Intramolecular Cyclisation Using Methyl(bismethylthio)sulphonium Salts, Bromine, and Iodine. 5-Methylene-4,5-dihydro-oxazoles from 3-Amidopropynes

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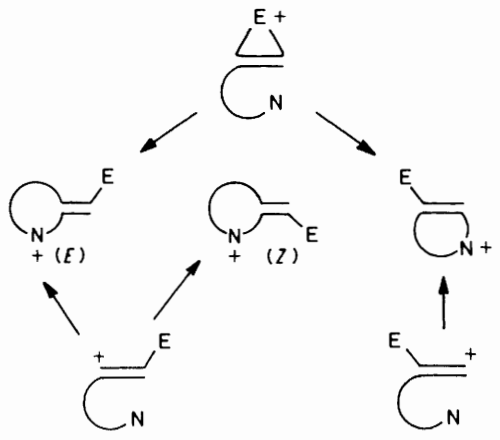
The reaction of methyl(bismethylthio)sulphonium hexachloroantimonate (3) with acylaminopropynes (1) and (2) gave (*E*)-5-methylthiomethylene-2-phenyl-4,5-dihydro-oxazolium (4) and (*E*)-2-methyl-5-methylthiomethylene-4,5-dihydro-oxazolium (7) hexachloroantimonates which were transformed into the corresponding methylenedihydro-oxazoles (10) and (13). The reaction of iodine with (1) and (2) gave (*E*)-5-iodomethylene-2-phenyl-4,5-dihydro-oxazolium (6) and (*E*)-5-iodomethylene-2-methyl-4,5-dihydro-oxazolium (9) tri-iodides which were also transformed into the methylenedihydro-oxazoles (12) and (14). The reaction of bromine with (1) gave (*E*)-5-bromomethylene-2-phenyldihydro-oxazole tribromide (5), which was also converted into the free base (11), while the reaction with (2) afforded ultimately 5-dibromomethyl-2-methyloxazolium bromide (25); from (25) the corresponding oxazole derivative (26) was obtained. In the reactions of both bromine and iodine with (2) some (*E*)-3-acetamido-1,2-dibromopropene (*E*)-(16) and (*E*)-3-acetamido-1,2-di-iodopropene (*E*)-(17) were also obtained.

The electrophilic addition of halogens and sulphenic derivatives to simple alkynes occurs with formation of cationic intermediates which have a bridged or an open structure depending on the nature of the electrophile and the structure of the alkyne.[1,2] The stereospecificity of the addition is often used as a means of differentiating between the two intermediates since the bridged species undergoes an in-plane substitution reaction [3,4] with the nucleophilic part of the reagent giving an overall *anti* addition to the triple bond, while the open intermediate gives mixtures of *E*- and *Z*-adducts. If the reactions are carried out in nucleophilic solvents such as alcohols, incorporation of the solvent is often observed.

It is evident that an internal nucleophile can in principle compete with the external nucleophile leading to the formation of cyclic products and the regio- and stereo-chemical course of the reaction may thus give some insight into the structures of the intermediates.



Although the intramolecular cyclisation has been widely explored for alkenes,[5] the corresponding reactivity of alkynes [6] has been investigated to a lesser extent. We report here the reactions of 3-benzamidopropyne (1) and 3-acetamidopropyne (2) with bromine, iodine, and methyl(bismethylthio)-sulphonium hexachloroantimonate (3), which proceed *via* intramolecular cyclisation [7] to give the 5-methylenedihydro-oxazole derivatives (4)—(9).

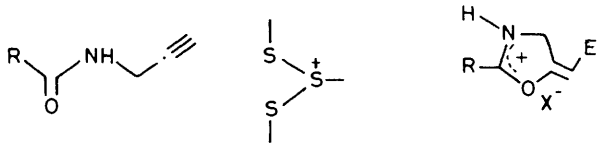
Results

The reaction of methyl(bismethylthio)sulphonium hexachloroantimonate (3) with 3-benzamido- (1) and 3-acetamidopropyne (2) was carried out in [$^2H_2$]dichloromethane solution at room temperature and monitored by ^1H n.m.r. spectroscopy. In a few minutes the signals of the alkyne derivative (1) or (2) and those of the sulphonium salt (3) disappeared and were replaced by a signal due to dimethyl disulphide at δ 2.43 and by a new set of signals at δ 8.4—7.6 (m, ArH), 6.62 (t, *J* 3.0 Hz, CH), 5.17 (d, CH_2), and 2.43 (s, CH_3) for the reaction with (1) and at δ 6.48 (t, *J* 3.5 Hz, CH), 4.96br (d, CH_2), 2.80br (s, CH_3), and 2.43 (s, SMe) for the reaction with (2); these were attributed to the formation of (*E*)-5-methylthiomethylene-3-phenyldihydro-oxazolium and (*E*)-5-methylthiomethylene-3-methyldihydro-oxazolium hexachloroantimonates (4) and (7) respectively.

The dihydro-oxazolium salt (4) partially precipitated from the solution; addition of n-pentane caused further precipitation of (4) which was recovered in almost quantitative yield (91%). Compound (7) is fully soluble in dichloromethane; however, it was isolated as a reddish viscous oil (98%) upon addition of n-pentane. The free dihydro-oxazoles (10) and (13) were obtained on treating (4) and (7) with aqueous sodium hydrogen carbonate solution.

The reactions of the alkynes (1) and (2) with bromine and iodine were carried out in ethanol-free chloroform at room temperature and required two equivalents of the halogen; however, the composition of the reaction products was dependent on the individual alkyne and halogen.

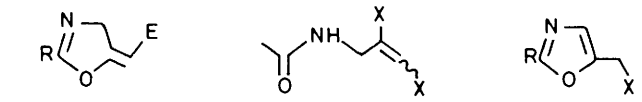
With 3-benzamidopropyne (1) bromine and iodine gave exclusively the (*E*)-5-bromomethylene-3-phenyldihydro-oxazolium tribromide (5) and (*E*)-5-iodomethylene-3-phenyldihydro-oxazolium tri-iodide (6) respectively. The trihalogenide salts (5) and (6) precipitated from the chloroform solution in fairly good yield (97 and 96% yield respectively) and gave the corresponding dihydro-oxazole derivatives (11) and (12) after



(1) R = Ph
(2) R = Me

(3)

(4) R = Ph, E = SMe, X = $SbCl_6$
(5) R = Ph, E = Br, X = Br_3
(6) R = Ph, E = I, X = I_3
(7) R = Me, E = SMe, X = $SbCl_6$
(8) R = Me, E = Br, X = Br_3 or Br
(9) R = Me, E = I, X = I_3 or I



(10) R = Ph, E = SMe
(11) R = Ph, E = Br
(12) R = Ph, E = I
(13) R = Me, E = SMe
(14) R = Me, E = I
(15) R = Ph, E = SO_2Me

(16) X = Br
(17) X = I

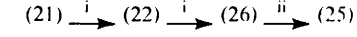
(18) R = Ph, X = H
(19) R = Ph, X = Br
(20) R = Ph, X = SMe
(21) R = Me, X = H
(22) R = Me, X = Br

reduction with aqueous sodium sulphite–sodium hydrogen carbonate.

The reaction of the acetamide (2) with iodine, under the same reaction conditions, gave a dark oily precipitate from which, after reduction with Na_2SO_3–$NaHCO_3$ solution and column chromatography, the dihydro-oxazole (14) (30%) and the di-iodo *E*-adduct (*E*)-(17) were recovered. Similar treatment of the mother-liquors afforded only the *E*-adduct (*E*)-(17) (44% total yield).

The reaction of compound (2) with bromine follows a slightly different course. In fact an unstable dihydro-oxazolium salt to which the structure (23) might be assigned, as well as the dibromo derivative (*E*)-(16) (47% yield), was obtained. The suggested structure of (23) is supported by its reactivity: treatment with Na_2SO_3–$NaHCO_3$ solution gave a viscous oil (24) which spontaneously rearranged to the oxazolium bromide (25) (19%). From compound (25), the oxazole (26) was easily obtained (Scheme 1).

The oxazole derivatives (25) and (26) were also synthesized as shown in Scheme 2. Bromination of (21) at the 5-methyl group is suggested by the lack of allylic coupling constants in (22) and (26).

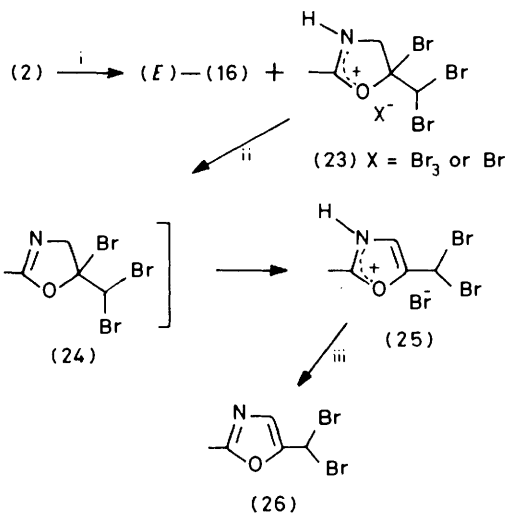


Scheme 2. *Reagents:* i, NBS; ii, HBr

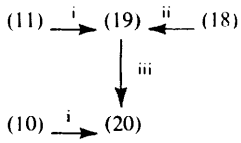
The ^1H n.m.r. parameters of the compounds described in the text are reported in Table 1. The cyclic pentatomic structure of the compounds obtained, suggested by the ^1H n.m.r. chemical shifts and coupling constants of the vinyl protons, was confirmed by the ^{13}C n.m.r. data obtained for (10), (11), and (12) (Table 2); these show the presence of a monosubstituted vinylic carbon which is attributed to the exocyclic carbon atom since its position varies in the individual compound according to the heavy atom effect.[8]

Further evidence arose from the behaviour of the methylene-dihydro-oxazoles (10) and (11) when heated at 150 °C for 1 h; an *exo-endo* migration of the double bond took place with formation of 5-methylthiomethyl-2-phenyloxazole (20) and 5-bromomethyl-2-phenyloxazole (19) respectively. The oxazoles (19) and (20) were identified by comparison with samples prepared by alternative routes as indicated in Scheme 3.

The *E* configuration of the dihydro-oxazole (10) is inferred from the low chemical shift value of the methylene protons [9] of



Scheme 1. *Reagents:* i, Br_2; ii, aq. Na_2SO_3–$NaHCO_3$; iii, aq. $NaHCO_3$



Scheme 3. *Reagents and conditions:* i, 150 °C for 1 h; ii, NBS; iii, MeSNa

Table 1. ^{1}H N.m.r. parameters. Chemical shifts for solutions in $CDCl_3$

Compound	δ (*J* in Hz)				
	Ph	CH	CH_2	Me	NH
(10)	8.0—7.3 (m)	5.80 (t, *J* 3.0)	4.74 (d)	2.24 (s)	
(11)	8.0—7.3 (m)	6.02 (t, *J* 3.3)	4.67 (d)		
(12)	8.0—7.4 (m)	5.77 (t, *J* 3.2)	4.62 (d)		
(13)		5.63 (t, *J* 3.0)	4.50 (dd)	2.2 (s), 2.08 (t, *J* 2)	
(14)		5.53 (t, *J* 3.0)	4.35 (m)	2.01br (t, *J* 1.3)	
(15)	8.2—7.4 (m)	6.27 (t, *J* 3.0)	5.18 (d)	3.07 (s)	
(*E*)-(16)		6.60 (s)	4.23 (d, *J* 6) [a]	2.05 (s)	6.1br
(*Z*)-(16)		6.95 (s)	4.17 (d, *J* 6) [a]	2.05 (s)	6.2br
(*E*)-(17)		7.20 (s)	4.28 (d, *J* 5) [a]	2.17 (s)	5.7br
(19)	8.1—7.4 (m)	7.18br (s)	4.57br (s)		
(20)	8.3—7.3 (m)	7.03br (s)	3.72br (s)	2.12 (s)	
(24)		6.32 (s)	4.61br (s)	2.10 (s)	
(26)		6.53 (s), 6.95 (s)		2.45 (s)	

[a] Singlet on D_2O addition.

Table 2. ^{13}C N.m.r. parameters. Chemical shifts for solutions in ($CDCl_3$)

Compound	δ/p.p.m.					
	Ph	2-C	4-C	5-C	*exo*-C	Me
(10)	131.8 (d), 128.5 (d), 128.0 (d), 126.6 (s)	163.4 (s)	57.7 (t)	159.7 (s)	95.3 (d)	18.1 (q)
(11)	132.1 (d), 128.6 (d), 128.1 (d), 127.5 (s)	163.6 (s)	59.2 (t)	155.6 (s)	81.5 (d)	
(12)	132.0 (d), 128.5 (d), 127.9 (d), 126.5 (s)	163.7 (s)	61.2 (t)	157.9 (s)	47.2 (d)	

the sulphone (15), obtained by oxidation of (10) with trifluoroperacetic acid. Spectroscopic similarities suggest the same *E* stereochemistry for the other methylenedihydro-oxazoles prepared.

The stereochemistry of the vinyl dibromide (*E*)-(16) was ascertained by nuclear Overhauser enhancement (n.O.e.) measurements on the *E*- and *Z*-derivatives which in turn were obtained as the sole products, in a 6 : 4 ratio, when (2) reacted with bromine in carbon tetrachloride at room temperature.

When the methylene signals of (16) were irradiated, the intensity of the signal of the vinylic proton of the *Z*-isomer (*Z*)-(16) showed a 15% increase whereas the intensity of the vinylic proton of the *E*-adduct (*E*)-(16) did not show any enhancement.

It is noteworthy that the reaction of iodine with compound (2) in carbon tetrachloride also gave exclusive addition to the triple bond. However, in this case only one isomer (*E*)-(17) was obtained. The *E* configuration assignment of the derivative (*E*)-(17) is based upon comparison with the chemical shift values of other di-iodoethylenes of the same stereochemistry.[10]

Discussion

The results reported above can be considered in terms of three factors: (i) the effect of the internal and external nucleophiles on the product distribution; (ii) the structure of the intermediate(s) and its relationship with the solvent; and (iii) the exclusive five-membered ring closure to methylenedihydro-oxazoles which is preferred over the possible six-membered ring closure to oxazine derivatives. However these features are often closely related and cannot be discussed separately.

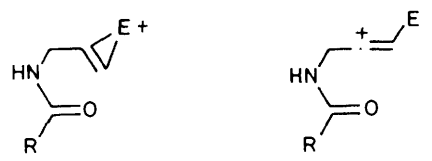
The stereospecificity of the reaction leading to the (*E*)-dihydro-oxazoles (10)—(14) suggests the presence of cyclic thiirenium, iodirenium, and bromirenium ions (27) in the reactions of both (1) and (2) with the sulphonium ion (3), iodine, and bromine respectively; both isomers would have been expected with a vinyl cation intermediate such as (28). Cyclic ions of type (27) have sometimes been suggested for the addition of iodine [11] and bromine to some alkynes; [1,10] moreover thiirenium ions have been detected at low temperature in the addition of sulphenyl chlorides [12] and sulphonium ions (3) to many acetylenic hydrocarbons,[2] and in a few cases have also been isolated at room temperature.[3]

The fact that the dihydro-oxazolium salt (8) was not isolated may be due either to the solubility of (8) or to the electrophilicity of the halogen, which reacts further to give (23). A possible alternative route to (23) from the adducts (16) has been ruled out since, under the same reaction conditions, neither the *E*- nor the *Z*-isomers give any cyclisation products.

The presence of some products from the addition of bromine and iodine to acetamidopropyne (2) which were not found in the corresponding reaction of (1) can be explained by taking into account the relative charge delocalization in the transition states which lead to the cyclic products. It is reasonable that the benzamido group can compete more effectively with the external halide (or perhalide) ions for attack at the vinylic carbon of (27) than the acetamido group.

In the reaction of the alkynes (1) and (2) with methyl(bismethylthio)sulphonium hexachloroantimonate (3), the low nucleophilicity of the anion strongly reduces external attack thus allowing exclusive cyclisation of both amidopropynes (1) and (2).

The absence of the dihydro-oxazole derivatives in the reaction of bromine and iodine with (1) and (2) in carbon tetrachloride may be due to solvation effects on the halide ions as they would certainly be less solvated in this solvent than in chloroform; smaller differences would be expected for sol-



(27) (28)

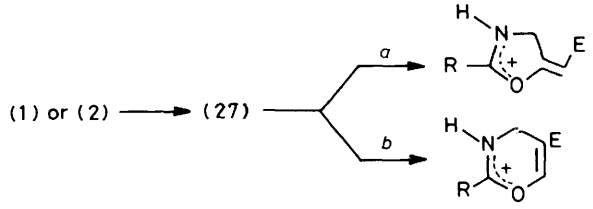
R = Ph or Me; E = SMe, Br, or I

vation of the amido group. Hence the increase in nucleophilicity of the halide ions leads to addition products only.

Although our data are limited we may also briefly discuss the stereochemistry of the addition of bromine and iodine in the two solvents. The formation of the (*E*)-(16) and (*E*)-(17) isomers in chloroform probably arises *via* the involvement of the cyclic intermediates (27). The bridging ability of iodine in similar systems, as judged both from data from the addition of halogens [1,10] to triple bonds and from the solvolysis of β-halogenovinyl sulphonates,[13] seems higher than that of bromine.

The lack of stereospecificity in the formation of the (*E*)-(16) and (*Z*)-(16) isomers in tetrachloromethane may also imply, according to previous findings,[1,14] that different intermediates, or transition states, are involved. In this non-polar solvent it is more probable that the *E*- and *Z*-mixture derives from a tightly bound ion pair which collapses to products before equilibration to solvent-separated ion pairs can take place; in fact the very poor anion solvation makes a fully ionic mechanism unlikely.

Finally, the exclusive five-membered ring closure of (1) and (2) to methylenedihydro-oxazole derivatives (Scheme 4, path *a*) may be due to entropy factors which favour five-membered ring formation over the six-membered ring closure [15] (Scheme 4, path *b*).



Scheme 4.

The formation of the oxazine corresponds to an anti-Markownikov type attack of the internal nucleophile in the three-membered ring intermediates (27), whereas the dihydro-oxazole derivatives are formed by a Markownikov oriented attack. Such an attack is rare in thiirenium ion chemistry where anti-Markownikov ring opening prevails, unless particular structural features or weak nucleophiles are involved; [2,3,16] in the latter case the Markownikov ring-opening of the three-membered ring intermediates (27) may occur with some S_N1 character. Indeed the amido oxygen is a weak nucleophile and oxygen–carbon bond formation may occur only when sufficient positive charge is developed at the ethylenic carbon of (27).

Experimental

M.p.s were determined on a Kofler apparatus and are uncorrected. I.r. spectra were taken on a Perkin-Elmer 225 instrument. ^{1}H N.m.r. spectra were recorded on a Varian EM-360 A spectrometer. ^{13}C N.m.r. spectra were performed on a Varian FT-80 instrument. Samples for n.O.e. measurements were prepared according to suggested procedures.[17] 3-Benzamidopropyne (1),[18] 3-acetamidopropyne (2),[19] methyl(bismethylthio)sulphonium (3) hexachloroantimonate,[20,21] 5-methyl-2-phenyloxazole (18),[22] and 2,5-dimethyloxazole (21),[23] were prepared by literature methods.

Reaction of Alkynes (1) *and* (2) *with Methyl(bismethylthio)-sulphonium* (3) *Hexachloroantimonate.*—Methyl(bismethylthio)sulphonium (3) hexachloroantimonate (3 g, 6.3 mmol) in CH_2Cl_2 (20 ml) was added to a solution of 3-benzamidopropyne (1) (1 g, 6.3 mmol) in CH_2Cl_2 (20 ml) at room temperature with stirring. After 15 min n-pentane (100 ml) was added and the (E)-5-*methylthiomethylene*-2-*phenyl*-4,5-*dihydro-oxazolium hexachloroantimonate* (4) (3.4 g, 91%) was filtered off, m.p. 111—113 °C (decomp.) (Found: C, 23.9; H, 2.4; N, 2.5. $C_{11}H_{12}Cl_6NOSSb$ requires C, 24.4; H, 2.2; N, 2.6%). The salt (4) (1 g) was suspended in CH_2Cl_2 (50 ml) and stirred with aqueous sodium hydrogen carbonate for a few minutes. The organic layer was dried (Na_2SO_4) and evaporated under reduced pressure to give (E)-5-*methylthiomethylene*-2-*phenyl*-4,5-*dihydro-oxazole* (10) (0.36 g, 98%), m.p. 47—49 °C (from light petroleum) (Found: C, 64.0; H, 5.7; N, 6.7. $C_{11}H_{11}NOS$ requires C, 64.4; H, 5.4; N, 6.8%); $\nu_{max.}$ 1 653, 1 325, 1 060, 1 026, 791, and 777 cm^{-1}. Analogously from 3-acetamidopropyne (2) (0.61 g, 6.3 mmol) and sulphonium (3) salt (3 g, 6.3 mmol) the (E)-2-*methyl*-5-*methylthiomethylene*-4,5-*dihydro-oxazolium hexachloroantimonate* (7) (2.84 g 98%) was recovered as a reddish viscous oil (Found: C, 15.2; H, 2.1; N, 2.9. $C_6H_{10}Cl_6NOSSb$ requires C, 15.6; H, 2.2; N, 3.0%). Further alkaline treatment afforded the (E)-2-*methyl*-5-*methylthiomethylene*-4,5-*dihydro-oxazole* (13) (0.85 g, 96%), which was purified by bulb-to-bulb distillation at 3 mmHg, oil-bath at 135—140 °C (Found: C, 50.1; H, 6.2; N, 10.0. C_6H_9NOS requires C, 50.4; H, 6.3; N, 9.8%).

Reaction of Alkyne (1) *with Bromine and Iodine.*—Bromine (2.0 g, 12.6 mmol) in $CHCl_3$ (10 ml) was added to a stirred solution of 3-benzamidopropyne (1) (1 g, 6.3 mmol) in the same solvent (40 ml) at room temperature. A yellow precipitate was readily formed; after 10 min the (E)-5-*bromomethylene*-2-*phenyl*-4,5-*dihydro-oxazolium perbromide* (5) was filtered off (2.9 g, 97%), m.p. 100—103 °C (decomp.) (Found: C, 25.4; H, 2.1; N, 3.0. $C_{10}H_9Br_4NO$ requires C, 25.1; H, 1.9; N, 2.9%). The perbromide (5) (1 g) was reduced by treatment with aqueous Na_2SO_3–$NaHCO_3$–CH_2Cl_2. Evaporation of the dried (Na_2SO_4) organic layer gave the (E)-5-*bromomethylene*-2-*phenyl*-4,5-*dihydro-oxazole* (11) (0.49 g, 97%), m.p. 94—96 °C (from light petroleum) (Found: C, 49.9; H, 3.4; N, 5.7. $C_{10}H_8BrNO$ requires C, 50.1; H, 3.3; N, 5.5%); $\nu_{max.}$ 1 642, 1 321, 1 115, 1 053, 1 021, and 766 cm^{-1}.

Following the same procedure from the alkyne (1) (1 g, 6.3 mmol) and iodine (6.3 g, 12.6 mmol) in $CHCl_3$ (150 ml) gave (E)-5-*iodomethylene*-2-*phenyl*-4,5-*dihydro-oxazolium periodide* (6) (4.0 g, 96%), m.p. 140—143 °C (Found: C, 18.5; H, 1.5; N, 2.1. $C_{10}H_9I_4NO$ requires C, 18.0; H, 1.3; N, 2.1%) and (E)-5-*iodomethylene*-2-*phenyl*-4,5-*dihydro-oxazole* (12) (0.40 g, 95%), m.p. 116 °C (from light petroleum) (Found: C, 42.2; H, 3.1; N, 4.8. $C_{10}H_8INO$ requires C, 42.1; H, 2.8; N, 4.9%).

Reaction of the Alkyne (2) *with Bromine.*—(*a*) *In chloroform.* Bromine (2.0 g, 12.6 mmol) in $CHCl_3$ (10 ml) was added to a stirred $CHCl_3$ (40 ml) solution of 3-acetamidopropyne (2) (0.61 g, 6.3 mmol) at 10 °C. After 20 min, the salt (23) (1 g) precipitated as an unstable yellowish material which was immediately filtered off and treated with aqueous Na_2SO_3–

$NaHCO_3$–CH_2Cl_2; the dried organic layer was evaporated under reduced pressure to give the tribromide (24) (0.40 g) as an oily residue which on standing rearranged to 5-dibromomethyl-2-methyloxazolium bromide (25) (0.40 g, 19%), m.p. 176—178 °C (decomp.). From the bromide (25) after treatment with aqueous $NaHCO_3$–CH_2Cl_2 and usual work-up 5-dibromomethyl-2-methyloxazole (26) was quantitatively recovered. Compounds (25) and (26) were identical with samples prepared by an alternative route (Scheme 2).

The mother-liquors from the filtration of (23) were washed with aqueous Na_2SO_3–$NaHCO_3$, dried and evaporated to give (E)-3-*acetamido*-1,2-*dibromopropene* (16) (0.77 g, 47%), m.p. 80 °C (light petroleum) (Found: C, 23.3; H, 2.9; N, 5.4. $C_5H_7Br_2NO$ requires C, 23.3; H, 2.7; N, 5.4%); $\nu_{max.}$ 3 247, 1 642, 1 562, 1 044, 800, and 709 cm^{-1}.

(*b*) *In carbon tetrachloride.* Bromine (2.0 g, 12.6 mmol) in CCl_4 (10 ml) was added at room temperature to a stirred CCl_4 (100 ml) solution of the alkyne (2) (0.61 g, 6.3 mmol). A yellowish oil (0.6 g) was separated and worked up with aqueous Na_2SO_3–$NaHCO_3$–CH_2Cl_2. Evaporation of CH_2Cl_2 and column chromatography on silica gel (7 : 3 diethyl ether–benzene as eluant) of the oily residue gave the previous (*E*)-(16) (0.26 g, 16%) and (Z)-3-*acetamido*-1,2-*dibromopropene* (*Z*)-(16) (0.18 g, 11%), m.p. 47—49 °C (from light petroleum) (Found: C, 23.7; H, 2.9; N, 5.8. $C_5H_7Br_2NO$ requires C, 23.3; H, 2.7; N, 5.4%); $\nu_{max.}$ 3 247, 1 639, 1 290, 1 212, 1 030, and 746 cm^{-1}. No other identifiable products were present in the carbon tetrachloride.

Reaction of the Alkyne (2) *with Iodine.*—(*a*) *In chloroform.* Iodine (3.2 g, 12.6 mmol) in $CHCl_3$ (150 ml) was added to a solution of the alkyne (2) (0.61 g, 6.3 mmol) in the same solvent (40 ml) at room temperature with stirring. After 1 h a gummy dark material precipitated; it was separated and immediately treated with aqueous Na_2SO_3–$NaHCO_3$–CH_2Cl_2 to give, after evaporation of the dried (Na_2SO_4) CH_2Cl_2, a crude oily mixture which, after column chromatography on silica gel (CH_2Cl_2 as eluant) gave (E)-5-*iodomethylene*-3-*methyl*-4,5-*dihydro-oxazole* (12) (0.42 g, 30%), m.p. 43—44 °C (from light petroleum) (Found: C, 27.2; H, 2.7; N, 6.1. C_5H_5INO requires C, 26.9; H, 2.7; N, 6.3%); $\nu_{max.}$ 1 690, 1 656, 1 192, 1 090, 1 045, 930, and 740 cm^{-1}, and (E)-3-*acetamido*-1,2-*di-iodopropene* (*E*)-(17) (0.23 g) m.p. 121—125 °C (from light petroleum) (Found: C, 17.1; H, 2.2; N, 4.0. $C_5H_7I_2NO$ requires C, 17.1; H, 2.0; N, 4.0%); $\nu_{max.}$ 3 275, 1 633, 1 365, 1 285, 1 027, and 668 cm^{-1}; (*E*)-(17) (0.79 g, 44% overall yield) was also obtained from the chloroform solution after the same work-up.

(*b*) *In carbon tetrachloride.* Iodine (3.2 g, 12.6 mmol) in CCl_4 (200 ml) was added to a stirred CCl_4 (40 ml) solution of the alkyne (2) (0.61 g, 6.3 mmol) at room temperature. A dark oil separated and was collected, dissolved in CH_2Cl_2 and washed with aqueous Na_2SO_3–$NaHCO_3$. From the organic layer, the (*E*)-adduct (17) (0.55 g, 50%) was obtained after the usual work-up. Evaporation of the CCl_4 solution gave only an intractable tar.

5-*Bromomethyl*-2-*phenyloxazole* (19).—5-Methyl-2-phenyloxazole (18) (1 g, 6.3 mmol) was refluxed with *N*-bromosuccinimide (NBS) (1.1 g, 6.3 mmol) in CCl_4 (100 ml) in the presence of a catalytic amount of benzoyl peroxide. After 1 h the cooled reaction mixture was washed with aqueous Na_2SO_3–$NaHCO_3$. The dried solvent was evaporated under reduced pressure to give 5-*bromomethyl*-2-*phenyloxazole* (19) as an oily residue (1.27, 85%) which was recrystallized from light petroleum, m.p. 52—55 °C (Found: C, 50.7; H, 3.3; N, 5.9. $C_{10}H_8BrNO$ requires C, 50.4; H, 3.4; N, 5.9%); $\nu_{max.}$ 1 546, 1 484, 1 449, 1 136, 988, 778, and 712 cm^{-1}.

5-*Methylthio*-2-*phenyloxazole* (20).—5-Bromomethyl-2-phenyloxazole (19) (1.1 g, 4.6 mmol) in anhydrous ethanol (20 ml) was added dropwise to an ethanolic solution (50 ml) of sodium methanethiolate prepared by saturation of ethanolic sodium ethoxide (0.11 g Na, 4.8 mmol) with gaseous methanethiol. The solution was refluxed for 30 min, water (100 ml) was added and the mixture was extracted with $CHCl_3$. Evaporation of $CHCl_3$ gave 5-*methylthio*-2-*phenyloxazole* (20) as a crude oil (0.81 g, 86%) which was purified by distillation (145—150 °C/3 mmHg) (Found: C, 64.6; H, 5.7; N, 6.9. $C_{11}H_{11}NOS$ requires C, 64.4; H, 5.4; N, 6.8%); $\nu_{max.}$ 1 550, 1 486, 1 357, 1 252, 1 188, 988, and 773 cm^{-1}.

5-*Dibromomethyl*-2-*methyloxazole* (26).—3,5-Dimethyloxazole (21) (6.3 mmol) and NBS (6.3 mmol) reacted as described for (19) and gave 5-bromomethyl-2-methyloxazole (22) (90%, n.m.r. based); $\delta(CDCl_3)$ 6.32 (s, CH), 4.38 (s, CH_2), and 2.45 (s, Me). The crude bromomethyl derivative (22) (0.5 g) was then treated with NBS to give a mixture of (22) and 5-*dibromomethyl*-2-*methyloxazole* (26) (1 : 1 ratio, n.m.r. based). The mixture was separated by column chromatography on silica gel (9 : 1 dichloromethane–diethyl ether as eluant) and gave the dibromo-oxazole (26) (0.25 g, 38%) (Found: C, 24.0; H, 2.3; N, 5.3. $C_5H_5Br_2NO$ requires C, 23.5; H, 2.0; N, 5.5%); $\nu_{max.}$ 1 597, 1 567, 1 223, 1 132, and 760 cm^{-1}. Attempts to purify (26) by vacuum distillation gave rise to extensive decomposition. Gaseous HBr was bubbled into a $(CH_3)_2CO$ solution (3 ml) of the dibromide (26) (0.3 g). 5-*Dibromomethyl-oxazolium bromide* (25) quantitatively precipitated and was filtered off, m.p. 176—178 °C (decomp.) (Found: C, 18.3; H, 2.1; N, 4.5. C_5H_6BrNO requires C, 17.9; H, 1.8; N, 4.2%). Compound (25) was insoluble in the most common n.m.r. solvents and hence its n.m.r. spectrum was not taken.

Isomerization of 5-*Methylthiomethylene*-2-*phenyl*-4,5-*dihydro-oxazole* (10) *and of* 5-*Bromomethylene*-2-*phenyl*-4,5-*dihydro-oxazole* (11).—The dihydro-oxazoles (10) (1 g) and (11) (1 g) were heated at 150 °C for 1 h. The resulting oils were purified by vacuum distillation to give 5-methylthio-2-phenyloxazole (20) (0.8 g, 80%) and 5-bromomethyl-2-phenyloxazole (19) (0.9 h, 90%).

Oxidation of (E)-5-*Methylthiomethylene*-2-*phenyl*-3,5-*dihydro-oxazole* (10).—To a solution of the dihydro-oxazole (10) (0.2 g, 0.98 mmol) in CF_3CO_2H (1 ml) at 0 °C, 33% H_2O_2 (2.2 equiv.) was added dropwise. After 15 min the solution was poured in water and extracted with CH_2Cl_2 which was kept neutral ($NaHCO_3$). Evaporation of the CH_2Cl_2 gave (*E*)-5-methylsulphonylmethylene-2-phenyl-4,5-dihydro-oxazole (15) which was extremely unstable and could not be further purified.

Acknowledgements

We acknowledge financial support to G. C. from Progetto Chimica Fine e Secondaria del C.N.R.

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Received 12*th May* 1983; *Paper* 3/755