem. Soc.*, 1961, **83**, 449; Crabtree, Johnson, and Tebby, *J.*, 1961, 3497.
[4] Johnson and Tebby, *J.*, 1961, 2126.

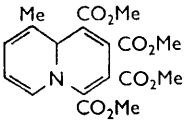
trans-(V) and was formed by the addition of carbon dioxide from the cooling bath to the intermediate (I).



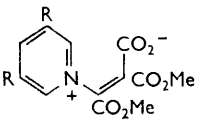
(I : R = H)
(II : R = Me)



(III)



(IV)



(V : R = H)
(VI : R = Me)

Cream-coloured adducts were obtained from pyridine and 3-methylpyridine, as described,[2] and similar adducts have also been prepared from 3,5- and 2,6-dimethylpyridine, isoquinoline, and phenanthridine. However in all cases the yields in successive experiments varied greatly, and on some occasions 4*H*- or 9a*H*-quinolizinetetra-esters (cf. structure IV) were obtained exclusively. This inconsistency was not overcome if the reactants were specially dried and distilled immediately before use, or when traces of peroxides or water were introduced.

Analysis of the adducts from the pyridines was not attempted as these products decompose rapidly at 0°. The adduct from isoquinoline was much more stable and although the carbon and hydrogen contents were not inconsistent with the compound being a 1 : 2 molar adduct, the type of structure suggested [2] for the 3-methylpyridine adduct (III) and an alternative [5] based on the same molecular formula are excluded by the low methoxyl content. Our analytical data and those [2] for the product from 3-methylpyridine are consistent with 1 : 1 : 1 molar-adduct structures built up from the acetylenic ester, carbon dioxide, and the heterocycle. The carbon dioxide, being derived from the cooling bath, accounts for our initial erratic yields, and its participation in the reaction was confirmed by the greatly increased yield of the isoquinoline adduct obtained when the gas was bubbled through the reaction mixture. The formulation of these adducts as zwitterions (*e.g.*, V) is supported by new evidence detailed below.

All the adducts decomposed rapidly and in the same way at about 0° in chloroform or carbon tetrachloride, as shown by the large changes in the infrared absorption spectra which occurred. All the adducts possessed a very strong band at 4·28 μ which was not observed or was extremely weak when the compounds were examined in Nujol paste. This band is due to the carbon dioxide resulting from the decomposition of the adducts; chloroform, through which carbon dioxide had been bubbled, possessed an identical maximum.

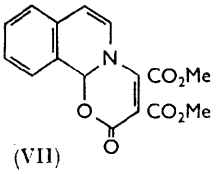
In the case of the isoquinoline adduct, the intensity of the carbon dioxide band increased threefold in 8 minutes after solution, and the maxima at 6·50 and 7·60 μ, present in the Nujol spectra and attributed to the carboxylate anion, disappeared at a corresponding rate. The last two maxima were absent from the spectra of the perchlorate (3,4-benzo-VIII), and their presence in the spectrum of the adduct itself excludes a cyclic uncharged formulation (VII).

Low-pressure hydrogenation of the *cis*-adducts from pyridine, 3,5-dimethylpyridine, and isoquinoline gave back the parent bases, indicating that the side-chain was attached to the nitrogen atom only. The isoquinoline adduct also gave some dimethyl fumarate. High-pressure hydrogenation of the pyridine adduct gave pyridine and dimethyl succinate, while a by-product of the low-pressure hydrogenation gave phthalic acid on hydrolysis. Lithium aluminium hydride with the pyridine adduct gave an oil which hydrolysed to *trans*-aconitic acid and butanol. These unexpected compounds may be derived from decomposition products of the pyridine adduct.

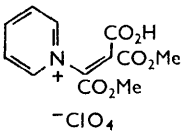
The pyridine adduct (V) with cold perchloric acid gave a carboxypyridinium perchlorate (VIII). When a second material, which slowly precipitated from the filtrate of the original

[5] Ref. 1, p. 153.

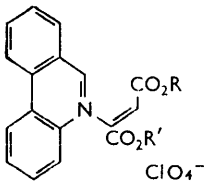
adduct preparation on storage at −15°, was similarly treated an isomeric carboxypyridinium perchlorate (X) was obtained. These perchlorates, which readily decarboxylate to the same vinylpyridinium perchlorate (XI), must be the *cis-trans* pair, respectively, and so define the stereochemistry of the parent adducts. The infrared absorption spectrum of the first acid closely resembled that of the phenanthridine derivative (IX, of established



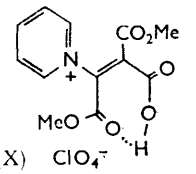
(VII)



(VIII)



(IX: R = H, R′ = Me, or R = Me, R′ = H)



(X) ClO_4^-

stereochemistry [6]) in the 2·5—5·5 μ region and possessed a strong band at about 2·85 μ, suggesting that the carboxyl group was largely unassociated. The lack of intermolecular association, in contrast to fumaric acid,[7] is probably due to the positive charges on the ions which would lead to association. The second acid (X) showed no sharp strong absorption maxima in this area but instead a broad strong absorption from about 2·6 to 4·0 μ, which indicated strong hydrogen-bonding. It has been clearly demonstrated by *X*-ray and infrared absorption-spectra measurements that crystalline maleic acid,[8] but not malonic acid,[7,9] possesses a strong hydrogen bond. As one of our acids is strongly hydrogen-bonded, and the other is not, it is clear that the former is of the maleic-acid type and has structure (X). The ultraviolet absorption spectra of both acids (VIII and X) and of the decarboxylation product (XI) are of the pyridinium-ion type and their extinction coefficients are only fractionally lower than that of 1-vinylpyridinium bromide ($\lambda_{max.}$ 258 mμ, ε 8,380).[10] The pyridinium perchlorate (XI) on attempted reaction with dimethyl acetylenedicarboxylate in methanol containing sodium methoxide gave a new pyridinium salt (XIV), addition of methanol to the double bond being indicated by changes in the ester's absorption in the infrared spectrum.

The adduct from 3,5-dimethylpyridine with perchloric acid gave, on one occasion, a very unstable compound whose infrared absorption spectrum was very similar to that of the *cis*-pyridine derivative (VIII) in the 2·5—5·5 μ region and probably had a similar structure, but otherwise the perchlorate (XII) was obtained. Hydrogenation of the last compound gave the ethylpyridinium perchlorate (XIII) and some 3,5-dimethylpyridine.

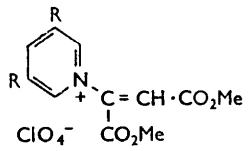
The isoquinoline adduct was similar and gave, with perchloric acid and ethereal hydrogen chloride, salts of the *cis*-acid (corresponding to VIII), as their infrared absorption spectra showed no hydrogen bonding. The perchlorate lost carbon dioxide on attempted crystallistion from water and methanol, yielding 2-(1,2-dimethoxycarbonylvinyl)isoquinolinium perchlorate and the corresponding methoxy-compound (cf. XIV). Although treatment of the adduct with dimethyl acetylenedicarboxylate gave a tar instead of the hoped for tetramethyl 11b*H*-benzo[*a*]quinolizine-1,2,3,4-tetracarboxylate, reaction with tetracyanoethylene yielded a product which appears to have structure (XV).

When isoquinoline was treated with the acetylenic ester in undried ether at −50° the dimolecular ether (XVI) was obtained. A number of such ethers have been described.[11] Like our compound, which gave 2-(1,2-dimethoxycarbonylvinyl)isoquinolinium perchlorate with perchloric acid, they yield salts of the original base with strong acids. The formation

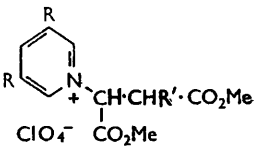
[6] Acheson and Bond, *J.*, 1956, 246.
[7] Lloyd and Prince, *Proc. Chem. Soc.*, 1961, 464.
[8] Dodd, Miller, and Wynne-Jones, *J.*, 1961, 2790; Sharat, *Acta Cryst.*, 1952, **5**, 763.
[9] Goedkoop and MacGillavry, *Acta Cryst.*, 1957, **10**, 125.
[10] Dulong and Price, *J. Amer. Chem. Soc.*, 1962, **84**, 578.
[11] Beke, *Adv. Heterocyclic Chem.* (ed. Katritzky), 1963, **1**, 167.

of the ether (XVI) from the isoquinoline analogue of the zwitterion (I) by reaction with water can be envisaged in a number of ways.

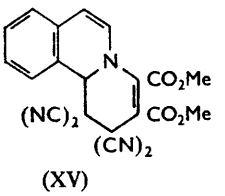
The unidentified ester described by Jackman, Johnson, and Tebby [2] is almost certainly dimethyl methoxyfumarate. Their analytical and spectral data for both the ester and its



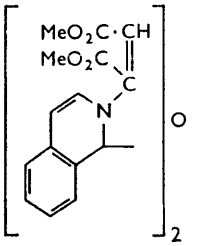
(XI: R = H)
(XII: R = Me)



(XIII: R = Me, R′ = H)
(XIV: R = H, R′ = OMe)



(XV)



(XVI)

hydrolysis product agree quite well with theoretical expectations; Diels and Meyer [12] previously observed the formation of this ester in the reaction between pyridine and dimethyl acetylenedicarboxylate in methanol.

Experimental

Infrared absorption spectra were measured for paraffin paste (P) or chloroform solutions (C) and are usually given for the 2·5—7 μ region. The unstable adducts were examined at about 0° in cooled apparatus. Ultraviolet absorption spectra are for methanol (M) or water (W) solutions and recorded in mμ; ε × 10^{-4} are given in parentheses. Inflexions are marked with asterisks.

Pyridine and Dimethyl Acetylenedicarboxylate.—Redistilled pyridine (3·0 ml.) in dry ether (30 ml.) at −60° was added to dimethyl acetylenedicarboxylate (9·0 ml.) in sodium-dried ether (50 ml.). The mixture was kept at −60 ± 10° for 18 hr. and then allowed to warm up slowly to 0°. The cream-coloured *cis*-pyridine adduct (V) (2·22 g.) was filtered off, washed with a little cold ether and stored at −60°. It decomposed slowly at −15° and rapidly at 0° to a red gum, $\nu_{max.}$ (C) 4·28 (CO_2), 5·77s, 5·88*, 6·22s, 6·39s, 6·62w, 6·97s, 7·24, and 8·55 μ. The 4·28 μ peak increased somewhat in intensity, and the 6·22 (aromatic C=C?), 6·29 and 7·24 μ (CO_2^-) peaks almost vanished after about 1 hr.; $\lambda_{max.}$ (W) 261 mμ immediately after solution but soon changes. Solutions in chloroform and carbon tetrachloride were dark red; chloride ion was not liberated.

The filtrate was kept at −60° and after two weeks the ochre-yellow precipitate of the *trans*-pyridine adduct (*trans*-isomer of V) (8·66 g.) was collected, washed with ether, and dried by suction. It was more stable than the *cis*-adduct and could be kept at −15° without appreciable decomposition; $\nu_{max.}$ (C), immediately after solution, 4·28s, 5·76s, 5·88*, 6·16, 6·22w, 6·37, 6·60, 6·80, 6·98s, 7·45, 8·10, and 8·50 μ.

1-(2-*Carboxy*-1,2-cis-*dimethoxycarbonylvinyl*)*pyridinium Perchlorate* (VIII).—Aqueous 12% perchloric acid (2·32 ml.) at its freezing point was added to the *cis*-pyridine adduct (1·0 g.) cooled in a dry-ice–methanol bath. After 1 hr. the mixture was allowed to warm to about 5° when the cream-white precipitate (0·75 g.) of 1-(2-*carboxy*-1,2-cis-*dimethoxycarbonylvinyl*)-*pyridinium perchlorate* was collected, washed with ether, and dried *in vacuo* over sodium hydroxide. It had m. p. 78° (decomp.) and was analysed without purification (Found: C, 39·3; H, 3·6; Cl, 9·7. $C_{12}H_{12}ClNO_{10}$ requires C, 39·5; H, 3·3; Cl, 9·7%); $\nu_{max.}$ (P) 2·83s, and 2·90* (free OH), 3·22 and 3·25 (pyridine-H), 4·02 (broad), 5·30w, 5·74, 5·86, 6·05*, 6·15, 6·79, and 6·95 μ; $\lambda_{max.}$ (W) 260 (0·63).

1-(2-*Carboxy*-1,2-trans-*dimethoxycarbonylvinyl*)*pyridinium Perchlorate* (X).—The *trans*-pyridine adduct (5·0 g.) was similarly treated with 12% perchloric acid (11·6 ml.) and after being allowed to warm to 0° the *perchlorate* (2·39 g.), m. p. 158° (decomp.), was obtained (Found: C, 39·2; H, 3·2; N, 3·6. $C_{12}H_{12}ClNO_{10}$ requires C, 39·5; H, 3·3; N, 3·8%); $\nu_{max.}$ (P) 2·88w, 3·20, 3·24, 3·86w, 5·74, 6·07, 6·14, 6·78, 6·90, and 6·95 μ; $\lambda_{max.}$ (W) 262 (0·58).

[12] Diels and Meyer, *Annalen*, 1934, **513**, 129.

After 24 hr. in the open air the *monohydrate* was formed, m. p. 148° (decomp.) (Found: C, 37·1; H, 3·5; Cl, 10·1; OMe, 16·1; active H, 0·66. $C_{12}H_{12}ClNO_{10},H_2O$ requires C, 37·45; H, 3·6; Cl, 9·2; 2OMe, 16·1; 3H, 0·78%). The absorption in the carbonyl region of the infrared spectrum was identical to that of the anhydrous material showing that the water had not added to the vinyl double bond.

1-(1,2-*Dimethoxycarbonylvinyl*)*pyridinium Perchlorate* (XI).—(i) The *cis*-perchlorate (VIII) (0·1 g.) was warmed with water (0·25 ml.); on cooling the *perchlorate* (XI) separated as needles (0·04 g.), m. p. 135° (Found: C, 41·0; H, 3·5; N, 3·8; OMe, 19·3; Cl, 11·65. $C_{11}H_{12}ClNO_8$ requires C, 41·1; H, 3·7; N, 4·35; 2OMe, 19·3; Cl, 11·05%); $\nu_{max.}$ (P) 3·20, 3·25, 5·75, 5·80, 6·02, 6·13, 6·80, 6·91, and 6·99 μ; $\lambda_{max.}$ (W) 262 (0·48).

(ii) The *trans*-perchlorate (X) (0·2 g.) was dissolved in hot ethanol (15 ml.) and cooled, whereupon needles (0·11 g.) precipitated [identical in m. p., mixed m. p., and infrared absorption spectrum with the product from (i) above].

(iii) The *cis*-pyridine adduct (V) (0·42 g.) on treatment with 12% aqueous perchloric acid at room temperature gave a white precipitate (0·27 g.), identical in m. p., mixed m. p., and infrared absorption spectrum with the product from (i) above.

1-(1,2-*Dimethoxycarbonyl*-2-*methoxyethyl*)*pyridinium Perchlorate* (XIV).—1-(1,2-Dimethoxycarbonylvinyl)pyridinium perchlorate (265 mg.), dimethyl acetylenedicarboxylate (0·3 ml.), methanol (2 ml.), and a trace of sodium methoxide were refluxed for 19 hr., evaporated to dryness and ether (5 ml.) added. The *methoxy-compound* (XIV) (205 mg.) separated and after recrystallisation from water (0·5 ml.) had m. p. 114° (Found: C, 40·8; H, 4·7; Cl, 10·2; N, 3·8; OMe, 26·3. $C_{12}H_{16}ClNO_9$ requires C, 40·8; H, 4·5; Cl, 10·0; N, 4·0; 3OMe, 26·3%); $\nu_{max.}$ (P) 3·20, 3·25, 4·91, 5·70—5·81, 6·14, 6·33, 6·74, 6·84, and 6·95 μ; $\lambda_{max.}$ (W) 256* (0·34), 261 (0·38), and 267 (0·30).

5-(*Carboxymethoxycarbonylvinyl*)*phenanthridinium Perchlorate* (IX).—The *trans*-betaine [6] corresponding to this *perchlorate* was dissolved in the minimum quantity of hot water and treated with 72% perchloric acid. On cooling, the *perchlorate dihydrate* (IX) separated as needles, m. p. 119° (Found: C, 48·75; H, 4·05. $C_{18}H_{14}ClNO_8,2H_2O$ requires C, 48·7; H, 4·05%); $\nu_{max.}$ (P) 2·84s, 3·23, 4·1 (broad) 5·24w, 5·8—5·85, 6·00, 6·14, 6·51, 6·67, 6·86, and 6·99*.

Reduction of the cis-*Pyridine Adduct* (V).—(i) The adduct, prepared as above from pyridine (4·15 g.), suspended in dry ether (100 ml.) at −50° was hydrogenated over Raney nickel at 2·5 atm. for 3·5 hr. during which time room temperature was attained. The filtered orange solution was extracted with 2N-hydrochloric acid, the extract evaporated to dryness, and the residue, dissolved in water (20 ml.), was treated with aqueous picric acid. The yellow precipitate, after crystallisation from ethanol, gave pyridine picrate (0·29 g.), m. p. and mixed m. p. 165—166°.

(ii) The adduct (about 2·5 g.), suspended in ether (100 ml.) at −20°, was hydrogenated (70 atm.) in a steel container, originally cooled to below −20°, over a mixture of Raney nickel and 5% palladium on charcoal for 24 hr., during which time room temperature was attained. After filtration the yellow solution was extracted with 2N-hydrochloric acid (2 × 20 ml.), washed with water, dried, and distilled. Dimethyl succinate, b. p. 80—100° (bath)/0·3 mm., was obtained as needles (at about −60°) which melted on warming and were identified by comparing its infrared absorption spectrum with that of an authentic specimen. A yellow oil (0·52 g.) subsequently distilled, b. p. 168—174°/0·1 mm. (Found: C, 70·4; H, 8·7%); $\nu_{max.}$ (film) 3·41, 3·48*, 5·79, 6·25, 6·35, 6·73*, 6·85, 7·26, and 7·8—7·9 μ; $\lambda_{max.}$ (M) 273 and 278*. Dimethyl phthalate gives $\nu_{max.}$ (C) 5·79, 6·24, 6·33, 6·72, 6·92*, 6·99, 7·77, and 7·80 μ; $\lambda_{max.}$ (M) 273 and 278*.

The yellow oil (0·24 g.) was refluxed with 10% aqueous sodium hydroxide for 3·5 hr., and the upper layer collected with ether. Distillation gave a mobile liquid, b. p. 50°/0·1 mm. (Found: C, 72·9; H, 13·4; active H, 0·88%; *M*, 128. Calc. for $C_7H_{16}O$: C, 73·05; H, 13·9; active H, 0·87%; *M* 116), which possessed the characteristic odour of a long-chain alcohol and resembled n-hexyl alcohol in its infrared absorption spectrum.

The aqueous layer was acidified and extracted with ether. Evaporation of the dried extract gave phthalic acid (35 mg.) which, after crystallisation from ethyl acetate, had m. p. 193—194° (rapid heating) (Found: C, 57·6; H, 3·75. Calc. for $C_8H_6O_4$: C, 57·8; H, 3·6%), identical in mixed m. p. and infrared absorption spectrum with an authentic sample.

(iii) The pyridine adduct (19 g.), suspended in dry ether (300 ml.) cooled in dry-ice–methanol, was added to a vigorously stirred, similarly cooled suspension of lithium aluminium hydride

(5·0 g.) in ether (100 ml.) and the mixture kept under these conditions for 2 hr. After standing overnight at room temperature, ethyl acetate (25 ml.), was added and the mixture poured into 2N-aqueous sulphuric acid (250 ml.) at 0°. The aqueous layer was separated, extracted with ether and then continuously extracted with chloroform for 3 hr. Distillation of the dried chloroform extract gave an oil (11·8 g.), b. p. 177°/0·2 mm. (Found: C, 59·75; H, 8·4; OMe, 22·78%; *M* 309, 324. Dibutyl methyl aconitate, $C_{15}H_{24}O_6$, requires C, 60·1; H, 8·0%; *M* 300); $\nu_{max.}$ (film) 5·73, 6·84, 6·98, 7·20*, 7·32, 7·42, 7·81, 8·15, and 8·48 μ.

The above oil (2·0 g.) was refluxed for 4·5 hr. with 2N-aqueous sodium hydroxide (20 ml.). The upper layer, when collected with ether, dried, and distilled, gave butan-1-ol (0·57 g.), b. p. 116—118°, n_D^{16} 1·3993 (lit.,[13] b. p. 118°, n_D^{20} 1·3993). It had an infrared absorption spectrum identical with that of an authentic specimen and was also characterised as the 3-nitrophthalate, m. p. 145—146° (lit.,[14] 147°).

The aqueous layer from the hydrolysis was acidified with concentrated hydrochloric acid (4 ml.) and extracted with ether (4 × 25 ml.). Evaporation of the dried extract gave *trans*-aconitic acid (0·53 g.), m. p. 192°, identical in m. p., mixed m. p. and infrared absorption spectrum with an authentic specimen. Warming the acid (90 mg.) with acridine (85 mg.) and water (2 ml.) gave the *bis-acridine salt* as yellow needles, m. p. 157° (decomp.) (Found: C, 72·1; H, 4·7; N, 5·25. $C_{32}H_{24}N_2O_6$ requires C, 72·2; H, 4·5; N, 5·25%).

3,5-*Dimethylpyridine and Dimethyl Acetylenedicarboxylate*.—3,5-Dimethylpyridine (2·8 ml.) in ether (10 ml.) and the ester (6 ml.) in ether (40 ml.) were mixed at −60°. After 2 hr. the mixture was allowed to warm up slowly to 0° and the unstable cream-coloured adduct (VI) (5·13 g.), m. p. 44° (decomp., very rapid heating) was collected and washed with cold ether. It showed $\nu_{max.}$ (C) 4·28, 5·76, 5·87*, 6·20, 6·32, 6·62, 6·96, 7·30, 7·43, 7·90*, and 8·30 μ immediately after solution. After 90 min. at room temperature, the 4·28 μ peak had increased a little and those at 5·87*, 6·20, 6·32 (especially), and 7·30 μ had substantially diminished.

Adducts similarly prepared from 3-methyl- and 2,6-dimethylpyridine were not more stable and showed similar spectral changes.

Reaction of 3,5-*Dimethylpyridine Adduct* (VI) *and Perchloric Acid*.—(i) The adduct (2·4 g.) was treated with 18% aqueous perchloric acid (6 ml.) at room temperature, giving a bright yellow solution, which after 14 days deposited 1-(1,2-*dimethoxycarbonylvinyl*)-3,5-*dimethylpyridinium perchlorate* (XII) (0·47 g.), which crystallised from water as plates, m. p. 156—157° (decomp.) (Found: C, 44·5; H, 5·1; Cl, 10·3; N, 4·2; OMe, 18·1. $C_{13}H_{16}ClNO_8$ requires C, 44·6; H, 4·6; Cl, 10·2; N, 4·0; 2OMe, 17·8%); $\nu_{max.}$ (P) 5·72, 5·77*, 6·03, 6·16, 6·24, 6·77*, 6·85, and 6·98 μ; $\lambda_{max.}$ (W) 273 (0·59), 281* (0·54). The *picrate*, obtained with aqueous sodium picrate, separated from methanol as needles, m. p. 166° (Found: C, 47·6; H, 3·7; N, 11·9; OMe, 13·0. $C_{19}H_{18}N_4O_{11}$ requires C, 47·7; H, 3·8; N, 11·7; 2OMe, 13·0%).

(ii) In an exploratory experiment, essentially as above but on a much smaller scale, a cream precipitate of, probably, 1-(2-carboxy-1,2-*cis*-dimethoxycarbonylvinyl)-3,5-dimethylpyridinium perchlorate (cf. VIII), m. p. 70—71° (decomp.), appeared instantly, and was washed with water and dried immediately. It showed $\nu_{max.}$ (P) 2·80s, 2·83*, 3·25, 3·93w, 5·03w, 5·73, 5·77*, 5·96, 6·07*w, 6·14, 6·22*, 6·78*, 6·90, and 6·99 μ; closely resembling that of the perchlorate (VIII), and decomposed overnight.

Reduction of 1-(1,2-*Dimethoxycarbonylvinyl*)-3,5-*dimethylpyridinium Perchlorate* (XII).—The perchlorate (0·19 g.) in methanol (5 ml.) was hydrogenated (6 atm.) over Raney nickel for 15 hr.; after filtration and evaporation it gave an oil (0·14 g.) which solidified on addition of ether. Crystallisation from water gave 1-(1,2-*dimethoxycarbonylethyl*)-3,5-*dimethylpyridinium perchlorate* (XIII) as needles, m. p. 148° (Found: C, 44·7; H, 5·25; N, 4·0; OMe, 17·6. $C_{13}H_{18}ClNO_8$ requires C, 44·4; H, 5·1; N, 4·0; 2OMe, 17·7%); $\nu_{max.}$ (P) 5·73, 6·13, 6·23, 6·69, 6·87*, and 6·97 μ; $\lambda_{max.}$ (W) 273 (0·59) and 280* (0·49).

The mother-liquor from the recrystallisation with aqueous sodium picrate gave 3,5-dimethylpyridinium picrate, m. p. and mixed m. p. 241°, of infrared absorption spectrum identical with that of an authentic sample.

Isoquinoline and Dimethyl Acetylenedicarboxylate.—(i) Isoquinoline (5·0 g.) in dry ether (50 ml.) and the ester (5·5 g.; 1 mol.) in dry ether (50 ml.) were separately cooled to −60° and then mixed, and carbon dioxide passed through at this temperature for 16 hr. The temperature was allowed to rise to 0° and the pale yellow precipitate (4·53 g.) of the 1 : 1 : 1 molar

[13] Heilbron and Bunbury, " Dictionary of Organic Compounds," 1953, Vol. I, p. 388.
[14] Vogel, " Practical Organic Chemistry," Longmans, London, 1959, 3rd ed., p. 267.

adduct (cf. structure V), m. p. 83—84° (decomp., rapid heating), was collected, washed with cooled ether, and dried *in vacuo*. The filtrate was cooled again to −60°, carbon dioxide was passed again for 48 hr., whereupon more adduct (5·17 g.; total yield 80%) was precipitated; it was analysed forthwith (Found: C, 61·2; H, 4·5; N, 4·45; OMe, 19·9. $C_{16}H_{13}NO_6$ requires C, 61·0; H, 4·15; N, 4·45; 2OMe, 19·7%).

(ii) A similar experiment with 2 mols. of the ester and omitting the deliberate introduction of carbon dioxide gave the adduct (7·53 g.), m. p. 84° (decomp., rapid heating) (Found: C, 60·8; H, 4·7; N, 4·0%); $\lambda_{max.}$ (M) 236 (1·69), 302* (1·12), and 337 (2·58); $\nu_{max.}$ (P) 5·79, 5·90, 6·11, 6·24, 6·35, 6·52, 6·71, 6·84, 6·90*, 7·03, 7·32, 7·41, and 7·55 μ; (C) immediately after solution, 4·28, 5·76, 5·89, 6·07, 6·26, 6·39, 6·50, 6·72, 6·89, 6·98, 7·02, 7·26, 7·34, 7·39*, and 7·56 μ. After 8 min. the absorption band at 4·28 μ had increased threefold and those at 6·07, 6·50, and 7·56 μ had vanished; the spectrum also became generally less definite. A test for ionic chlorine at this stage was negative. A solution of carbon dioxide in chloroform gave a sharp strong absorption at 4·28 μ.

The adduct (0·25 g.) in chloroform (0·8 ml.) was treated with dry ether (10 ml.), 30% of the original adduct being precipitated, m. p. 80° (decomp.), of infrared spectrum (P) identical to that of the starting material.

(iii) In an experiment comparable to (i), except that carbon dioxide was rigorously excluded, a dark yellow precipitate (2·75 g.) was obtained, and after crystallisation from methanol yielded tetramethyl 11b*H*-benzo[*a*]quinolizine-1,2,3,4-tetracarboxylate, identical in m. p., mixed m. p. and infrared absorption spectrum with an authentic specimen.[15]

(iv) Isoquinoline (2·5 g.) in undried ether (25 ml.), and the ester (4·5 ml.) in undried ether (25 ml.), were separately cooled to −60° and mixed. After 1 hr. the temperature was allowed to rise to 0° and the *ether* (XVI) (2·78 g.) slowly precipitated. Attempted crystallisation caused decomposition, but washing with acetonitrile gave needles, m. p. 116—117° (decomp.), which were analysed without further purification (Found: C, 64·45; H, 5·05; N, 5·05; OMe, 22·0. $C_{30}H_{28}N_2O_9$ requires C, 64·3; H, 5·0; N, 5·0; 4OMe, 22·1%); $\nu_{max.}$ (P) 5·74, 5·86, 6·24, 6·37, 6·71, 6·86, 6·96, and 7·0* μ; $\lambda_{max.}$ (M) 238 (2·66), 303* (1·15), and 337 (4·21).

The ether (XVI) (0·2 g.) with aqueous perchloric acid gave 2-(1,2-*dimethoxycarbonylvinyl*)*isoquinolinium perchlorate* (0·19 g.) which separated from methanol as hexagons, m. p. 161—162° (Found: C, 48·8; H, 3·8; Cl, 8·9; N, 3·7; OMe, 16·8. $C_{15}H_{14}ClNO_8$ requires C, 48·5; H, 3·8; Cl, 9·6; N, 3·8; 2OMe, 16·7%); $\nu_{max.}$ (P) 3·22*, 3·28, 5·77, 6·03, 6·13, 6·23, 6·66, 6·88, and 7·0 μ; $\lambda_{max.}$ (W) 237 (5·00), 270* (0·30), 280 (0·34), 292* (0·18), and 344 (0·37).

2-(1,2-*Dimethoxycarbonylvinyl*)*isoquinolinium picrate*, obtained from the ether (XVI) with ethanolic picric acid, separated in needles (86% yield), m. p. 173° (Found: C, 50·5; H, 3·3; N, 11·5; OMe, 12·8. $C_{21}H_{16}N_4O_{11}$ requires C, 50·4; H, 3·2; N, 11·2; 2OMe, 12·4%).

Reactions of the Isoquinoline–Dimethyl Acetylenedicarboxylate–Carbon Dioxide Adduct.—(i) The adduct (1·0 g.) suspended in dry ether (200 ml.) originally at 0°, was hydrogenated (4 atm.) over Raney nickel for 6 hr. After filtration the solution was extracted with 2N-aqueous hydrochloric acid (3 × 5 ml.), washed, dried, and distilled [up to 60° (bath temperature) at 0·5 mm.]; it gave dimethyl fumarate (60 mg.), m. p. 102° alone and mixed with an authentic specimen and also of identical infrared absorption spectrum.

The hydrochloric acid extract was basified and extraction with ether gave isoquinoline (0·31 g., 99%), identified by its infrared absorption spectrum, and by the m. p., mixed m. p., and infrared absorption spectrum of the picrate with an authentic sample.

(ii) The adduct (1·0 g.) at −15° was treated with 19% aqueous perchloric acid (1·36 ml.) at its freezing point. The mixture was allowed to warm to 0° and the cream precipitate of 2-(2-carboxy-1,2-*cis*-dimethoxycarbonylvinyl)isoquinolinium perchlorate (1·28 g.) was collected, and, after being washed with ether and dried *in vacuo*, had m. p. 102° (decomp.). A satisfactory analysis was not obtained, partial decarboxylation probably occurring before this could be carried out. The infrared absorption spectrum was very similar to that of the *cis*-pyridine derivative (VIII) in the OH region; $\nu_{max.}$ (P) 2·81s, 2·92*, 3·25* (unresolved), 3·90 and 4·1* (broad), 5·30*, 5·73—5·85, 5·93, 6·14, 6·23, 6·66, 6·85—6·95 μ; $\lambda_{max.}$ (W) 237 (3·99), 282* (0·53), 295* (0·31), and 346 (0·42).

The filtrate slowly deposited 2-(1,2-dimethoxycarbonylvinyl)isoquinolinium perchlorate, which was identical in m. p., mixed m. p., and infrared absorption spectrum with the analysed specimen.

[15] Acheson and Hole, *J.*, 1962, 748.

Attempted crystallisation of the above carboxyisoquinolinium perchlorate from methanol gave 2-(1,2-*dimethoxycarbonyl*-2-*methoxyethyl*)*isoquinolinium perchlorate* as needles, m. p. 134° (Found: C, 48·0; H, 4·7; Cl, 9·2; N, 3·9; OMe, 22·3. $C_{16}H_{18}ClNO_6$ requires C, 47·6; H, 4·5; Cl, 8·8; N, 3·5; 3OMe, 23·0%); $\nu_{max.}$ (P) 5·67, 5·79, 6·08, 6·22, 6·33, 6·62, 6·89, and 6·98 μ.

(iii) The adduct (0·27 g.) in chloroform (5 ml.) at −5° was treated with ethereal hydrogen chloride (2 ml.), with cooling and stirring. The highly deliquescent cream precipitate was collected, washed with cold ether, and dried *in vacuo* giving 2-(2-*carboxy*-1,2-*dimethoxycarbonylvinyl*)*isoquinolinium chloride*, m. p. 78° (decomp.), which was analysed forthwith (Found: C, 52·4; H, 5·0; Cl, 10·6; N, 3·8. $C_{16}H_{14}ClNO_6,H_2O$ requires C, 52·0; H, 4·35; Cl, 9·6; N, 3·8%); $\nu_{max.}$ (C) 4·07, 4·28, 5·74, 5·85, 6·10, 6·25, 6·39, 6·49*, 6·89*, and 6·98 μ. Warming this compound with aqueous sodium picrate gave 2-(1,2-dimethoxycarbonylvinyl)isoquinolinium picrate, identical in m. p., mixed m. p., and infrared absorption spectrum to the sample obtained from the ether (XVI).

(iv) The adduct (0·5 g.) was refluxed with tetracyanoethylene (0·5 g.) in dry ether (50 ml.) for 2 hr., and the tar obtained after cooling and decanting the ether solidified on trituration with methanol. Crystallisation from acetonitrile gave *dimethyl* 1,1,2,2-*tetracyanobenzo*[*a*]-1,2-*dihydro*-11b*H*-*quinolizine*-3,4-*dicarboxylate* (XV) as yellow crystals, m. p. 217° (decomp.) (Found: C, 63·7; H, 3·4; N, 17·5; OMe, 15·5. $C_{21}H_{13}N_5O_4$ requires C, 63·6; H, 3·3; N, 17·5; 2OMe, 15·5%); $\nu_{max.}$ (P) 4·43w, 5·72, 5·92, 6·07, 6·30, 6·37, 6·67, 6·89, and 6·95 μ; $\lambda_{max.}$ (M) 245 (2·26), 298 (0·69), 312 (0·68), and 363 (1·84). Its n.m.r. spectrum in methyl cyanide measured at 29·92 Mc./sec., assuming that this solvent absorbs at τ 8·03, showed a complex at about τ 2·4; (aromatic protons), doublets centred on τ 3·41 and 3·86 (2 protons, $J \simeq 8{\cdot}1$ c./sec.), assigned to the protons at psitions 6 and 7, a single proton at τ 4·22 assigned to the 11b*H*-atom, and two 3 proton peaks at τ 6·00 and 6·10 assigned to the ester-methyl groups.

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