Reaction of 2-Methyl-1,4-naphthoquinone and its 3-Substituted Derivatives with Active Methylene Group Anions and with Diazo Compounds

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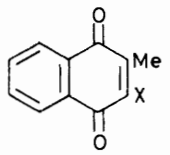
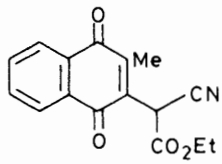
The reaction of 2-chloro-3-methyl-1,4-naphthoquinone (**3**) with the anion of ethyl cyanoacetate led to a mixture of two epimeric fused-ring cyclopropane compounds, characterised as *exo*- and *endo*-1-cyano-1-ethoxycarbonyl-1a-methyl-1a,7a-dihydro-1*H*-cyclopropa[*b*]naphthalene-2,7-dione (**8**) *and* (**9**). Various hydrolysis products of these were prepared and an *X*-ray crystallographic analysis was carried out on one of them, 1-carbamoyl-1-carboxy-1a-methyl-1a,7a-dihydro-1*H*-cyclopropa[*b*]-naphthalene-2,7-dione (**17**). The reaction of 2-methyl-1,4-naphthoquinone (**1**) with ethyl diazoacetate gave a fused pyrazoline derivative, 3-ethoxycarbonyl-4-hydroxy-9a-methyl-1,9a-dihydro-benz[*f*]indazol-9-one (**22**), while reaction of 2-methyl-3-nitro-1,4-naphthoquinone (**5**) with diazomethane led to a fused Δ^2-isoxazoline *N*-oxide, 3a-methyl-3,3a-dihydroisoxazolo[3,4-*b*]naphthalene-4,9-dione 1-oxide (**26**).

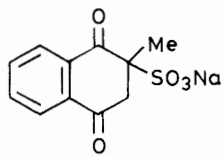
Enolate anions are included among the wide variety of nucleophiles which have been reported[1] to add to the enone system of 1,4-quinones. The base-catalysed reaction of ethyl cyanoacetate and menadione (2-methyl-1,4-naphthoquinone) (**1**), for example,[2] gives the product (**6**), formed by initial Michael attack at position 3 of (**1**). There is no attack by the nucleophile at position 2, that is on the quinone carbon atom bearing the methyl group, and this regiospecificity appears to be quite general.[1] The only well documented exception[3] is the formation of menadione sodium bisulphite (hydrogen sulphite) (MSB) (**7**), an important vitamin K active compound. Even when position 3 of menadione (**1**) is occupied by a methoxy group or by a halogen atom, attack still takes place here. For example Kallmayer[2] found that compound (**6**) was also formed by treatment of the bromoquinone (**2**) with ethyl cyanoacetate and sodium ethoxide, and Akatsuka[4] found that the same product (**6**) was formed from both the chloro- and methoxy-quinones, (**3**) and (**4**), on treatment with ethyl cyanoacetate in the presence of ammonia. We have carried out further studies on the reaction of active methylene group compounds with 2-chloro-3-methyl-1,4-naphthoquinone (**3**) and wish to report some new reactions.



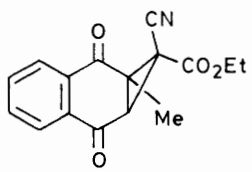
(**1**) X = H
(**2**) X = Br
(**3**) X = Cl
(**4**) X = OMe
(**5**) X = NO_2



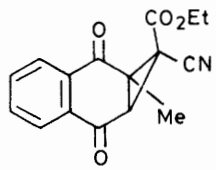
(**6**)



(**7**)



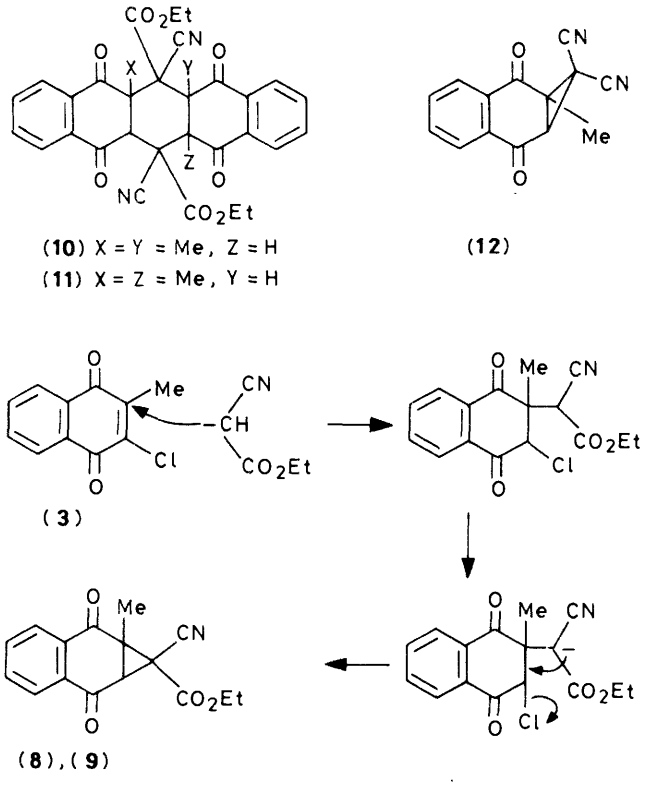
(**8**)



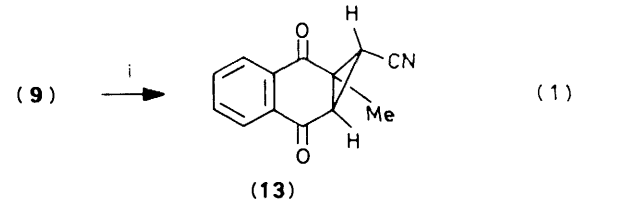
(**9**)

Results and Discussion

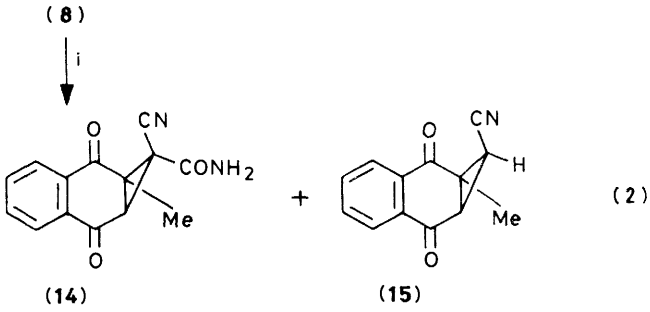
We repeated Akatsuka's procedure[4] and confirmed that treatment of the quinone (**3**) with ethyl cyanoacetate and ammonia as described leads to the product (**6**). However, we further found that this preparation is extremely sensitive to the reaction conditions. On using ethanolic dioxane as solvent and more dilute ammonia as base the reaction was found to take a completely different course, and a good yield (75%) of two new products was obtained, in the approximate ratio of 2:1. Each of the new products was shown to have a molecular formula of $C_{16}H_{13}NO_4$, and on the basis of the evidence described below the epimeric structures (**8**) and (**9**) are assigned to them. The new products were not naphthoquinones since they were white, and showed no quinone chromophore in their u.v. spectra. Neither were they hydroquinones, for they were stable to oxidising agents and showed no hydroxy peaks in their i.r. spectra. The i.r. spectra, on the other hand, did show bands characteristic of ester and cyano groups, together with a strong band at 1 685 cm^{-1}, suggesting the presence of one or more conjugated carbonyl groups in each compound. This agreed with the shape of the u.v. spectra which was almost the same as that of MSB (**7**) and was typical of a 1,4-dioxo-1,2,3,4-tetrahydronaphthalene chromophore. The ^1H n.m.r. spectrum of each of these new products showed a three-proton methyl singlet and a one-proton singlet somewhat further downfield, due to the cyclopropyl hydrogen atom. These signals occurred at 1.66 and 3.50 p.p.m. for compound (**8**) and at 1.83 and 3.05 p.p.m. for compound (**9**). We considered the possibility[5] of dimeric structures such as (**10**) and (**11**) for the new products. However, each of these structures could exist in several stereoisomeric forms, and we have consistently observed the formation of only two stereoisomers in our reaction. Furthermore, no trace of a molecular ion corresponding to a dimer could be found in the mass spectra of the two products. Finally, we carried out a molecular weight determination on one of the products by measuring the freezing point depression of its solution in



Scheme 1.



Reagents: i, NH_3, EtOH–H_2O



Reagents: i, NH_3, EtOH–H_2O

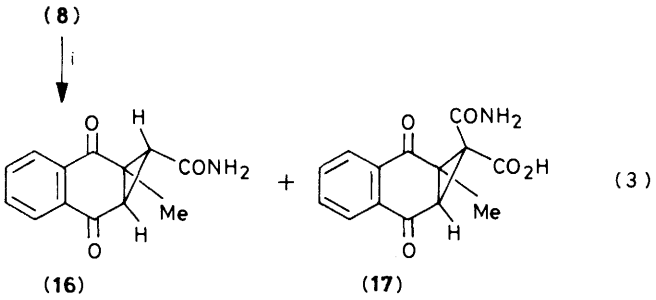
benzene and a molecular weight of 277 was obtained, clearly indicating a molecular formula of $C_{16}H_{13}NO_4$ (*M*, 283) rather than any dimeric species.

The stereochemistry of the products (**8**) and (**9**) was assigned by a comparison of their ^1H n.m.r. spectra with the spectrum of compound (**12**), obtained when malononitrile was used in place of ethyl cyanoacetate in the reaction with 2-chloro-3-methyl-1,4-naphthoquinone (**3**), using dilute ammonia as the basic catalyst. The spectral properties of (**12**) showed clearly that it was related in structure to compounds (**8**) and (**9**). Its i.r. spectrum showed absorption bands at 2 230 and 1 680 cm^{-1}, due to cyano and aryl conjugated carbonyl groups respectively. As well as a resonance due to four aromatic protons, its ^1H n.m.r. spectrum showed only two other signals, a three-proton singlet at 1.80 p.p.m. and a one-proton singlet at 3.26 p.p.m. The methyl group in this product (**12**) must perforce be *cis* to a cyano group, and it has practically the same chemical shift as the methyl group in one of the two isomeric products obtained using ethyl cyanoacetate, the minor one (1.83 p.p.m.). This latter, therefore, must be the isomer with the stereochemistry shown in (**9**), having a *cis* disposition of the methyl and cyano groups.

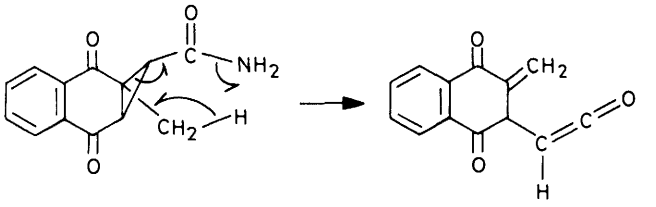
The formation of these products is of particular interest because their method of synthesis demands an initial attack by an enolate anion on the chloromenadione (**3**) at the carbon atom bearing the methyl group (see Scheme 1). As already mentioned, this mode of addition is unusual, although unfused polyfunctional cyclopropane derivatives have been synthesised from α-chloroacrylonitrile and active methylene group compounds by a reaction involving an analogous mechanism.[6] The cyclopropane products (**8**) and (**9**) are not intermediates on the pathway to the previously described product (**6**), because they are not converted into (**6**) upon treatment with more concentrated ammonia.

When the cyclopropane isomer (**9**) was stirred at room temperature in aqueous ethanolic ammonia, the product (**13**) was obtained, formed presumably by decarboxylation of an intermediate cyclopropane carboxylic acid [equation (1)]. The two cyclopropyl protons of (**13**) appear in the ^1H n.m.r. spectrum as an AB quartet with a coupling constant of 5.0 Hz, suggesting their *trans* orientation as shown, so that configuration at the unfused cyclopropane carbon atom must have been retained during the reaction. When the cyclopropane isomer (**8**) was treated with aqueous ethanolic ammonia under the same conditions, an insoluble product separated from the solution within 2 h. Its spectral data and elemental analysis suggested structure (**14**), formed by ammonolysis of the ester group of (**8**) [equation (2)]. The mother-liquor of this reaction afforded a second product (**15**), formed by hydrolysis of either the ester group of (**8**) or the amide group of (**14**), followed by decarboxylation. Here again reaction occurred with retention of configuration. The cyclopropyl cyanide (**15**) was isomeric with that, (**13**), already described. It showed an AB quartet in the ^1H n.m.r. spectrum. The coupling constant, 8.8 Hz, was greater than that observed in the spectrum of its isomer (**13**), and was consistent with the assigned *cis* stereochemistry of the cyclopropyl protons in (**15**). When the cyclopropane ethyl esters (**8**) and (**9**) were treated with triethylamine in methanol, trans-esterification occurred and the corresponding methyl esters were isolated and characterised.

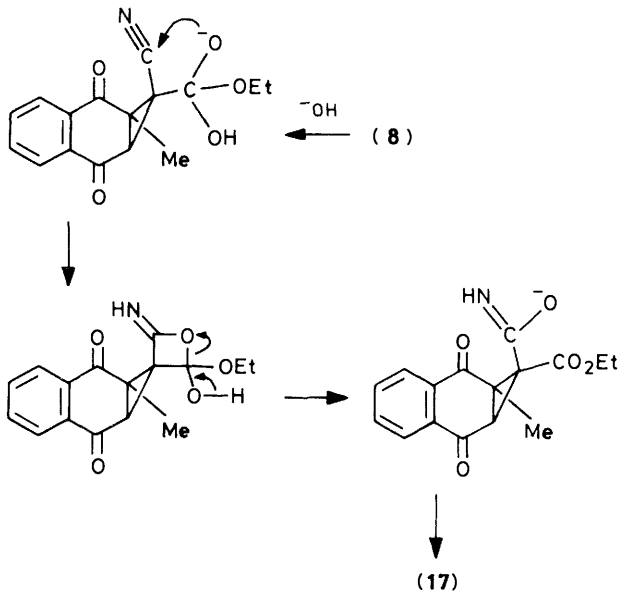
The cyclopropane isomers (**8**) and (**9**) behaved differently from each other when treated with sodium hydroxide. On warming compound (**8**) in 0.01M-aqueous sodium hydroxide and cooling the resulting solution, a white crystalline product separated. After collection of this, a second product was obtained by acidification of the mother-liquor. The first, neutral, product was insoluble in water and in most organic solvents. Elemental analysis gave a molecular formula of $C_{13}H_{11}NO_3$, showing that three carbon atoms had been lost from the original molecule (**8**) during the sodium hydroxide treatment, and structure (**16**) is suggested [equation (3)]. It arises by hydrolysis of the cyano group in (**8**) to give an amide, hydrolysis of the ester to the corresponding carboxylic acid, and then decarboxylation of the latter. During this reaction, inversion of configuration at the unfused cyclopropane carbon atom must have occurred. The benzene *ortho*-dicarbonyl chromophore in (**16**) was suggested by its u.v.



Reagents: i, NaOH, H_2O



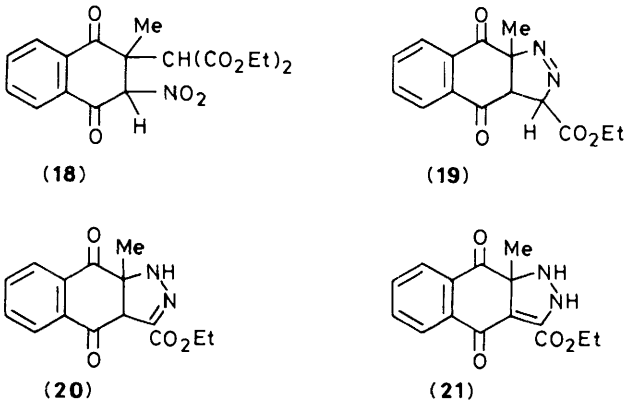
Scheme 2.



Scheme 3.

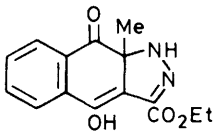
spectrum, while the presence of the amide group was inferred from the i.r. spectrum and from two broad, deuterium exchangeable singlets at lower field in the ^1H n.m.r. spectrum measured in dimethyl sulphoxide. In this n.m.r. spectrum the two cyclopropyl protons appeared as a singlet. However, in acetone solution this signal was split, and the two protons appeared as an AB quartet, centred at 2.94 p.p.m., with a coupling constant of 5.2 Hz. The *trans* orientation of the two cyclopropyl protons, as shown in (**16**), may be inferred from the magnitude of their coupling. The mass spectrum of (**16**) exhibits two strong peaks at *m/z* 212 ($M^+ - 17$) and 174 ($M^+ - 45$), as well as a molecular ion peak at *m/z* 229. In the absence of a carboxy group, these peaks can be explained by a McLafferty rearrangement involving the methyl group *cis* to the amide, as shown in Scheme 2. The same pattern was also observed in the mass spectrum of compound (**14**), which also contains *cis* methyl and amide groups. This compound (**14**) exhibits a molecular ion peak at *m/z* 254, with strong peaks at 237 ($M^+ - 17$) and 209 ($M^+ - 45$), corresponding to loss of NH_3 followed by loss of CO.

The second, acidic, product formed by the alkaline hydrolysis of compound (**8**) was more difficult to identify. Apart from the lack of spectroscopic evidence for a carboxy group, however, the data appeared to point to structure (**17**), formed by hydrolysis of the original ester function to a carboxy group and of the cyanide to a primary amide (Scheme 3), and this conclusion was confirmed by an *X*-ray crystal structure determination. The product (**17**) was slightly soluble in water but very insoluble in most organic solvents. Its aqueous solution was acidic and a crystal of the solid caused evolution of carbon dioxide from sodium hydrogen carbonate solution. The presence of a carboxy group was also suggested by the fact that this product was only precipitated from alkaline solution upon acidification. The i.r. spectrum, however, was not typical of a carboxylic acid. There was no broad strong hydroxy stretching band, and in the carbonyl region there was a strong high frequency absorption at 1 745 cm^{-1} which could only be due to a carboxy group if the latter were completely unassociated and not involved in hydrogen bonding even in the solid state. This interpretation was proved to be correct by the *X*-ray data, which revealed that the carbonyl oxygen atom of the carboxy group was indeed unco-ordinated. The ^1H n.m.r. spectrum measured



in dimethyl sulphoxide showed a methyl and a one-proton singlet at 1.47 and 3.07 p.p.m., respectively, and four aromatic protons centred as a multiplet around 7.9 p.p.m. There was also a broad hump which was variable in position between 3 and 6 p.p.m., and a broad singlet at 7.05 p.p.m., both of these signals disappearing on addition of deuterium oxide. This spectrum showed clearly that the original ester group of compound (**8**) had been lost, but there was no trace of a carboxy proton at low field. The mass spectrum of the product (**17**) was identical with that of (**16**), as could happen if decarboxylation occurred in the inlet probe of the mass spectrometer. The product (**17**) was, in fact, converted into (**16**) by heating it to 180 °C, and also by further treatment with 0.01M-sodium hydroxide. Compound (**17**) was also obtained by stirring (**8**) in 0.01M-sodium hydroxide solution at room temperature until it dissolved, followed by acidification. No decarboxylated product (**16**) was formed under these conditions.

When the cyclopropane isomer (**9**) was hydrolysed with dilute sodium hydroxide using the same conditions as for the hydrolysis of (**8**), the main product formed was the amide (**16**), so that reaction in this instance must have proceeded with retention of configuration. This contrasts with the conversion of the acid (**17**) into (**16**) which proceeded with inversion, presumably reflecting a tendency of the carbamoyl group to



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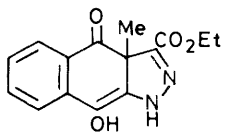

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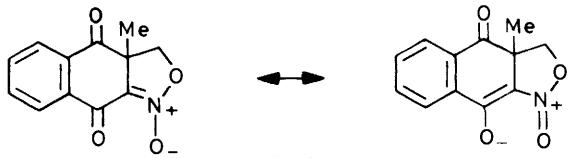

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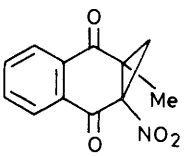

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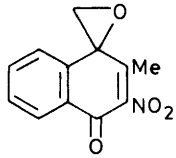

(25)

assume in each case the least sterically crowded *exo* orientation. The smaller steric demands of the cyano group, on the other hand, allow formation of both *exo* and *endo* orientated cyano products, (**13**) and (**15**). Another unusual feature in these reactions of (**8**) and (**9**) is the ready hydrolysis of the cyano group to an amide under the very mild conditions used. This suggests a neighbouring group interaction by the ester group, or alternatively by the corresponding carboxylate anion (see Scheme 3). Neighbouring group interactions with an adjacent ketone group from the six-membered ring can be ruled out, for while such an interaction could conceivably be involved in the hydrolysis of the cyano group of (**8**), the *exo* orientated cyano group of (**9**) could not interact in this way.

A new condensation product (**18**) was obtained when 2-methyl-3-nitro-1,4-naphthoquinone (**5**) was allowed to react with diethyl sodiomalonate in dioxane solution. The nitroquinone (**5**) was prepared by nitration of menadione (**1**) in a mixture of concentrated nitric and sulphuric acids. The product (**18**) was obtained in crude form as an orange solid, which decomposed in boiling ethanol and also in hot ethyl acetate so that its purification by recrystallisation was difficult. However, several rapid recrystallisations from warm ethanol gave a white crystalline compound, of formula $C_{18}H_{19}NO_8$, showing that one molecule of diethyl malonate had added to one of the nitroquinone. The ^{1}H n.m.r. spectrum of (18) showed two sets of ethyl group signals, a methyl singlet at 1.85 p.p.m., a one proton singlet at 4.72 p.p.m., a multiplet centred at 8.0 p.p.m. due to four aromatic protons, and a broad low-field singlet at 15.3 p.p.m., which exchanged with deuterium oxide. The i.r. spectrum showed three carbonyl stretching bands at 1 740, 1 700, and 1 680 cm^{-1}, and bands due to a nitro group at 1 590 and 1 350 cm^{-1}. The very low-field exchangeable peak in the n.m.r. spectrum was assigned to the proton next to the nitro group. This proton should be relatively acidic, and (**18**) does give a reddish brown colour with ferric chloride. The product (**18**) would be formed by attack of enolate anion on the methyl-bearing carbon atom of the nitroquinone (**5**), and is analogous to that described by Smith and Cutler [7] in 1949, arising from the reaction between diethyl sodiomalonate and 2,3,5-trimethyl-6-nitro-1,4-benzoquinone.

We also explored further the use of diazo compounds as a route to the cyclopropane-fused quinones. Different groups of workers over the years [1] have allowed quinones to react with diazo compounds and have reported the formation of various pyrazoline and cyclopropane products, and we investigated the use of diethyl diazomalonate and ethyl diazoacetate as reagents. The former is the less reactive, and we found that no reaction occcurred when it was treated with menadione (**1**), either in the presence or absence of copper acetylacetonate [8] as catalyst. A new product was obtained, however, when ethyl diazoacetate was allowed to react with menadione (**1**) in refluxing benzene solution. We were unable to obtain an analytically pure sample of this compound but the evidence described below leads us to favour structure (**22**) for it. The new product was not very soluble in organic solvents, and had a molecular formula $C_{15}H_{14}N_2O_4$, so that it must have been formed by the addition of one molecule of ethyl diazoacetate to one of menadione. Its ^{1}H n.m.r. spectrum showed a triplet and a quartet due to an ethoxycarbonyl group, together with a methyl singlet at 1.75 p.p.m. and an aromatic multiplet centred at 7.8 p.p.m. There were also two broad, exchangeable, one-proton singlets, one appearing at 6.45 p.p.m., and the other with a much greater chemical shift appearing at a somewhat variable position below 10 p.p.m. The i.r. spectrum showed a sharp band at 3 440 cm^{-1}, a broader one at 3 230 cm^{-1}, an ester carbonyl band at 1 735 cm^{-1}, and another carbonyl at 1 670 cm^{-1}. The u.v. spectrum did not correspond to that of a compound containing a benzene-*ortho*-dicarbonyl chromophore. Several attempts were made to convert this product into a cyclopropane compound by pyrolysis, both dry and in diglyme, by treatment with nitric,[8] sulphuric,[9] and perchloric [10] acids, by potassium hydroxide in ethylene glycol,[11] and by potassium permanganate.[12] No cyclopropane compound could be isolated, however. The first formed product in the addition of ethyl diazoacetate to menadione (**1**) should be the Δ^1-pyrazoline (**19**). This structure is ruled out by the observed u.v. and n.m.r. spectra, however, and because it would be expected to lose nitrogen on pyrolysis to give a cyclopropane product. An initially formed Δ^1-pyrazoline (**19**) could readily rearrange to its more stable Δ^2-isomer. Structure (**20**), however, could also lose nitrogen on pyrolysis, and it should reveal a benzene-*ortho*-dicarbonyl chromophore in its u.v. spectrum. Moreover it would not exhibit two exchangeable protons in its n.m.r. spectrum, one at very low field. Further rearrangement of the Δ^2-pyrazoline (**20**) could lead to structures (**21**) or (**22**), and of these we prefer the latter. This contains two exchangeable protons, one of which being enolic and relatively acidic would be expected [13] to resonate at very low field, as is observed. The two exchangeable protons attached to nitrogen in structure (**21**) would be expected to have chemical shifts similar to one another. Structure (**21**), moreover, should show three carbonyl stretching bands in the i.r. spectrum, whereas only two are observed, at 1 735 (ester) and 1 670 cm^{-1} (aryl ketone). The i.r. spectrum also shows two peaks in the O–H and N–H stretching region, at 3 230 and 3 440 cm^{-1}. In previous reports,[10,14–16] diazo compounds have been found to add to alkyl substituted quinones with a high degree of regiospecificity, and almost entirely in the sense leading to products (**19**)—(**22**). Addition in the opposite sense leading to products such as (**23**) is therefore unlikely, although it cannot be ruled out on the basis of the spectroscopic evidence.

The failure to obtain a cyclopropane product from the reaction of ethyl diazoacetate with menadione (**1**) is probably due to rearrangement of an initially formed Δ^1-pyrazoline (**19**) to give the product (**22**), as described above. Such a rearrangement would be blocked in a pyrazoline formed from 2-methyl-3-nitro-1,4-naphthoquinone (**5**) and diazomethane. Reaction of these two compounds did, in fact, lead to a new

product (**26**), in the formation of which both of the diazo nitrogen atoms were lost. The ^{1}H n.m.r. spectrum of this product showed a methyl group singlet at 1.66 p.p.m. and a methylene group quartet centred at 4.65 p.p.m. In the ^{13}C n.m.r. spectrum a very weak carbonyl peak occurred at 195.0 p.p.m. and four strong and two weak peaks in the aromatic region, 128—136 p.p.m. In addition, there was a weak peak at 55.7 p.p.m. and two strong peaks at 72.8 and 24.7 p.p.m. Assuming that these last two strong peaks are due to carbon atoms bearing hydrogen, they can be assigned respectively to the methylene and methyl carbons. These n.m.r. data seem to rule out the expected cyclopropane structure (**24**), because the methylene group signals in both the ^{1}H and ^{13}C spectra resonate too far downfield. Another structure (**25**), which could have been formed[16,17] by the addition of diazomethane to one of the quinone carbonyl groups, is also not favoured. The observed i.r. spectrum showed strong bands at 1 700, 1 685, 1 580, and 1 260 cm^{-1}. The first two of these suggest the presence of two carbonyl groups in the molecule, while the band at 1 580 cm^{-1} is at too high a frequency for the asymmetric stretching vibration of an α,β-unsaturated nitro group. Moreover, the mass spectrum of the new product shows a peak at *m/z* 171, corresponding to ($M^+ - CH_2NO_2$). Also, the ^{13}C resonance at 55.7 p.p.m. seems to be too far upfield[16] for an epoxide quaternary sp^3 carbon atom adjacent to both a benzene ring and a double bond. We therefore suggest that the new product is a fused ring 4,5-dihydroisoxazole *N*-oxide, with the structure shown in (**26**), and this suggestion is supported by the data already described. In particular, the ^{1}H resonance at 4.65

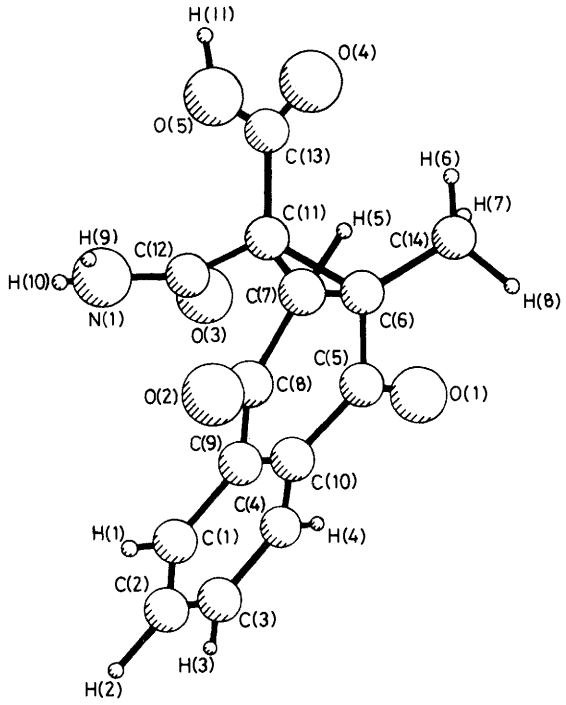

Figure 1. A single molecule of the acid (**17**) showing the crystallographic numbering scheme

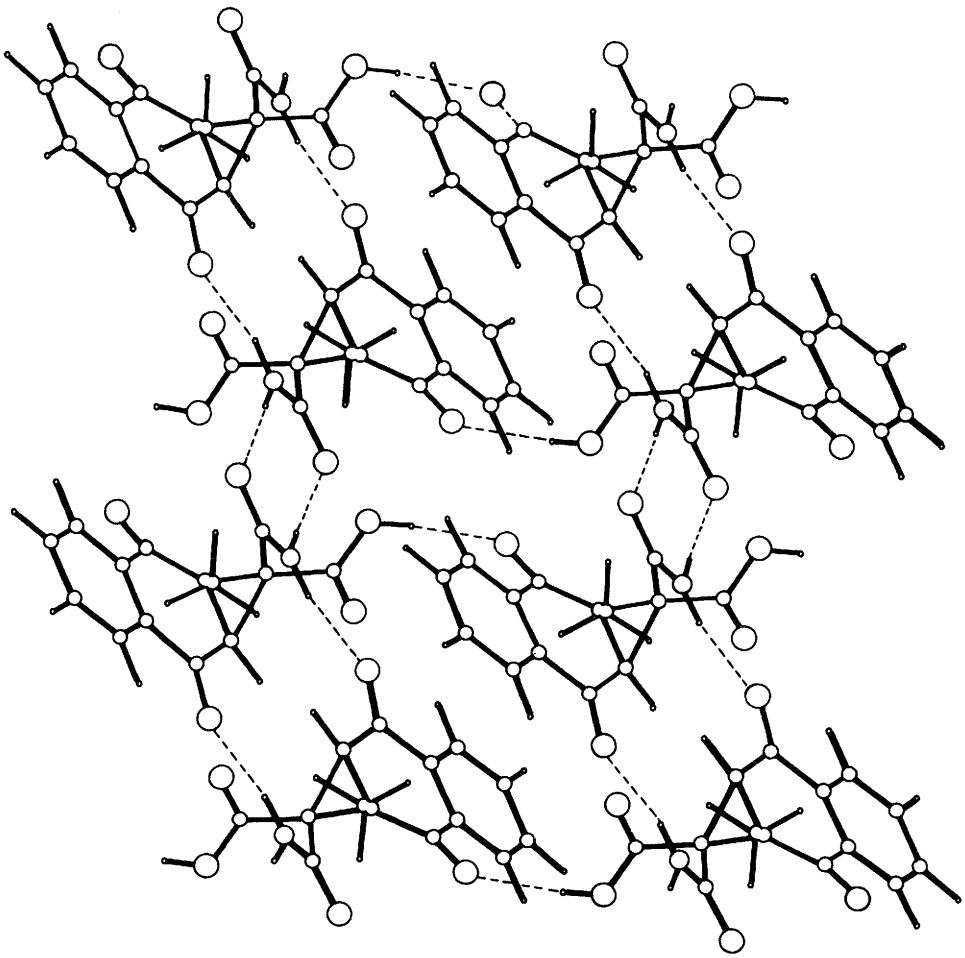

Figure 2. Intermolecular hydrogen bonding in the acid (**17**). The structure is shown as a projection on to the *ac* plane

Table 1. Atom co-ordinates ($\times 10^4$) for the acid (**17**) with e.s.d.s in parentheses

C(1)	5 758(4)	1 924(4)	−0 900(4)
C(2)	4 565(4)	2 545(5)	−1 667(4)
C(3)	4 022(4)	1 445(5)	−2 855(4)
C(4)	4 630(4)	−0 273(5)	−3 268(3)
C(5)	6 441(3)	−2 791(4)	−2 931(3)
C(6)	7 998(3)	−3 450(4)	−2 369(3)
C(7)	8 631(3)	−2 169(4)	−1 131(3)
C(8)	7 705(3)	−0 439(4)	−0 502(3)
C(9)	6 415(3)	0 192(4)	−1 333(3)
C(10)	5 840(3)	−0 922(4)	−2 511(3)
C(11)	9 547(3)	−2 648(4)	−2 655(3)
C(12)	9 488(3)	−1 426(4)	−3 607(3)
C(13)	11 243(4)	−3 719(4)	−2 818(4)
C(14)	8 152(5)	−5 295(5)	−2 352(5)
N(1)	10 151(3)	−0 025(4)	−3 083(3)
O(1)	5 643(3)	−3 800(4)	−3 666(3)
O(2)	7 992(3)	0 448(3)	0 666(3)
O(3)	8 890(3)	−1 798(3)	−4 770(2)
O(4)	11 713(4)	−4 450(4)	−1 954(4)
O(5)	12 146(3)	−3 635(4)	−3 971(3)
H(5)	933(5)	−304(5)	−033(4)
H(9)	1 059(6)	015(6)	−228(6)
H(10)	1 035(6)	048(6)	−363(6)
H(11)	1 319(7)	−410(6)	−395(5)

p.p.m. and the ^{13}C resonance at 72.8 p.p.m. are as expected[18] for a methylene group next to oxygen. Under the conditions of measurement used, no resonances were visible in the ^{13}C spectrum for the second carbonyl group or for the C=N group, presumably because of the long relaxation times of these carbon atoms. The strong peaks observed at 1 580 and 1 260 cm^{-1} in the i.r. spectrum show the C=N and N–O bonds of structure (**26**). The peaks are at slightly lower and higher frequencies, respectively, than those reported in the literature[19] for 4,5-dihydroisoxazole *N*-oxides. This shift would be expected for structure (**26**), however, because the C=N bond of the heterocyclic ring is conjugated with a carbonyl group. This conjugation would decrease and increase, respectively, the bond order (and therefore the force constants) of the C=N and N–O bonds. There is, moreover, an analogy for the present reaction in the work of a Russian group[20] which has demonstrated the presence of 4,5-dihydroisoxazole *N*-oxides among the products formed when nitroalkenes are treated with diazoalkanes.

The Crystal and Molecular Structure of the Acid (**17**).—In order to confirm the structure of (**17**), a single-crystal *X*-ray diffraction study was carried out. This study has substantially accounted for the unusual properties of this compound (*vide supra*). Figure 1 shows a single molecule of (**17**) with the numbering scheme used, and Figure 2 shows the crystal structure in projection to display the intermolecular hydrogen bonding pattern. Apart from these bonds there are no abnormally short intermolecular contacts. The molecule consists of a naphthoquinone skeleton fused to a substituted cyclopropane ring. The main features of the molecular skeleton are similar to those revealed by the early work of Grant and Speakman in 1958[21] on the unsubstituted parent compound 2,3-dihydro-2,3-methylene-1,4-naphthoquinone.

The atomic co-ordinates are given in Table 1. The bond lengths and angles within the naphthoquinone moiety appear to be normal (Table 2). As in the parent compound, the fused cyclohexane ring is not flat, adopting a shallow 'boat' conformation in which the carbonyl oxygen atoms follow the line of the 'boat.' The benzene and cyclohexane ring mean

Table 2. Bond lengths and angles in the acid (**17**)

(*a*) Bond lengths

C(1)–C(2)	1.381(5)	C(7)–C(8)	1.475(4)
C(2)–C(3)	1.386(6)	C(7)–C(11)	1.528(4)
C(3)–C(4)	1.379(6)	C(7)–H(5)	1.29(4)
C(4)–C(10)	1.395(4)	C(8)–O(2)	1.216(4)
C(9)–C(10)	1.397(4)	C(11)–C(12)	1.528(4)
C(9)–C(1)	1.398(5)	C(11)–C(13)	1.516(4)
C(5)–C(10)	1.491(5)	C(12)–N(1)	1.322(4)
C(9)–C(8)	1.482(4)	C(12)–O(3)	1.223(4)
C(5)–C(6)	1.503(4)	C(13)–O(4)	1.202(5)
C(5)–O(1)	1.217(4)	C(13)–O(5)	1.313(5)
C(6)–C(7)	1.524(4)	N(1)–H(9)	0.85(6)
C(6)–C(11)	1.533(3)	N(1)–H(10)	0.77(6)
C(6)–C(14)	1.512(4)	O(5)–H(11)	0.89(6)

(*b*) Bond angles

C(9)–C(1)–C(2)	119.8(3)	C(6)–C(7)–C(11)	60.3(2)
C(1)–C(2)–C(3)	119.8(3)	C(6)–C(7)–H(5)	106.5(1.8)
C(2)–C(3)–C(4)	120.9(3)	C(11)–C(7)–C(8)	119.8(2)
C(3)–C(4)–C(10)	120.1(3)	C(11)–C(7)–H(5)	111.6(1.8)
C(4)–C(10)–C(9)	119.0(3)	C(8)–C(7)–H(5)	121.8(1.8)
C(10)–C(9)–C(1)	120.4(3)	C(6)–C(11)–C(7)	59.7(2)
C(10)–C(5)–C(6)	119.7(2)	C(6)–C(11)–C(13)	120.0(2)
C(5)–C(6)–C(7)	115.3(2)	C(6)–C(11)–C(13)	118.1(2)
C(6)–C(7)–C(8)	121.2(2)	C(7)–C(11)–C(12)	122.7(2)
C(7)–C(8)–C(9)	118.2(2)	C(7)–C(11)–C(13)	114.4(2)
C(8)–C(9)–C(10)	120.9(3)	C(12)–C(11)–C(13)	112.5(2)
C(9)–C(10)–C(5)	121.3(2)	O(3)–C(12)–C(11)	120.0(3)
C(10)–C(5)–O(1)	120.9(3)	N(1)–C(12)–C(11)	114.8(2)
C(6)–C(5)–O(1)	119.3(3)	N(1)–C(12)–O(3)	125.2(3)
C(7)–C(8)–O(2)	121.0(3)	O(4)–C(13)–C(11)	124.0(3)
C(9)–C(8)–O(2)	120.8(3)	O(5)–C(13)–O(4)	125.4(2)
C(5)–C(6)–C(11)	115.4(2)	O(5)–C(13)–C(11)	110.4(3)
C(5)–C(6)–C(14)	115.4(3)	H(9)–N(1)–C(12)	121(3)
C(11)–C(6)–C(7)	60.0(2)	H(10)–N(1)–C(12)	116(3)
C(11)–C(6)–C(14)	120.9(3)	H(9)–N(1)–H(10)	120(5)
C(7)–C(6)–C(14)	118.7(3)	C(13)–O(5)–H(11)	109(3)

planes are aligned at 6.5° to each other (Table 3). The ring carbonyl carbon atoms, C(5) and C(8), are both displaced 0.112 Å from the cyclohexane ring mean plane in the direction away from the cyclopropane ring which can therefore be thought of as fused to the underside of the 'boat.' The co-ordination around C(5) and C(8) is, however, planar, so that the carbonyl groups are inclined at angles of 102.6 and 106.1° to the cyclohexane ring mean plane. In the parent structure[21] the carbonyl oxygen atoms show a significant displacement towards the benzene ring, so that the C=O bonds are not collinear; however we cannot find any suggestion of this distortion in the present work. The difference is probably due to the different hydrogen bonding patterns found on the two crystals; in the parent structure there is probably a weak interaction with the hydrogen atom attached to the cyclopropane/cyclohexane ring junction [H(5) in our numbering], whereas our ring carbonyl oxygen atoms are hydrogen bonded to an amide and a carboxy hydrogen [O(1)···H(11)] and [O(2)···H(9)] (see Table 3 and further discussion below).

The normal to the cyclopropane ring makes an angle of 100.0° with the normal to the mean cyclohexane ring plane, and is notable for the remarkable regularity of its geometry, being a perfect equilateral triangle within experimental error with a mean side length of 1.528(4) Å, slightly longer than the mean side lengths of 1.511(2) Å determined for cyclopropane and closer to the value of 1.534(2) Å for ethane.[22] The hydrogen atom position, H(5), attached to one of the highly strained cyclopropyl carbon atoms, C(7), has refined to give the rather

Table 3. Hydrogen bonding in the acid (**17**)

(*a*) Contact distances (Å)

O(1)···O(5)	2.969
N(1)···O(3)	2.975
N(1)···O(2)	2.919

(*b*) Geometry around H atoms

H(9)···O(2)	2.12 Å
H(10)···O(3)	2.20
H(11)···O(1)	2.06
N–H(9)···O(2)	157.0
N–H(10)···O(3)	175.4
O(5)–H(11)···O(1)	149.5

Table 4. Angles between mean planes and lines

(Å)	R.m.s.d.[a]
Plane 1: C(1), C(2), C(3), C(4), C(9), C(10)	0.008
Plane 2: C(5), C(6), C(7), C(8), C(9), C(10)	0.080
Plane 3: C(6), C(7), C(11)	
Plane 4: C(11), C(12), N(1), O(3), H(9), H(10)	0.053
Plane 5: C(11), C(13), O(4), O(5), H(11)	0.044
Plane 6: N(1), H(9), H(10)	
Plane 7: C(12), N(1), O(3)	
Line 1: C(8), O(2)	
Line 2: C(5), O(1)	

(*a*) Angles between normals to planes and mean planes (°)

Plane 1/Plane 2	6.5
Plane 2/Plane 3	100.0
Plane 3/Plane 4	50.5
Plane 3/Plane 5	103.2
Plane 4/Plane 5	81.5
Plane 6/Plane 7	16.8

(*b*) Angles between normals to planes and lines (°)

Plane 2/Line 1	102.6
Plane 2/Line 2	106.1

[a] Root mean square deviation of constituent atoms from the least squares plane.

long C–H bond length of 1.29(4) Å, but the position does give chemically reasonable bond angles around C(7) (Table 2).

The amide group is not quite planar (Table 4), the NH_2 plane making an angle of about 17° with the carbonyl plane [containing C(11), C(12), and O(3)]. This distortion of the amide probably arises from the constraints imposed by the intermolecular hydrogen bond N(1)–H(10)···O(3) since the deviation from the amide plane is furthest for H(10) (0.093 Å).

The carboxy group is approximately orthogonal to the amide group (angle between planes 81.5°) and is again not strictly planar because the OH group is twisted slightly [the H(11)–O(5)–C(13)–O(4) torsion angle is −4.4°]. The intermolecular hydrogen bond O(5)–H(11)···O(1) is assumed to be responsible for this.

The details of the hydrogen bonding network are shown in Figure 2, and in Table 3. Both amide hydrogen atoms are intramolecularly hydrogen bonded, H(9) to one of the ring carbonyl oxygen atoms, O(2), and H(10) to an adjacent amide oxygen, O(3). The third bond is between the carboxy hydrogen atom, H(9), and the other ring carbonyl oxygen atom, O(1). None of the three hydrogen bonds appears to be strictly linear (Table 4), the largest deviation being that for the bond O(5)–H(11)···O(1). This network leaves the carboxy oxygen atom, O(4), unco-ordinated, a result which accounts for the high-frequency carbonyl band of 1 745 cm^{-1} in the i.r. spectrum. The hydrogen bonding network is presumably responsible also for the comparative insolubility of (**17**) in most solvents.

Experimental

^{13}C N.m.r. spectra were measured on a Bruker WP–80 instrument, and ^{1}H n.m.r. spectra either on this instrument or on a JEOL PMX–60. Chemical shifts were determined relative to tetramethylsilane. U.v. spectra were recorded using a Perkin-Elmer 402 spectrophotometer, and i.r. spectra for Nujol mulls using a Perkin-Elmer 298 spectrophotometer. Ether refers to diethyl ether.

1-*Cyano*-1-*ethoxycarbonyl*-1a-*methyl*-1a,7a-*dihydro*-1H-*cyclopropa*[b]*naphthalene*-2,7-*dione* (**8**) *and* (**9**) (with Mr. M. P. Napier).—2-Chloro-3-methyl-1,4-naphthoquinone[23] (1.4 g) and ethyl cyanoacetate (1.6 g) were dissolved in a mixture of ethanol (20 ml) and dioxane (20 ml). Concentrated aqueous ammonia (2 ml) was then added, giving a deep red colour, and the reaction mixture stirred at room temperature for 16 h. After acidification with sulphuric acid, the mixture was diluted with water and extracted with ether. The green ether extract was washed with saturated aqueous sodium hydrogen carbonate until the washings were colourless. The ether layer was then washed with water, dried ($MgSO_4$), and evaporated. The brown oily residue crystallised from ethanol, giving a mixture of isomeric products (**8**) and (**9**), as white crystals (1.55 g, 75%). The two isomers were separated by fractional crystallisation from ethanol. The endo-*cyano*-exo-*ethoxycarbonyl isomer* (**8**) had m.p. 114 °C (Found: C, 67.35; H, 5.05; N, 5.1. $C_{16}H_{13}NO_4$ requires C, 67.85; H, 4.65; N, 4.95%); $\lambda_{max.}(H_2O)$ 239 and 278 nm; $\nu_{max.}$ 2 230, 1 745, 1 685, 1 590, 1 260, and 1 230 cm^{-1}; $\delta_H(CDCl_3)$ 1.36 (3 H, t, CH_3CH_2), 1.66 (3 H, s, Me), 3.50 (1 H, s), 4.35 (2 H, q, CH_3CH_2), and 7.6—8.2 (4 H, m, Ar); $\delta_C(CDCl_3)$ 13.1 (CH_3CH_2), 14.1 (Me), 32.7, 42.1, and 42.9 (cyclopropyl), 64.5 (CH_3CH_2), 113.2 (CN), 127.1, 127.8, 133.1, 133.2, 135.4, and 135.7 (Ar), 162.6 (CO, ester), 187.4, and 188.7 p.p.m. (CO, ketone); *m/z* 283 (M^+, 100%), 255 (26), 237 (90), 211 (76), 210 (74), 182 (26), 153 (20), 127 (25), 104 (34), and 76 (36). The exo-*cyano*-endo-*ethoxycarbonyl isomer* (**9**) had m.p. 124 °C (Found: C, 67.75; H, 5.05; N, 5.0. $C_{16}H_{13}NO_4$ requires C, 67.85; H, 4.65; N, 4.95%); $\lambda_{max.}(H_2O)$ 239 and 278 nm; $\nu_{max.}$ 2 240, 1 740, 1 685, 1 590, and 1 290 cm^{-1}; δ_H ($CDCl_3$) 1.06 (3 H, t, CH_3CH_2), 1.83 (3 H, s, Me), 3.05 (1 H, s), 3.93 (2 H, q, CH_3CH_2), and 7.6—8.2 (4 H, m, Ar); $\delta_C(CDCl_3)$ 13.5 (CH_3CH_2), 18.0 (Me), 34.5, 39.8, and 42.4 (cyclopropyl), 64.2 (CH_3CH_2), 126.6, 127.2, and 134.7 (Ar), 161.9 (CO, ester), 186.5, and 189.0 p.p.m. (CO, ketone); *m/z* 283 (M^+).

Conversion of the Ethyl Esters (**8**) *and* (**9**) *into the Corresponding Methyl Esters.*—The ethyl ester, (**8**) or (**9**) (100 mg), was dissolved in methanol (5 ml) and triethylamine (10 drops) added. The solution was stored at 0 °C for 16 h, and the white crystalline product (40 mg) collected and crystallised from methanol. endo-1-*Cyano*-exo-1-*methoxycarbonyl*-1a-*methyl*-1a,7a-*dihydro*-1H-*cyclopropa*[b]*naphthalene*-2,7-*dione* had m.p. 145 °C (Found: C, 66.85; H, 4.15; N, 5.3. $C_{15}H_{11}NO_4$ requires C, 66.9; H, 4.1; N, 5.2%); $\nu_{max.}$ 2 240, 1 755, and 1 690 cm^{-1}; $\delta_H(CDCl_3)$ 1.67 (3 H, s, CMe), 3.52 (1 H, s), 3.91 (3 H, s, OMe), and 7.6—8.2 (4 H, m, Ar). The exo-1-*cyano*-endo-1-*methoxycarbonyl isomer* had m.p. 152 °C (Found: C, 66.95; H, 4.4; N, 5.2. $C_{15}H_{11}NO_4$ requires C, 66.9; H, 4.1; N, 5.2%); $\nu_{max.}$ 2 240 (CN), 1 740, and 1 685 cm^{-1}; $\delta_H(CDCl_3)$ 1.88 (3 H, s, CMe), 3.10 (1 H, s), 3.56 (3 H, s, OMe), and 7.6—8.2 (4 H, m).

1,1-*Dicyano*-1a-*methyl*-1a,7a-*dihydro*-1H-*cyclopropa*[b]-*naphthalene*-2,7-*dione* (**12**).—2-Chloro-3-methyl-1,4-naphthoquinone (0.92 g) and malononitrile (0.60 g) were dissolved in a mixture of ethanol (10 ml) and dioxane (10 ml). Concentrated aqueous ammonia (2 ml) was added and the reaction mixture stirred at room temperature for 16 h. After acidification with sulphuric acid, it was poured into water and extracted with ether. The extract was washed with saturated aqueous sodium hydrogen carbonate and water, dried ($MgSO_4$), and evaporated, leaving a brown oily residue. This was crystallised from ethanol, giving white crystals of the *dicyanocyclopropanaphthalenedione* (**12**) (0.4 g, 38%), m.p. 200—202 °C (decomp.) (Found: C, 71.1; H, 3.25; N, 11.75. $C_{14}H_8N_2O_2$ requires C, 71.2; H, 3.4; N, 11.85%); $\nu_{max.}$ 2 240, 1 685, 1 590, and 1 290 cm^{-1}; $\delta_H(CDCl_3)$ 1.87 (3 H, s, Me), 3.26 (1 H, s), and 7.8—8.2 (4 H, m, Ar); *m/z* 236 (M^+, 100%), 208 (11), 182 (20), 168 (32), 153 (15), 104 (64), 76 (77), and 50 (48).

exo-1-*Cyano*-1a-*methyl*-1a,7a-*dihydro*-1H-*cyclopropa*[b]-*naphthalene*-2,7-*dione* (**13**).—Concentrated aqueous ammonia (1 ml) was added to a solution of the *exo*-1-cyano-*endo*-1-ethoxycarbonyl isomer (**9**) (100 mg) in ethanol (3 ml). The solution was allowed to stand at room temperature for 3 h and was then warmed and partially evaporated. On cooling, white crystals were obtained, which on crystallisation from ethanol afforded the pure exo-*cyanide* (**13**) (50 mg, 67%), m.p. 138—139 °C (Found: C, 73.8; H, 4.0; N, 6.6. $C_{13}H_9NO_2$ requires C, 73.9; H, 4.3; N, 6.65%); $\nu_{max.}$ 2 240, 1 700, 1 680, and 1 600 cm^{-1}; $\delta_H(CDCl_3)$ 1.76 (3 H, s, Me), 2.48 (1 H, d, *J* 5.0 Hz, cyclopropyl-H), 2.95 (1 H, d, *J* 5.0 Hz, cyclopropyl-H), and 7.7—8.2 (4 H, m, Ar); *m/z* 211 (M^+), 183, 154, 149, 143, 140, 128, 115, 104, 85, 83, 76, 50, and 45.

exo-1-*Carbamoyl*-endo-1-*cyano*-1a-*methyl*-1a,7a-*dihydro*-1H-*cyclopropa*[b]*naphthalene*-2,7-*dione* (**14**) *and* endo-1-*Cyano*-1a-*methyl*-1a,7a-*dihydro*-1H-*cyclopropa*[b]*naphthalene*-2,7-*dione* (**15**).—The *endo*-1-cyano-*exo*-1-ethoxycarbonyl isomer (**8**) (0.35 g) was dissolved in ethanol (10 ml) and concentrated aqueous ammonia (3 ml) added. After 2 h at room temperature a dense white precipitate had formed, which after collection and crystallisation from ethyl acetate gave the exo-1-*carbamoyl*-endo-1-*cyanocyclopropanaphthalenedione* (**14**) (0.10 g, 32%), m.p. 226 °C (decomp.) (Found: C, 66.2; H, 3.9; N, 11.2. $C_{14}H_{10}N_2O_3$ requires C, 66.15; H, 3.95; N, 11.0%); $\nu_{max.}$ 3 430, 3 330, 3 280, 3 200, 2 230, 1 700, 1 690, 1 675, 1 610, and 1 590 cm^{-1}; $\delta_H(CDCl_3)$ 1.68 (3 H, s, Me), 3.64 (1 H, s), 5.78 (1 H, s, exchangeable, NH) 6.34 (1 H, s, exchangeable, NH), and 7.6—8.3 (4 H, m, Ar); $\delta_H[(CD_3)_2SO]$ 1.44 (3 H, s, Me), 3.37 (1 H, s), 8.37 (1 H, s, exchangeable, NH), and 7.96 (5 H, m, Ar + NH, 1 H exchangeable); *m/z* 254 (M^+), 237 ($M^+ - NH_3$), 209 ($M^+ - NH_3 - CO$), 181, 153, 127, 104, 76, 51, and 50. Preparative t.l.c. separation of the mother-liquor remaining after the isolation of (**14**) afforded the endo-1-*cyanocyclopropanaphthalenedione* (**15**), m.p. 151—152 °C (from EtOH) (Found: C, 74.15; H, 4.45; N, 6.65. $C_{13}H_9NO_2$ requires C, 73.9; H, 4.3; N, 6.65%); $\nu_{max.}$ 2 230, 1 680, and 1 590 cm^{-1}; $\delta_H(CDCl_3)$ 1.62 (3 H, s, Me), 2.35 (1 H, d, *J* 9.0 Hz, cyclopropyl-H), 2.88 (1 H, d, *J* 9.0 Hz, cyclopropyl-H), and 7.6—8.2 (4 H, m, Ar); *m/z* 211 (M^+, 100%), 183 (52), 154 (44), 128 (34), 104 (53), 76 (100), and 50 (85).

exo-1-*Carbamoyl*-1a-*methyl*-1a,7a-*dihydro*-1H-*cyclopropa*-[b]*naphthalene*-2,7-*dione* (**16**).—The ethyl ester (**8**) (100 mg) was heated in 0.01M-aqueous sodium hydroxide (10 ml) for 1 h on a water-bath. The resulting solution was cooled in ice, precipitating white crystals of the exo-1-*carbamoylcyclopropanaphthalenedione* (**16**) (50 mg, 62%), m.p. 278—280 °C (from water) (Found: C, 68.1; H, 4.6; N, 6.1. $C_{13}H_{11}NO_3$ requires C, 68.1; H, 4.85; N, 6.1%); $\lambda_{max.}(H_2O)$ 235, 271, and 305 nm; $\nu_{max.}$ 3 420, 3 160, 1 705, 1 670, 1 630, and 1 590 cm^{-1}; $\delta_H[(CD_3)_2SO]$ 1.55 (3 H, s, Me), 2.88 (1 H, d, *J* 5.1 Hz, cyclopropyl-H), 3.01 (1 H, d, *J* 5.1 Hz, cyclopropyl-H), 6.61 (1 H, br s, exchangeable, NH), 7.24 (1 H, br s, exchangeable, NH), and 7.87 (4 H, m, Ar); $\delta_H[(CD_3)_2SO]$ 1.46 (3 H, s, Me), 2.86 (2 H, s, cyclopropyl-H), 7.30 (1 H, br s, exchangeable, NH), 7.71 (1 H, br s, exchangeable, NH), and 7.89 (4 H, m, Ar); $\delta_C[(CD_3)_2SO]$ 11.4 (Me), 37.9, 38.2, 38.6 (cyclopropyl), 126.1, 127.1, 132.1, 132.4, 134.4, 134.6 (Ar), 166.9 (amide CO), 192.5 and 193.1 p.p.m. (ketone CO); *m/z* 229 (M^+, 9%), 212 ($M^+ - NH_3$, 100), 184 ($M^+ - NH_3 - CO$, 58), 128 (26), and 76 (16).

endo-1-*Carbamoyl*-exo-1-*carboxy*-1a-*methyl*-1a,7a-*dihydro*-1H-*cyclopropa*[b]*naphthalene*-2,7-*dione* (**17**).—The ethyl ester (**8**) (0.30 g) was heated in 0.01M-aqueous sodium hydroxide (30 ml) until it had dissolved. The solution was cooled and filtered. The filtrate was acidified with sulphuric acid and allowed to stand for 16 h at 0 °C. The resulting white solid was collected (0.22 g) and crystallised from water. The endo-1-*carbamoyl*-exo-1-*carboxycyclopropanaphthalenedione* (**17**) had m.p. 180 °C (Found: C, 61.6; H, 4.1; N, 5.25. $C_{14}H_{11}NO_5$ requires C, 61.55; H, 4.05, N, 5.15%); $\lambda_{max.}(H_2O)$ 235, 265, and 310 nm; $\nu_{max.}$ 3 350, 3 180, 1 745, 1 700, 1 680, 1 670, 1 630, and 1 595 cm^{-1}; $\delta_H[(CD_3)_2SO]$ 1.47 (3 H, s, Me), 3.07 (1 H, s), 4.5 (2 H, very br s), 7.05 (1 H, s, exchangeable), and 7.89 (4 H, m, Ar); *m/z* 229 ($M^+ - CO_2$, 22%), 212 (78), 184 (100), 128 (38), and 76 (21).

2-*Methyl*-3-*nitro*-1,4-*naphthoquinone* (**5**).—2-Methyl-1,4-naphthoquinone (12.3 g) was heated for 40 min at 60 °C in a mixture of concentrated nitric acid (27 ml) and concentrated sulphuric acid (9 ml). The solution was cooled and added to ice (300 g) and water (300 ml). The yellow precipitate was collected and redissolved in concentrated nitric acid (60 ml) and heated for 5 min at 80 °C. The solution was added to ice and water as before and the yellow precipitate collected. It was recrystallised from ethanol without allowing the ethanol to boil, as this led to decomposition of the material. The yield of 2-methyl-3-nitro-1,4-naphthoquinone [24] (**5**) was 5.25 g; $\nu_{max.}$ 1 670 (CO), 1 540 (NO_2), and 1 290 (NO_2) cm^{-1}; $\delta_H(CDCl_3)$ 2.23 (3 H, s, Me) and 7.7—8.3 (4 H, m, Ar).

2-*Bis*(*ethoxycarbonyl*)*methyl*-2-*methyl*-3-*nitro*-2,3-*dihydro*-*naphthalene*-1,4-*dione* (**18**).—Diethyl malonate (2.0 g) was refluxed with sodium (0.25 g) in dry dioxane (4 ml) for 1.5 h. The solution was cooled and added slowly to a solution of 2-methyl-3-nitro-1,4-naphthoquinone (**5**) (1.09 g) in dioxane (15 ml). The reaction mixture was stirred at room temperature for 16 h and was then poured into a mixture of concentrated hydrochloric acid (5 ml) and ice (100 g). An orange oil formed, which solidified on stirring. Crystallisation from ethanol gave the *diester* (**18**) (1.62 g, 86%), m.p. 90—92 °C (Found: C, 57.3; H, 4.95; N, 3.7. $C_{18}H_{19}NO_8$ requires C, 57.3; H, 5.1; N, 3.7%); $\lambda_{max.}$ (water) 242, 266sh, 300, and 380 nm; $\nu_{max.}$ 1 735, 1 720, and 1 685 cm^{-1}; $\delta_H(CDCl_3)$ 1.06 (3 H, t, CH_3CH_2), 1.33 (3 H, t, CH_3CH_2), 1.85 (3 H, s, Me), 3.99 (2 H, q, CH_3CH_2), 4.29 (2 H, q, CH_3CH_2), 4.72 (1 H, s), 7.6—8.4 (4 H, m, Ar), and 15.3 (1 H, br s, exchangeable).

3-*Ethoxycarbonyl*-4-*hydroxy*-9a-*methyl*-1,9a-*dihydrobenz*[f]-*indazol*-9-*one* (**22**).—2-Methyl-1,4-naphthoquinone (1.0 g) and ethyl diazoacetate (1.0 g) were refluxed in dry benzene (20 ml) for 48 h. The mixture was cooled and the resulting yellowish brown solid collected and washed well with ether, giving a white solid. Crystallisation from ethyl acetate gave the *ester* (**22**) (0.68 g, 41%), m.p. 187 °C (decomp.) (Found: C, 61.8; H, 5.05; N, 9.2. $C_{15}H_{14}N_2O_4$ requires C, 62.95; H, 4.95; N, 9.8%); $\lambda_{max.}(H_2O)$ 222, 263sh, and 287 nm; $\nu_{max.}$ 3 340, 3 230, 1 735, and 1 670

cm^{-1}; δ_H[$(CD_3)_2SO$] 1.34 (3 H, t, CH_3CH_2), 1.75 (3 H, s, Me), 4.36 (2 H, q, CH_3CH_2), 6.45 (1 H, s, exchangeable, NH), 7.4—8.2 (4 H, m, Ar), and 10.1, variable in position (1 H, s, exchangeable, OH); *m/z* 286 (M^+, 3%), 271 ($M^+ - CH_3$, 100) 243 (15), 225 (100), 195 (13), 171 (15), 141 (44), and 113 (57).

3a-*Methyl*-3,3a-*dihydroisoxazolo*[3,4-b]*naphthalene*-4,9-*dione* 1-*Oxide* (**26**).—2-Methyl-3-nitro-1,4-naphthoquinone (**5**) (0.50 g) was dissolved in ether (50 ml). To this solution was added slowly a solution of diazomethane in ether until t.l.c. showed that all the quinone had reacted. Most of the solvent was evaporated, and the resulting yellow solid collected and crystallised from ethanol, giving the *isoxazolonaphthalenedione* (**26**) (0.35 g, 66%), m.p. 182 °C (Found: C, 62.0; H, 4.05; N, 6.05. $C_{12}H_9NO_4$ requires C, 62.35; H, 3.9; N, 6.05%); $\lambda_{max.}$ 248 and 317 nm; $\nu_{max.}$ 1 705, 1 685, 1 585, 1 260, and 1 205 cm^{-1}; δ_H($CDCl_3$) 1.70 (3 H, s, Me), 4.62 (2 H, q, *J* 8.5 Hz), and 7.6—8.3 (4 H, m, Ar); δ_C 24.7 (Me), 55.7, 72.8 (CH_2), 128.1, 128.3, 132.9, 135.1, 135.5, 135.9 (Ar), and 195.0 p.p.m. (CO); *m/z* 231 (M^+), 214 ($M^+ - OH$), 200 ($M^+ - NO$), 185 ($M^+ - NO_2$), 171 ($M^+ - CH_2NO_2$), 160, 143, 130, 115, and 104.

Crystal Data for the Acid (**17**).—$C_{14}H_{11}NO_5$, M = 273.24, triclinic, a = 8.120(2), b = 8.225(2), c = 9.603(2) Å, α = 105.5(2), β = 86.5(2), γ = 82.9(2)°, U = 610.17 Å^3, D_m = 1.40 g cm^{-3} (by flotation), Z = 2, D_c = 1.487 g cm^{-3}, F(000) = 284, space group $P\bar{1}$, Mo-K_α radiation, λ = 0.710 69 Å, μ(Mo-K_α) = 0.71 cm^{-1}.

The compound crystallises from distilled water as colourless rhombs, and the crystal used had the approximate dimensions 0.25 × 0.2 × 0.1 mm.

Measurements.—The space group and preliminary unit cell dimensions were determined from Weissenberg photographs. Final values of the unit-cell dimensions and the intensities of 2 603 reflections in the range $2 \leq \theta \leq 25°$ were measured using Zr filtered Mo-K_α radiation on an Enraf-Nonius CAD-3 diffractometer, over one-half of reciprocal space. A θ—2θ scan technique was employed, and the scan angle and aperture settings were calculated using the expression A + B tanθ (A = 1.20°, B = 0.4° for scan angle and A = 0.8 mm, B = 0.4 mm for aperture settings). Reflections were measured for six complete scans or 10 000 peak counts, which ever was completed sooner. The data were reduced by applying Lorentz and polarization corrections to give a total of 2 152 unique reflections, of which 1 186 having $|F| > 5\sigma|F|$ were used in refinement. The structure was successfully solved in space group $P\bar{1}$ using the program MULTAN.

Isotropic refinement of the non-hydrogen atoms converged at R = 11.5%, and anisotropic refinement at 5.96%. The final refinement (by full-matrix least-squares) included the anisotropic refinement of all the non-hydrogen atoms, the geometric location of the aromatic and methyl hydrogens (the latter being allowed to rotate as a rigid group about the C–C bond axis) and the refinement of the positions of the remaining four hydrogen atoms (located from difference maps). The hydrogen atom temperature factors were refined as shown, and are available with the structure factor tables as a Supplementary Publication (SUP No. 23839, 10 pp).* The final residuals were R = 3.90% and R' = 5.09% after refinement of the weighting scheme (shown to be satisfactory by a smoothing of the analysis of variance).

* For details of the Supplementary Publications Scheme see Instructions for Authors (1984) in *J. Chem. Soc., Perkin Trans. 1*, 1984, Issue 1.

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