Synthesis of 2*H*-1,3-Oxazin-2-ones [1]

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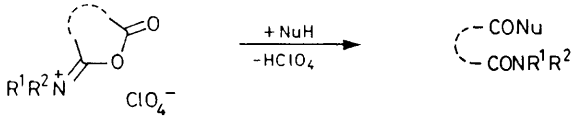
Treatment of *C*-substituted ternary maleisoimidium perchlorates (5), (18), and (24) with sodium azide gave the corresponding maleamic acid azides, which on heating underwent a Curtius rearrangement, followed by electrocyclisation, to yield 6-dialkylamino-derivatives of the novel 1,3-oxazin-2-one system. The action of sodium azide on maleisoimidium salts derived from secondary and tertiary maleamic acids resulted in the formation of the corresponding fumaramic acid azides.

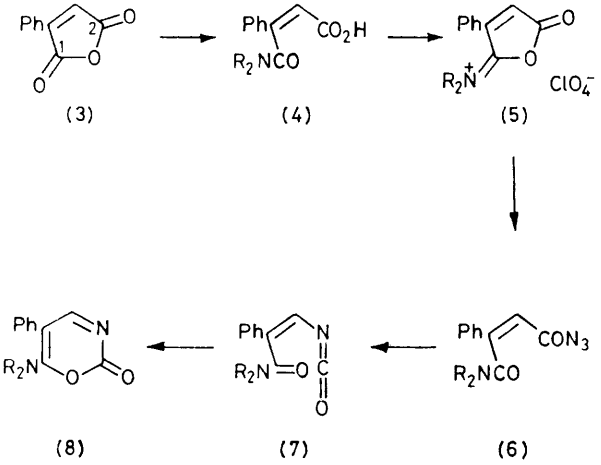
We recently described [2] the synthesis of various cyclic isoimidium perchlorates (1) and their reactions with nucleophiles NuH, which usually afforded derivatives (2) of amic acids. We now report on the action of sodium azide on isoimidium salts derived from *N*-substituted maleamic acids and the chemistry of the resulting azides.

Treatment of phenylmaleic anhydride (3) [3] with morpholine yielded a single amic acid, which we considered to be (4), since attack by the nucleophile should



(1) (2)

R^1 = H or alkyl, R^2 = alkyl or aryl

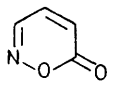


R_2N = morpholino

occur at C-1 of the anhydride, the electrophilic character of C-2 being decreased by conjugation with the phenyl group. Proof of the orientation of the morpholide is given later. The action of acetic anhydride and perchloric acid on the morpholide gave the isoimidium salt (5), which reacted with sodium azide in aqueous acetone to yield the crystalline azide (6). Its i.r. spectrum contained bands at 2 140, 1 690, and 1 642 cm^{-1}, due, respectively, to azide, azide carbonyl, and amide carbonyl absorptions. When the azide was heated in boiling toluene and the reaction monitored by i.r. spectroscopy, it was seen that it underwent a Curtius rearrangement to the isocyanate (7) ($\nu_{max.}$ 2 258 cm^{-1}), which was unstable and rapidly reacted further. After 7 min the bands due to the isocyanate and the azide had been replaced completely by an intense absorption at 1 750 cm^{-1}. Examination of the resulting solution by t.l.c. indicated the presence of essentially one component, which was isolated in 83% yield. Elemental analysis and mass spectrometry showed that the compound was isomeric with the isocyanate; its i.r. spectrum lacked OH and NH absorptions and the ^1H n.m.r. spectrum showed the presence of phenyl and morpholine groups and of a deshielded isolated proton at δ 7.78. The product is accordingly assigned the 1,3-oxazin-2-one structure (8).

Of the four possible 1,*n*-oxazin-6-ones (aza-2-pyrones), only derivatives of compounds (9)—(11) had been described; [4] compound (8) thus represents a new heterocyclic system. The electrocyclic ring-closure leading to it illustrates a general principle for the formation of six-membered heterocyclic compounds; other examples are the cyclisations of the ketens (12)—(15) and of the isocyanates (16) to the corresponding pyridone,[5] pyrimidone,[6] 2-pyrone,[7] oxazinones,[8] and oxadiazinones,[9] respectively. In each case the ketens or isocyanates were intermediates in a complex sequence of reactions and were not observed directly. However, in the conversions of ethyl β-isocyanatocrotonate into 2-ethoxy-4-methyl-1,3-oxazin-6-one [10] and of penta-1,3-dienyl isocyanate into 3-methyl-2(1*H*)-pyridone [11] the open-chain isomers were characterised by spectroscopy.

Further derivatives of the 6-dialkylamino-1,3-oxazin-2-one system were prepared, starting with substituted maleic anhydrides. Diphenylmaleic anhydride reacted with diethylamine to give the diethylammonium salt (17) of the desired amic acid, which could not be converted into the isoimidium salt (18) by the usual treatment with acetic anhydride and perchloric acid, diphenylmaleic anhydride being regenerated. When, however, the diethylammonium salt was added to preformed acetylium perchlorate, the isoimidium perchlorate (18) was obtained in quantitative yield. The derived crystalline azide (19) was heated in toluene to yield the oxazinone (20); the reaction required 20 min



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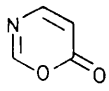

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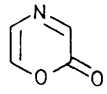
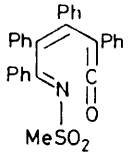


(11)



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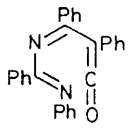

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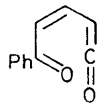

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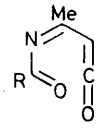
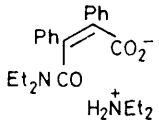


(15)
R = Ph or Bu^t

(16)



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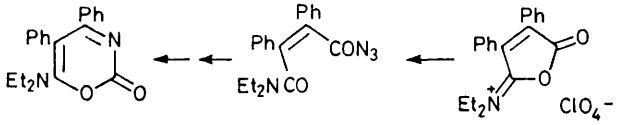
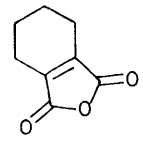


(18) (19) (20)



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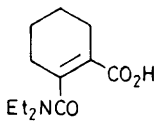

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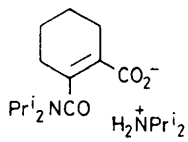

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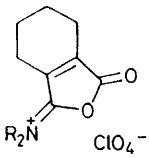

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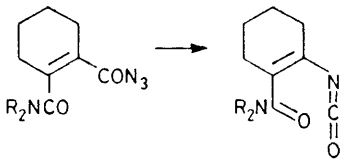
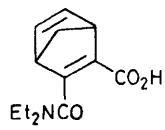


(25) (26)

a; R = Et
b; R = Pr^i



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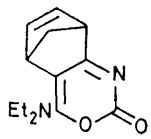
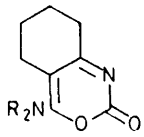
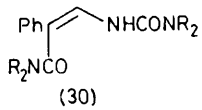


(29)



(27)

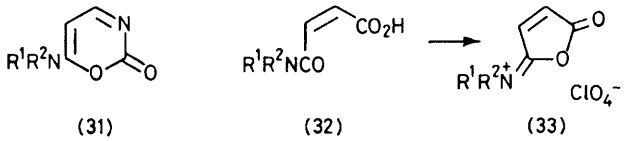


(30)
R$_2$N = morpholino

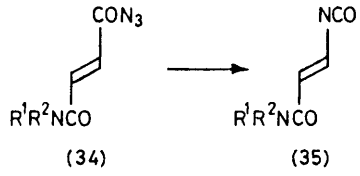
for completion. 3,4,5,6-Tetrahydrophthalic anhydride (21) formed the amic acid (22) by the action of diethylamine; with di-isopropylamine the ammonium salt (23) was obtained. The corresponding isoimidium salts (24a, b) were treated with sodium azide in aqueous acetone; the resulting azides (25a, b) were isolated as water-soluble oils after removing the acetone *in vacuo* at room temperature and the water by freeze-drying. The azides decomposed in boiling toluene to the isocyanates (26a, b) at about the same rate (29 and 22 min, respectively), but whereas the former cyclised to the oxazinone (27a) almost as soon as it was formed, the latter required 3 h 40 min for ring-closure. We attribute the slowness of the electrocyclic reaction to steric hindrance imposed by the bulky alkyl groups. Attempts to prepare the bridged fused oxazinone (29) failed because we were unable to convert the amic acid (28) into the corresponding isoimidium salt.

The 1,3-oxazin-2-ones showed carbonyl absorptions at 1 750—1 732 cm^{-1}. A characteristic feature in their mass spectra was signals due to $(M - CO)^{+\bullet}$ fragments; other prominent peaks were $(M - NR_2)^{+\bullet}$ and $(M - CONR_2)^{+\bullet}$. The ^{1}H n.m.r. spectrum of compound (8) contained a singlet due to the morpholine protons, which indicates free rotation of the substituent. When the solution was cooled, the signal broadened and there were signs of resolution, showing that the rotation was slowed down. The oxazinones were stable at room temperature but decomposed on heating (see the following paper). They were remarkably resistant to hydrolysis; compound (8), for instance, was not affected by boiling water. Prolonged treatment with morpholine in hot benzene gave the acyclic dimorpholide (30). This compound was important because its structure served to establish that of the original amic acid (4). The ^{1}H n.m.r. spectrum of the dimorpholide contained two doublets with $J = 10$ Hz (which were decoupled by irradiation experiments), due to the protons attached to carbon and nitrogen atoms, which are therefore adjacent. Hence the phenyl and morpholine groups in the oxazinone and its precursors are likewise attached to adjacent atoms and the orientation of the original amic acid (4) is as shown.

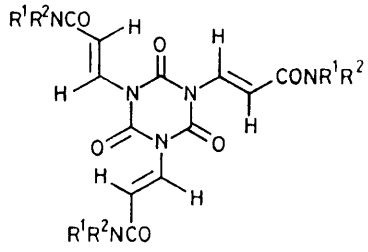
The Action of Sodium Azide on Maleisoimidium Salts.—For the preparation of 6-dialkylamino-oxazinones (31) lacking additional substituents we required



(31) (32) (33)

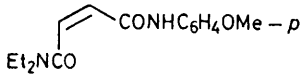


(34) (35)



(36)

a; $R^1 = R^2 = Et$
b; R^1R^2N = morpholino
c; $R^1 = H$, $R^2 = Bu^t$
d; $R^1 = H$, $R^2 = Bu^n$
e; $R^1 = H$, $R^2 = p\text{-}MeOC_6H_4$



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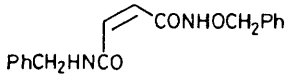

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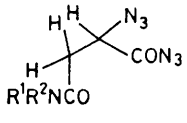


(39)

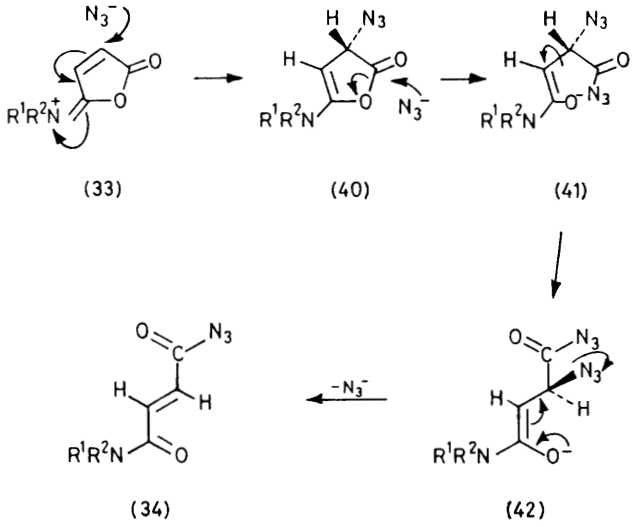
simple maleisoimidium salts, such as (33a and b). These were readily obtained from the corresponding maleamic acids (32). Treatment of the perchlorates (33a, b) with sodium azide gave oily acyl azides, characterised by their i.r. spectra, which exhibited azide, azide carbonyl, and amide carbonyl absorptions at *ca.* 2 140, 1 690, and 1 630 cm^{-1}, respectively. When the azides were heated in benzene or toluene they rearranged to isocyanates, as shown by the appearance of bands at 2 260 cm^{-1} and the shift of the amide carbonyl bands to 1 650 cm^{-1} in the i.r. spectra of the reaction mixtures. Further heating caused the disappearance of the isocyanate absorptions but no bands attributable to the oxazinones (31a, b) developed and no well-defined products could be isolated. The experiments were extended to the secondary maleamic acids (32c—e), which were converted into the salts (33c—e) and thence into acyl azides, which were isolated as crystalline solids. The t-butyl derivative underwent Curtius rearrangement to the corresponding isocyanate ($\nu_{max.}$ 2 260 cm^{-1}) in boiling benzene during 15 min; after heating for a further 1 h the isocyanate had completely reacted. The isolated product was a sparingly soluble high-melting solid, whose mass spectrum showed that it was a trimer of the isocyanate. Its analysis and i.r. spectrum, which exhibited NH absorption and cyclic (1 730 and 1 670) and acyclic (1 625 cm^{-1}) amide carbonyl bands, indicated it to be a 1,3,5-triazine-2,4,6-trione (' isocyanurate '), formed by trimerisation [12] of the isocyanate. Analogous trimers were obtained from the azides prepared from the secondary isoimidium salts (33d and e).

The ^1H n.m.r. spectrum of the first triazinetrione contained two doublets due to adjacent olefinic protons; the high coupling constant, $J = 14.6$ Hz, indicated that the side-chains of the triazinetrione possessed the *trans*-geometry shown in formula (36c). The configuration of this compound explained the anomalous behaviour of the acyl azides obtained from the maleisoimidium salts (33). If these azides were *trans*-compounds (34), they would yield *trans*-isocyanates (35), since configuration is retained in the Curtius rearrangement.[13] The isocyanates, being incapable of electrocyclisation, would instead undergo trimerisation. Inspection of the ^1H n.m.r. spectra of the acyl azides (34) revealed that they indeed belonged to the *trans*-series, the signals due to the olefinic protons being split by 15.4—15.7 Hz, whereas the original maleamic acids (32) showed $J = 12.0$—12.5 Hz. The surprising *cis*→*trans* isomerisation occurred only in the reaction of maleisoimidium salts with sodium azide; other nucleophiles yielded compounds of the maleic acid series. Thus water regenerated the original maleamic acids and amines gave substituted maleamides. For example, the action of *p*-anisidine on the salt (33a) gave the diamide (37), which showed two olefinic proton doublets with $J = 12.4$ Hz; the same compound was obtained when the salt (33e) was treated with diethylamine.

Stereoisomeric transformations of maleoid compounds have long been known. Pfeiffer [14] found that maleic acid changed into fumaric acid in the presence of pyridine, and Clemo and Graham [15] described the piperidine-catalysed conversion of dimethyl maleate into dimethyl

fumarate; another example is the isomerisation of the *cis*-diamide (38) to the *trans*-compound on treatment with benzylamine.[16] The last two reactions probably involve intermediates, in which piperidine or benzylamine have added to the double bond. In order to test whether the present isomerisations proceeded by way of analogous adducts (39) of hydrazoic acid, we treated the salt (33e) with sodium azide dissolved in a mixture of acetone and deuterium oxide, but the ^{1}H n.m.r. spectrum of the resulting azide (34e) showed that no deuterium had been incorporated. It was also found that the maleamic acids (32) were not affected by aqueous sodium azide. Hence the observed *cis*→*trans* change is specific to the reaction of maleisoimidium salts with sodium azide.

A possible mechanism (see Scheme) involves attack by



SCHEME

the strongly nucleophilic azide ion at an olefinic carbon atom of the isoimidium cation; the resulting lactone (40) then reacts with further azide ion to yield the enolate (41), which can change to the less crowded conformer (42) by rotation round the carbon–carbon single bond before expelling azide anion to form the isomerised acyl azide (34). In the phenyl- and diphenyl-maleisoimidium series (5) and (18) no isomerisation occurs because the favoured conformations of the corresponding enolates are like (41) rather than (42).

EXPERIMENTAL

Perchloric acid was of 70% strength. Light petroleum refers to the fraction of b.p. 40—60 °C. I.r. spectra were recorded for Nujol mulls and ^{1}H n.m.r. spectra for solutions in trifluoroacetic acid (for perchlorates) and in deuteriochloroform for other compounds, unless stated otherwise. Acyl azides could not be submitted for elemental analysis, since they decomposed both with time and on attempted purification.

6-*Morpholino*-5-*phenyl*-2H-1,3-*oxazin*-2-*one* (8).—Morpholine (4.35 g, 50 mmol) was added to a suspension of phenylmaleic anhydride [3] (8.7 g, 1 mol equiv.) in benzene (50 ml). The resultant solution deposited (Z)-3-*morpholinocarbonyl*-3-*phenylpropenoic acid* (4) (12.6 g, 97%), m.p. 154—155 °C (from benzene), $\nu_{max.}$ 1 702, 1 632, and 1 110 (morpholine ether) cm^{-1}; δ 8.76 (br s, OH), 7.6—7.23 (m, Ph), 6.39 (s, =CH), and 3.8—3.2 (m, 8 H, morpholine) (Found: C, 64.3; H, 5.85; N, 5.3. $C_{14}H_{15}NO_4$ requires C, 64.35; H, 5.8; N, 5.35%). The n.m.r. spectrum of the crude reaction mixture showed the presence of only one amic acid. Perchloric acid (4.5 ml, *ca.* 1.5 mol equiv.) was added dropwise to a suspension of the foregoing amic acid (7.83 g, 30 mmol) in acetic anhydride (50 ml) at such a rate that the temperature did not exceed 50 °C. The resulting solution was treated with ether to incipient turbidity, when 2,5-*dihydro*-5-*morpholiniumylidene*-4-*phenylfuran*-2-*one perchlorate* (5) (8.74 g, 84%) crystallised; it had m.p. 178—179 °C (decomp.), $\nu_{max.}$ 1 845, 1 685, and 1 095 (br, ClO_4^-) cm^{-1}; δ 7.63 (s, Ph), 7.16 (s, =CH), and 4.5—3.4 (m, 8 H, morpholine) (Found: C, 48.9; H, 4.2; Cl, 10.3; N, 4.0. $C_{14}H_{14}ClNO_7$ requires C, 48.9; H, 4.1; Cl, 10.3; N, 4.1%). The perchlorate (6.88 g, 20 mmol) was added in small portions to a stirred solution of sodium azide (2.6 g, 2 mol equiv.) in water (10 ml) and acetone (20 ml). The acetone was removed *in vacuo* at room temperature and the residual (Z)-3-*morpholinocarbonyl*-3-*phenylpropenoyl azide* (6) (5.4 g, 90%) was collected, washed with water, and dried (P_2O_5). It had m.p. 102 °C (decomp.), $\nu_{max.}$ 2 140, 1 690, 1 642, and 1 110 cm^{-1}; δ 7.64—7.3 (m, Ph), 6.27 (s, =CH), and 3.6—3.1 (m, 8 H, morpholine). A solution of the azide (2.86 g, 10 mmol) in toluene (20 ml) was boiled under reflux for 7 min, when i.r. spectroscopy indicated that the absorptions due to the azide and the transient isocyanate (7) at 2 258 cm^{-1} had disappeared. The toluene was removed *in vacuo* and the solid residue crystallised from benzene, giving the *oxazinone* (2.13 g, 83%), m.p. 148—150 °C, $\nu_{max.}$ 1 742, 1 592, 1 576, and 1 120 cm^{-1}; $\lambda_{max.}$ (MeOH) 250 (log ε 4.17) and 340 nm (4.13); δ 7.78 (s, CH), 7.65—7.2 (m, Ph), and 3.72 (s, 8 H, morpholine, broadens on lowering the temperature to −70 °C); *m/e* 259 $(M+1)^+$, 258 (M^+), 230 $(M-CO)^+$, 172 $(M-$ morpholino$)^+$, and 144 $(M-$ morpholinocarbonyl$)^+$ (Found: C, 64.9; H, 5.45; N, 10.8. $C_{14}H_{14}N_2O_3$ requires C, 65.1; H, 5.45; N, 10.8%). A mixture of the oxazinone (0.258 g, 1 mmol), morpholine (0.087 g, 1 mol equiv.), and benzene (15 ml) was refluxed for 24 h. The benzene was removed; the residual (Z)-1-*morpholinocarbonyl*-2-*morpholinocarbonylamino*-1-*phenylethene* (30) (0.26 g, 75%) was crystallised from benzene–light petroleum; it had m.p. 188—190 °C, $\nu_{max.}$ 3 260, 1 672, 1 644, and 1 112 cm^{-1}; δ 9.55 (d, *J* 10 Hz, disappears on adding D_2O, NH), 7.53 (d, *J* 10 Hz, =CH), 7.25 (br s, Ph), and 3.8—3.1 (m, 16 H, 2 × morpholino) (Found: C, 62.3; H, 6.9; N, 12.0. $C_{18}H_{23}N_3O_4$ requires C, 62.6; H, 6.7; N, 12.15%).

6-*Diethylamino*-4,5-*diphenyl*-2H-1,3-*oxazin*-2-*one* (20).—A mixture of diphenylmaleic anhydride [3] (10.0 g, 40 mmol), diethylamine (14.6 g, 5 mol equiv.), and benzene (80 ml) was refluxed for 15 min; on cooling, *diethylammonium* NN-*diethyldiphenylmaleamate* (17) (15.8 g, 93%) crystallised; it had m.p. 144—145.5 °C (decomp.) (from benzene), $\nu_{max.}$ 2 460—2 380, 1 615, and 1 600 cm^{-1}; δ 8.66 (br s, exchangeable for deuterium, NH_2), 7.06 (s, 2 × Ph), 3.39 (quintet, 2 × CH_2), 2.66 (q, 2 × CH_2), 1.13 (t, 2 × Me), 1.09 (t, Me), and 0.73 (t, Me) (Found: C, 72.7; H, 8.2; N, 6.8. $C_{24}H_{27}N_3O_3$ requires C, 72.8; H, 8.15; N, 7.05%). The salt (11.9 g, 30 mmol) was added in small portions to an ice-

cold solution of perchloric acid (4.5 ml) in acetic anhydride (45 ml), whereupon the hygroscopic 2,5-*dihydro*-5-*diethylammonio*-3,4-*diphenylfuran*-2-*one perchlorate* (18) (11.64 g, 96%) separated. It had m.p. 226—230 °C (decomp.), $\nu_{max.}$ 1 850, 1 670, and 1 090 cm^{-1}; δ 7.7—7.1 (m, 2 × Ph), 3.99 (q, CH_2), 3.58 (q, CH_2), 1.5 (t, Me), and 1.13 (t, Me) (Found: C, 57.7; H, 4.95; N, 3.45. $C_{20}H_{20}ClNO_6$ requires C, 57.9; H, 4.9; N, 3.4%). The perchlorate (8.12 g, 20 mmol) was added in small portions to a stirred solution of sodium azide (2.6 g, 2 mol equiv.) in water (10 ml) and acetone (30 ml). The acetone was removed *in vacuo* at room temperature; the resulting gum solidified during 12 h in the refrigerator. It was collected, washed with M-$NaHCO_3$ and then with water and dried over P_2O_5. NN-*Diethyldiphenylmaleamoyl azide* (19) (7.08 g, 89%) had m.p. 55—57 °C (decomp.), $\nu_{max.}$ 2 134, 1 680, and 1 634 cm^{-1}; δ 7.4—7.0 (m, 2 × Ph), 3.48 (q, CH_2), 3.27 (q, CH_2), and 1.14 (t, 2 × Me). The azide (6.96 g, 20 mmol) was boiled in toluene (50 ml) until i.r. spectroscopy showed that it had reacted completely (20 min); a transient isocyanate absorption at 2 258 cm^{-1} was observed during the process. The toluene was removed *in vacuo*; the resulting *oxazinone* (4.86 g, 70%) had m.p. 125—127 °C (from benzene–light petroleum), $\nu_{max.}$ 1 732, 1 603, and 1 590 cm^{-1}; $\lambda_{max.}$ (MeOH) 247 (log ε 4.39) and 348 nm (4.17); δ 7.3—6.5 (m, 2 × Ph), 3.52 (q, 2 × CH_2), and 1.2. (t, 2 × Me); *m/e* 321 $(M + 1)^+$, 320 (M^+), 292 $(M - CO)^+$, 248 $(M - NEt_2)^+$, 220 (M — Et_2NCO), and 178 $(PhC{\equiv}CPh)^+$ (Found: C, 74.6; H, 6.25; N, 8.4. $C_{20}H_{20}N_2O_2$ requires C, 74.95; H, 6.3; N, 8.7%).

4-*Diethylamino*-5,6,7,8-*tetrahydro*-2H-3,1-*benzoxazin*-2-*one* (27a).—A solution of 3,4,5,6-tetrahydrophthalic anhydride (21) (7.6 g, 50 mmol) and diethylamine (3.65 g, 1 mol equiv.) in ethyl acetate (80 ml) was refluxed for 20 min; NN-*diethyl*-3,4,5,6-*tetrahydrophthalamic acid* (22) (10.15 g, 90%) crystallised on cooling. It had m.p. 129—130 °C (from benzene), $\nu_{max.}$ 1 705 and 1 573 (amide carbonyl) cm^{-1}; δ 10.33 (br s, exchangeable for deuterium, OH), 3.32 (q, 2 × CH_2), 2.5—2.1 (m, 4 H) and 1.9—1.6 (m, 4 H) (cyclohexeno), and 1.1 (t, 2 × Me) (Found: C, 64.1; H, 8.5; N, 6.35. $C_{12}H_{19}NO_3$ requires C, 64.0; H, 8.5; N, 6.2%). The amic acid (9.0 g, 40 mmol) was converted into the pale-yellow hygroscopic NN-*diethyl*-3,4,5,6-*tetrahydrophthalisoimidium perchlorate* (24a) (9.36 g, 76%) in the usual way. The salt had m.p. 146—148 °C (decomp.), $\nu_{max.}$ 1 833, 1 679, and 1 080 cm^{-1}; δ 3.98 (q, 2 × CH_2), 2.9—2.3 (m, 4 H) and 2.0—1.7 (m, 4 H) (cyclohexeno), 1.53 (t, Me), and 1.5 (t, Me) (Found: C, 46.3; H, 5.9); N, 4.55. $C_{12}H_{18}ClNO_6$ requires C, 46.8; H, 5.9; N, 4.55%. The perchlorate (6.14 g, 20 mmol) was added in small portions to a solution of sodium azide (2.6 g, 2 mol equiv.) in water (8 ml) and acetone (12 ml). The acetone was removed *in vacuo* at room temperature and the water by freeze-drying. The residue was dissolved in ether; the filtered solution was dried ($MgSO_4$) and the ether was removed at room temperature, leaving 2-*diethylcarbamoyl*-3,4,5,6-*tetrahydrobenzoyl azide* (25a) (3.8 g, 76%), oil, $\nu_{max.}$ 2 138, 1 680, and 1 620 cm^{-1}. A solution of the azide (2.50 g, 10 mmol) in toluene was refluxed for 29 min, when i.r. spectroscopy indicated the absence of azide and transient isocyanate (2 260 cm^{-1}) absorptions. The toluene was removed and the *oxazinone* (2.49 g, 80%) was isolated by thick-layer chromatography on silica plates (R_F = 0.55 in 1 : 3 ethyl acetate–light petroleum). It had m.p. 41—42 °C, $\nu_{max.}$ 1 750, 1 610, and 1 565 cm^{-1}; $\lambda_{max.}$ (MeOH) 317 nm (log ε 3 66); δ 3.48 (q, 2 × CH_2), 2.5—2.2 (m, 4 H) and 1.4—1.1 (m, 4 H) (cyclohexeno), and 1.2 (t, 2 × Me); *m/e* 222 (M^+), 194 $(M - CO)^+$, 150 $(M - NEt_2)^+$, and 122 $(M - CONEt_2)^+$ (Found: C, 64.8; H, 8.2; N, 12.4. $C_{12}H_{18}N_2O_2$ requires C, 64.85; H, 8.2; N, 12.6%).

5,6,7,8-*Tetrahydro*-4-*di-isopropylamino*-2H-3,1-*benzoxazin*-2-*one* (27b).—A solution of the anhydride (21) (7.6 g) and di-isopropylamine (10.1 g, 2 mol equiv.) in benzene (100 ml) was refluxed for 20 min and then cooled, whereupon the very hygroscopic *di-isopropylammonium* 3,4,5,6-*tetrahydro*-NN-*di-isopropylphthalamate* (23) (14.3 g, 80%) crystallised; it had m.p. 139—144 °C (decomp.), $\nu_{max.}$ 2 800—2 200, 1 640, and 1 620 cm^{-1}; δ 9.29 (br s, NH_2), 3.98 (septet, CH), 3.23 (septet, CH), 3.21 (septet, 2 × CH), 2.5—2.1 (m, 4 H) and 1.7—1.5 (m, 4 H) (cyclohexeno), 1.42 (d, 2 × Me), 1.25 (d, 4 × Me), and 1.13 (d, 2 × Me) (Found: C, 67.4; H, 10.9; N, 7.8. $C_{20}H_{38}N_2O_3$ requires C, 67.75; H, 10.8; N, 7.9%). The salt (14.16 g, 40 mmol) was added in small portions to a stirred ice-cold mixture of perchloric acid (6 ml) and acetic anhydride (50 ml); ether precipitated pale-yellow 3,4,5,6-*tetrahydro*-NN-*di-isopropylphthalisoimidium perchlorate* (24b) (12.64 g, 94%), m.p. 166—170 °C (decomp.), $\nu_{max.}$ 1 850, 1 668, and 1 080 cm^{-1}; δ 3.49 (septet, 2 × CH), 2.9—2.4 (m, 4 H) and 2.0—1.7 (m, 4 H) (cyclohexeno), and 1.42 (d, 4 × Me). Satisfactory analytical figures could not be obtained because the perchlorate was extremely hygroscopic. The salt (10.08 g, 30 mmol) was converted into the oily 3,4,5,6-*tetrahydro*-2-*di-isopropylcarbamoylbenzoyl azide* (25b) (6.55 g, 76%) as described for the previous azide. The compound showed $\nu_{max.}$ 2 140, 1 680, and 1 630 cm^{-1}. A solution of it (5.56 g, 20 mmol) in toluene (50 ml) was heated under reflux and the reaction was followed by i.r. spectroscopy. The azide had disappeared after 22 min, but the band at 2 260 cm^{-1} due to the isocyanate (26b) persisted for 3 h 40 min. The *oxazinone* (3.4 g, 68%) was isolated by thick-layer chromatography; it had m.p. 81 °C (from hexane), $\nu_{max.}$ 1 742, 1 592, and 1 550 cm^{-1}; δ 4.22 (septet, 2 × CH), 2.5—2.2 (m, 4 H) and 1.9—1.6 (m, 4 H) (cyclohexeno), and 1.3 (d, 4 × Me); *m/e* 251 $(M^+ + 1)$, 250 $(M)^+$, 150 $(M - NPr^i_2)^+$, and 122 $(M - CONPr^i_2)^+$ (Found: C, 67.1; H, 9.0; N, 11.3. $C_{14}H_{22}N_2O_2$ requires C, 67.15; H, 8.9; N, 11.2%).

2-*Diethylcarbamoylbicyclo*[2.2.1]*hepta*-2,5-*diene*-3-*carboxylic Acid* (28).—A solution of bicyclo[2.2.1]hepta-2,5-diene-2,3-dicarboxylic acid [17] (1.8 g, 10 mmol), *NN'*-dicyclohexylcarbodi-imide (2.06 g, 1 mol equiv.), and diethylamine (0.73 g, 1 mol equiv.) in dichloromethane (25 ml) was set aside for 4 days. The precipitated *NN'*-dicyclohexylurea (1.88 g, 100%) was filtered off, the filtrate was evaporated, and the gummy residue was submitted to thick-layer chromatography. The *amic acid* (0.8 g, 34%), R_F = 0.24 in ethyl acetate–light petroleum (1 : 1), had m.p. 115—117 °C (from benzene), $\nu_{max.}$ 1 700, 1 638, and 1 590 cm^{-1}; δ 10.45 (br s, disappears on adding D_2O, OH), 6.92 (t, 2 × =CH), 4.1—3.9 (m, CH), 3.8—3.7 (m, CH), 2.35—2.0 (m, bridge CH_2), 3.3 (q, 2 × CH_2) and 1.13 (t, 2 × Me) (2 × Et) (Found: C, 66.5; H, 7.3; N, 6.0. $C_{13}H_{17}NO_3$ requires C, 66.35; H, 7.3; N, 5.95%). Treatment of the amic acid with acetic anhydride and perchloric acid gave an oil, whose i.r. spectrum did not exhibit any absorptions above 1 750 cm^{-1} in the carbonyl region.

Maleisoimidium Perchlorates (33).—The *p*-methoxyphenyl derivative (33e) has been described; [2] the other salts were prepared by treating a suspension of the requisite maleamic

acid (32) * (10 mmol) in acetic anhydride (12 ml) with perchloric acid (1.5 ml), collecting the product, and washing it with ether. The following *perchlorates* were obtained: NN-*diethylmaleisoimidium* (33a) (2.01 g, 78%), very hygroscopic, m.p. 108—112 °C (decomp.), $\nu_{max.}$ 1 860, 1 705, and 1 090 cm^{-1}; δ 8.19 (d, =CH) and 7.32 (d, =CH) (*J* 6 Hz), 4.18 (q, CH_2), 4.12 (q, CH_2), 1.6 (t, Me), and 1.57 (t, Me) (a satisfactory analysis could not be carried out because of the hygroscopic nature of the salt); 2,5-*dihydro*-5-*morpholiniofuran*-2-*one* (33b) (2.14 g, 80%), hygroscopic, m.p. 165—168 °C (decomp.), $\nu_{max.}$ 1 845, 1 710, and 1 090 cm^{-1}; δ 8.27 (d, =CH) and 7.36 (d, =CH), (*J* 6 Hz), and 4.45—3.5 (m, 8 H, morpholine) (Found: C, 34.6; H, 3.95; N, 5.0. $C_8H_{10}ClNO_7 \cdot \frac{1}{2}H_2O$ requires C, 34.7; H, 4.0; N, 5.0%); N-*t-butylmaleisoimidium* (33c) (2.19 g, 90%), m.p. 124—126 °C (decomp.), $\nu_{max.}$ 3 220, 1 860, 1 712, and 1 090 cm^{-1}; δ 7.96 (d, =CH) and 7.19 (d, =CH) (*J* 5.8 Hz), and 1.7 (s, Bu^t) (Found: C, 37.7; H, 4.85; Cl, 13.7; N, 5.4. $C_8H_{12}ClNO_6$ requires C, 37.9; H, 4.75; Cl, 14.0; N, 5.5%); N-*n-butylmaleisoimidium* (33d) (1.67 g, 70%), very hygroscopic, m.p. 64—65 °C (decomp.), $\nu_{max.}$ 3 220, 1 865, 1 715, and 1 100 cm^{-1}; δ 7.7 (d, =CH) and 7.05 (d, =CH) (*J* 6 Hz), 3.6—3.0 (m, 3 × CH_2), and 1.3 (t, Me) (satisfactory analytical data could not be obtained because of the hygroscopic nature of the salt).

Fumaramic Acid Azides (34).—A freshly prepared maleisoimidium perchlorate (33) (10 mmol) was added in small portions to a stirred solution of sodium azide (1.3 g, 2 mol equiv.) in a mixture of water (8 ml) and acetone (10 ml). The acetone was removed under reduced pressure at room temperature and the azide, if solid, was collected, washed succesively with M-sodium hydrogen carbonate and water, and dried over P_2O_5. If no solid appeared, the water was removed by freeze-drying, the residue was stirred with dichloromethane, the filtered solution was dried ($MgSO_4$), and the solvent was removed *in vacuo* at room temperature. The following (E)-*propenyl azides* were obtained: 3-*diethylcarbamoyl*- (34a) (0.98 g, 50%), oil, decomposes slowly even at 0 °C, $\nu_{max.}$ (C_6H_6) 2 140, 1 690, and 1 630 cm^{-1}; δ 7.44 (d, =CH) and 6.79 (d, =CH) (*J* 15.4 Hz), 3.6—3.3 (m, 2 × CH_2), 1.23 (t, Me) and 1.16 (t, Me); 3-*morpholinocarbonyl*- (34b) (1.2 g, 60%), oil, $\nu_{max.}$ (C_6H_6) 2 120, 1 720, and 1 630 cm^{-1} (a n.m.r. spectrum could not be determined because the azide was too hygroscopic); 3-*t-butylcarbamoyl*- (34c) (1.7 g, 87%), m.p. 80—81 °C (decomp.), $\nu_{max.}$ 3 395, 2 160, 1 670, and 1 647 cm^{-1}; δ 6.96 (d, =CH), and 6.69 (d, =CH), (*J* 15.7 Hz), 6.1 (br s, exchangeable for deuterium, NH), and 1.41 (s, Bu^t); 3-*n-butylcarbamoyl*- (34d) (0.9 g, 50%), m.p. 85—87 °C (decomp.), $\nu_{max.}$ 3 310, 2 150, 1 690, and 1 650 cm^{-1}; δ 7.02 (d, =CH) and 6.64 (d, =CH) (*J* 15.5 Hz), 6,51 (br s, exchangeable for deuterium, NH), 3.36 (q, CH_2), 1.7—1.2 (m, 2 × CH_2), and 0.93 (t, Me); and 3-*p-methoxyphenylcarbamoyl*- (34e) (1.9 g, 77%), m.p. 128 °C (decomp.), $\nu_{max.}$ 3 320, 2 160, 1 682, and 1 642 cm^{-1}; δ[$(CD_3)_2SO$] 7.62 (d, 2 H) and 6.83 (d, 2 H) (*J* 9 Hz) (Ar), 7.29 (d, =CH) and 6.67 (d, =CH) (*J* 15.7 Hz), 3.98 (br s, exchangeable for deuterium, NH), and 3.73 (s, Me).

Thermolysis of the Azides (34).—(*a*) A solution of the diethylamino-derivative (34a) (0.98 g, 5 mmol) in benzene (25 ml) was heated under reflux; i.r. spectroscopy showed that the bands due to the azide were gradually replaced by those due to the isocyanate (35a) ($\nu_{max.}$ 2 260 and 1 650 cm^{-1}), and these, in turn, were replaced by absorptions at 1 700 and 1 660 cm^{-1}. The process was complete after 2 h 30 min; in boiling toluene the reaction required 45 min. Work-up of the reaction mixtures gave intractable gums.

(*b*) The morpholino-compound (34b) similarly decomposed to the isocyanate (35b) ($\nu_{max.}$ 2 260 and 1 650 cm^{-1}) during 30 min in boiling toluene; these bands were replaced by broad absorptions at 1 700 and 1 660 cm^{-1} after a further 4 h. Work-up yielded an intractable gum.

(*c*) The t-butyl derivative (34c) (0.49 g, 2.5 mmol) decomposed completely to the isocyanate (35c) ($\nu_{max.}$ 2 260 and 1 650 cm^{-1}) during 15 min in refluxing benzene (15 ml); after a further hour there was no evidence for the presence of the isocyanate. T.l.c. of the resulting solution indicated the presence of two compounds. The major, less polar, product was isolated by thick-layer chromatography [R_F = 0.4 in ethyl acetate–light petroleum (3 : 1)] as 1,3,5-*tri*[(E)-2-*t-butylcarbamoylvinyl*]*triazine*-2,4,6-(2H,4H,6H)-*trione* (36c) (0.21 g, 52%), m.p. 300—302 °C, $\nu_{max.}$ 3 320, 1 730, 1 670, 1 625, and 1 550 cm^{-1}; δ[$(CD_3)_2SO$] 7.81 (d, =CH) and 6.92 (d, =CH) (*J* 14.6 Hz), 7.15 (br s, exchangeable for deuterium, NH), and 1.38 (s, Bu^t), *m/e* 504 (M^+) (Found: N, 16.7. $C_{24}H_{36}N_6O_6$ requires N, 16.65%).

(*d*) The n-butyl derivative (34d) (0.98 g, 5 mmol) had decomposed completely to the isocyanate (35d) ($\nu_{max.}$ 2 240 and 1 650 cm^{-1}) in boiling toluene (25 ml) after 30 min; after a further 3 h 1,3,5-*tri*-[(E)-2-*n-butylcarbamoylvinyl*]*triazine*-2,4,6(1H,3H,5H)-*trione* (36d) (0.34 g, 42%) was produced, which was isolated by repeated thick-layer chromatography [R_F = 0.3 in acetonitrile–ethyl acetate (2 : 1)], m.p. 212—213 °C, $\nu_{max.}$ 1 740, 1 720, and 1 660 cm^{-1} (Found: C, 56.8; H, 7.4; N, 16.4. $C_{24}H_{36}N_6O_6$ requires C, 57.1; H, 7.2; N, 16.65%).

(*e*) A solution of the *p*-methoxyphenyl derivative (34e) (0.62 g, 2.5 mmol) in benzene (15 ml) was refluxed; the azide had decomposed completely after 30 min to the isocyanate (35e) ($\nu_{max.}$ 2 260 and 1 680 cm^{-1}), during which time a solid separated. The mixture was boiled for a further 1 h, cooled, and the 1,3,5-*tri*[(E)-2-p-*methoxyphenylcarbamoylvinyl*]*triazine*-2,4,6(1H,3H,5H)-*trione* (36c) (0.21 g, 38%) was collected. It had m.p. 256—258 °C, $\nu_{max.}$ 1 740, 1 720, and 1 665 cm^{-1} (Found: C, 60.8; H, 4.7; N, 12.9. $C_{33}H_{30}N_6O_9$ requires C, 60.6; H, 4.6; N, 12.85%).

NN-*Diethyl*-N′-p-*methoxyphenylmaleamide* (37).—*NN*-Diethylmaleisoimidium perchlorate (33a) (2.53 g, 10 mmol) was added to a solution of *p*-anisidine (1.23 g, 1 mol equiv.) and triethylamine (1.01 g, 1 mol equiv.) in dichloromethane (50 ml). The resulting solution was decanted from the precipitated triethylammonium perchlorate and evaporated. The residual *maleamide* (2.3 g, 80%) had m.p. 145—147 °C (from ethanol), $\nu_{max.}$ 3 260, 1 672, and 1 590 cm^{-1}, δ 10.79 (br s, exchangeable for deuterium, NH), 7.57 (d, 2 H) and 6.82 (d, 2 H) (*J* 9 Hz) (Ar), 6.42 (d, =CH) and 6.21 (d, =CH) (*J* 12.4 Hz), 3.74 (s, OMe), 3.45 (q, CH_2), 3.38 (q, CH_2), and 1.17 (t, 2 × Me) (Found: C, 65.0; H, 7.3; N, 10.1. $C_{15}H_{20}N_2O_3$ requires C, 65.2; H, 7.3; N, 10.1%). The reaction of the *N-p*-methoxymaleisoimidium salt (33e) (3.03 g, 10 mmol) with diethylamine under the same conditions afforded the maleamide (2.35 g, 85%).

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