1,2-Oxazolidines.   Part V.[1]   Spiro and Condensed Biheterocyclic Isomers from Nitrones and 1,3-Oxazolidin-2-ones

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The cycloaddition reaction between nitrones and substituted 1,3-oxazolidin-2-ones yields condensation products and spiro-compounds, each type of product containing a 1,2-oxazolidine nucleus. Their stereochemistry was elucidated by lanthanide shift analysis. The main spectrometric characteristics and the chemical behaviour of these new systems are discussed. Evidence is reported that the formation of the two types of isomeric adduct is controlled by a rearrangement process in competition with the cycloaddition.

THE chemistry and properties of the 1,2-oxazolidine nucleus have not yet been fully investigated.[2] This type of compound may be synthesized by $[_{\pi}4_{s} + _{\pi}2_{s}]$ cycloaddition reactions of nitrones with olefinic double bonds.[3] Previous reports [1,3-6] have dealt with some synthetic and spectrometric aspects of 1,2-oxazolidine chemistry, and in some cases it has been shown that the 1,2-oxazolidine nucleus rearranges to an isomeric heterocyclic system.[7,8] We now report the preparation of some new polynuclear systems containing both a 1,3- and a 1,2-oxazolidine ring.

The reaction of 4-methylene-1,3-oxazolidin-2-ones (I) with various nitrones (III) generates two structural isomers. In a typical example, N-benzylideneaniline N-oxide (IIIa) and 4-methylene-3-phenyl-1,3-oxazolidin-

2-one (Ia) afforded the isomeric products (Va) and (IVa), with the former predominating.

The mass spectrum of the product (IVa) (Scheme 2) shows that the main unimolecular decomposition of the molecular ion (m/e 372) leads to the base peak at m/e 264; this is confirmed by the appearance of an intense metastable peak (89% of the total metastable ion abundance) in the DADI (Direct Analysis of Daughter Ions) spectrum [9] of the ion m/e 372. Minor processes are those defined by the sequences $M^{+\cdot} \longrightarrow 279$ and $M^{+\cdot} \longrightarrow 181$ (5 and 6%, respectively, in metastable transitions). The most important gas-phase fragmentation of the molecular ion produces daughter ions (m/e 264) which undergo competing unimolecular decompositions to ions of m/e 246 (20%), 220 (76%), and 118

[1] Part IV, F. Caruso, G. Cum, and N. Uccella, *Tetrahedron Letters*, 1971, 3711.

[2] See, *e.g.*, R. Huisgen, R. Grashey, and J. Sauer, in ' The Chemistry of Alkenes,' ed. S. Patai, Interscience, New York, 1964, p. 861; N. A. LeBel, *Trans. New York. Acad. Sci.*, 1965, **27**, 858.

[3] N. A. LeBel and J. J. Whang, *J. Amer. Chem. Soc.*, 1959, **81**, 6334; R. Huisgen, R. Grashey, H. Hauck, and H. Seidl, *Chem. Ber.*, 1968, **101**, 2043, 2548, 2559.

[4] G. Cum, M. C. Aversa, and N. Uccella, *Gazzetta*, 1968, **98**, 782.

[5] G. Cum, M. C. Aversa, N. Uccella, and M. Gattuso, *Atti Soc. Peloritana Sci. Fis. Mat. Nat.*, 1968, **14**, 413.

[6] H. Lumbrosos, D. M. Bertin, and G. Cum, *Compt. rend.*, 1969, **269C**, 5.

[7] M. C. Aversa, G. Cum, and N. Uccella, *Chem. Comm.*, 1971, 156.

[8] M. C. Aversa, G. Cum, I. Stagno d'Alcontres, and N. Uccella, *J.C.S. Perkin I*, 1972, 222.

[9] K. H. Maurer, C. Brunnee, G. Kappus, K. Habfast, U. Schröder, and P. Schulze, 19th Annual Conference on Mass Spectrometry, ASTM Committee E-14, Atlanta, Georgia, May 1971; W. J. Richter, J. G. Liehr, and P. Schulze, *Tetrahedron Letters*, 1972, 4503; G. Cum, P. D. Giannetto, and N. Uccella, *J.C.S. Perkin II*, 1973, 2038.

(4%), as derived from the Ion Kinetic Energy (IKE) spectrum [10] of second drift region metastable ions. The predominant fragmentation of species m/e 264 (loss of carbon dioxide) leads to ions of m/e 220 (10% of the base peak). Furthermore, a minor fragment peak, m/e 253, can be assigned to a fast transition with loss of 119 mass units (PhNCO) from the molecular ion.

The loss of 108 mass units from the molecular ion leads to two important structural inferences. First,
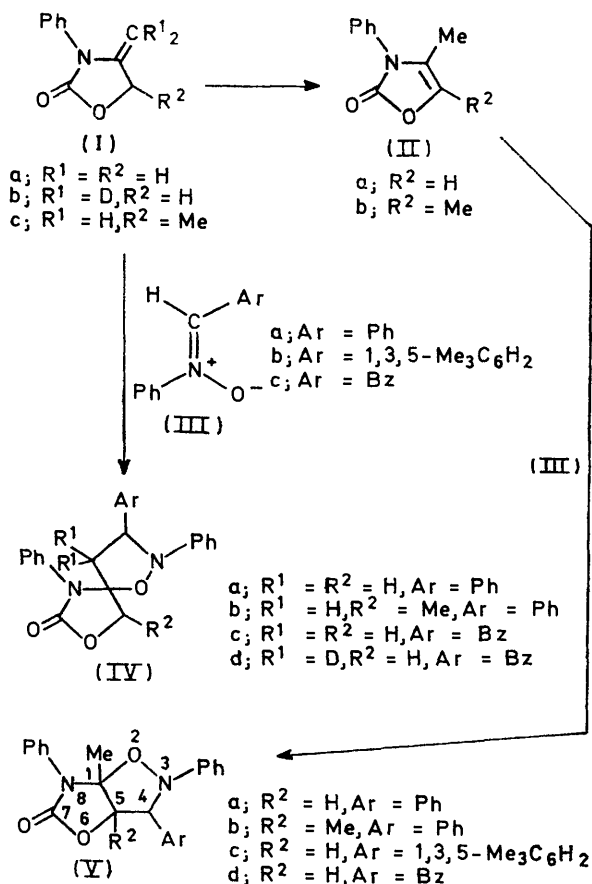
SCHEME 1

the molecular ions show the fragmentation characteristics of a substituted 1,2-oxazolidine; thus cycloaddition has occurred at the exocyclic double bond of compound (Ia). Secondly, as would be expected from the charge distribution on the exocyclic double bond, the reversed mode of cycloaddition leading to a different spiro-1,2-oxazolidine is ruled out. The occurrence of the reaction involving loss of 108 mass units has been previously shown, by isotopic labelling and competing metastable transition studies,[1] to imply the presence of at least one hydrogen atom at position 4; this position is fully substituted in a compound having the reversed spiro-1,2-oxazolidine structure. In addition, the ready

loss of CO_2 from m/e 264 and the loss of PhNCO from the molecular ion are in agreement with the expected decomposition of N-phenyl-1,3-oxazolidin-2-ones.[11] These results firmly support the assignment of structure (IVa).

Structure (IVa) can be independently and unambiguously defined by n.m.r. data. The 60 MHz spectrum shows an ABX system ($>CH\cdot CH_2-$) consisting of a triplet and a multiplet having chemical shifts and coupling constants comparable with those found for substituted 1,2-oxazolidines.[4] These results agree closely with deductions from u.v. and i.r. data.

The mass spectrum of the major product (Va) (52% of the recrystallized crude material) shows the molecular ion (m/e 372) undergoing unimolecular decomposition to ions m/e 264 via a unique metastable process [100% of the total metastable ion abundance (Scheme 3)], which reveals different behaviour from radical ions generated by electron impact on (IVa). The DADI spectrum of the ion m/e 264 shows decomposition in the second drift region via three competing metastable transitions. Two of these are the same, although they occur in different ratios, as the decomposition processes of m/e 264 produced from the molecular ion of (IVa), i.e. loss of CO_2 (68%) and loss of $C_9H_6O_2$ (29%). The other reaction, loss of PhNCO (3%), is not apparent in the metastable spectrum of the ion m/e 264 from (IVa), where loss of 18 mass units occurs in competition with losses of 44 and 146 mass units. This evidence shows that the fragmentations of ions of the same elemental composition, m/e 372 and 264, from compounds (IVa) and (Va) take place from different structures or mixtures of structures, as has been shown for other isomeric organic ions.[12] Furthermore, the major fragmentations of the molecular ion from (Va), i.e. loss of PhNHO from the 1,2-oxazolidine ring [1] and loss of PhNCO, and the decomposition of the ion m/e 264, i.e. by loss of PhNCO and of CO_2,[11] support the conclusions that the cycloadduct (Va) is isomeric with (IVa), and that both contain the same major structural groups.

The evidence drawn from the fragmentation pattern shown in Scheme 3 and from n.m.r. data strongly suggest that (Va) must be a structural, not just a configurational isomer of (IVa). However, the n.m.r. spectrum of (Va) is not consistent, at first sight, with this proposed structure. The spectrum of a solution in $CDCl_3$ is similar to that expected for the adduct formed by cycloaddition in the opposite direction, since the expected AB coupling for the vicinal protons at C-4 and C-5 is not observed. However, since this might have been due to a zero value for $J_{4,5}$, an internal magnetic probe was used to clarify the configuration of compound (Va).

Lanthanide shift reagents have successfully been applied to the study of molecular geometry.[13] Complex-

[10] J. H. Beynon, J. W. Amy, and W. E. Baitinger, Chem. Comm., 1969, 723.

[11] R. A. Auerbach, D. L. von Minden, and C. A. Kingsbury, Org. Mass Spectrometry, 1970, 4, 41; G. Cum, P. D. Giannetto, and N. Uccella, unpublished results.

[12] H. M. Rosenstock, V. H. Dibeler, and F. N. Harlee, J. Chem. Phys., 1964, 40, 591; N. A. Uccella, I. Howe, and D. H. Williams, J. Chem. Soc. (B), 1971, 1933.

[13] B. C. Mayo, Chem. Soc. Rev., 1973, 2, 49.

ing between Eu(fod)$_3$ or Pr(fod)$_3$ (L) and the substrate (S) leads to deshielding or shielding respectively of each proton of the molecule under investigation. Thus a reasonable average geometry for the compound may be deduced, by use of the McConnell–Robertson equation for the pseudocontact interaction.[13] Available data for

induced shift values (Δ) within the limits of experimental error. A plot of log Δ *versus* log R for the various protons of (Va) (see Table), gives a straight line with a slope of −3. This indicates that the contribution of the angular term to the isotropic shift is minor, and that the distance parameter dominates the shift magnitude.[16]
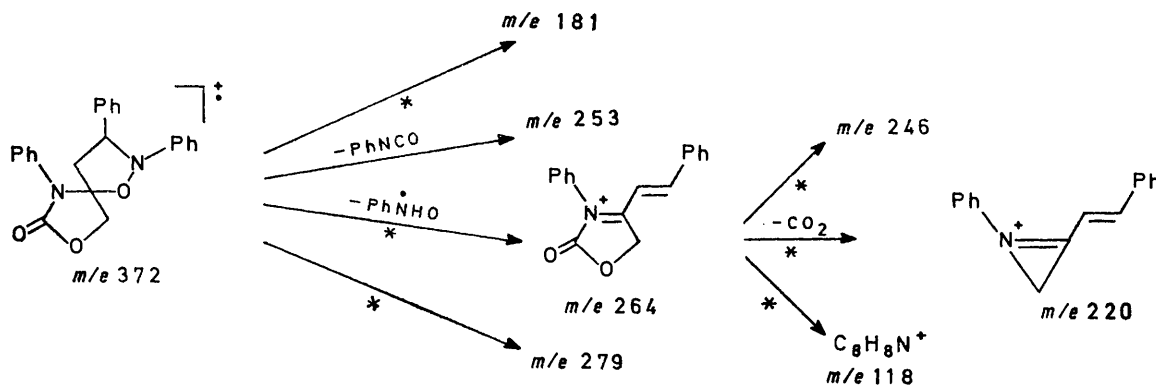
SCHEME 2
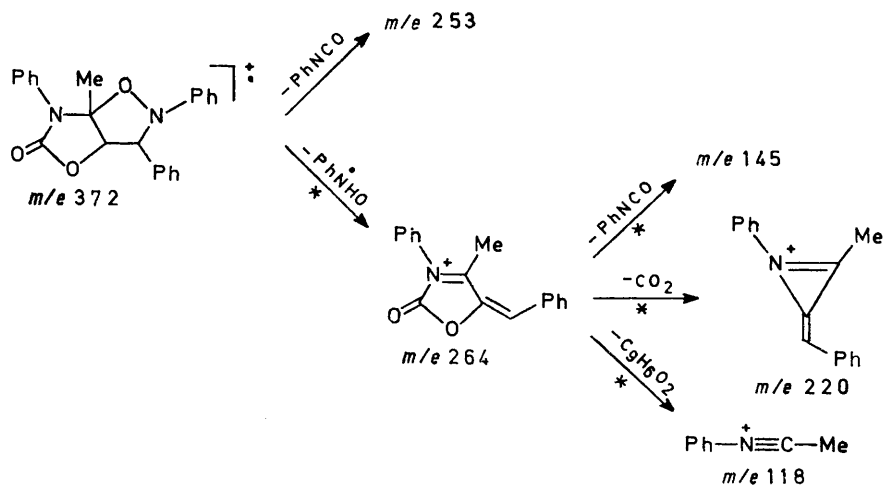
SCHEME 3

a number of oxygenated compounds show that the shifts induced by association of ligand molecules with paramagnetic chelates are entirely due to complexation of the lanthanides to the carbonyl oxygen atoms of ester and amide groupings.[14] The urethane system in the 1,3-oxazolidin-2-one nucleus of the cycloadduct (Va) provides a carbonyl site for association with the lanthanides; co-ordination to the oxygen and nitrogen lone pairs of the 1,2-oxazolidine ring may be ruled out on the basis of experimental evidence.[15] The data reported in the Table show a considerable decrease in the isotropic shifts in the order H-5 > H-4 > 1-Me, indicating an increasing distance of the respective nuclei from the site of bonding between shift reagent and substrate. The distances (R) from the lanthanides to these protons, determined by means of a Dreiding model of compound (Va), are in agreement with the observed

The above arguments reconcile the apparent discrepancies between the n.m.r. results and the other spectrometric and chemical data, confirming the proposed structure (Va).

Induced chemical shift data for the cycloadducts (V) with Pr(fod)$_3$ [a]

Compound		Δ(p.p.m.)	$R/(Å)$	$K_{av}/(mol^{-1})$
(Va)	H-5	7·1	6·7	
	H-4	5·8	7·1	70 ± 3
	1-Me	4·4	8·0	
(Vb)	H-5	6·9	6·7	
	4-Me	5·9	7·3	74 ± 5
	1-Me	4·5	8·0	
(Vd)	H-5	17·1	5·5	
	H-4	12·5	6·0	130 ± 5
	1-Me	4·8	8·2	

[a] Values for Δ and K were obtained from plots of [S] *vs.* $(1/Δδ)$, as described in ref. 16; R is the distance of a proton from the lanthanide.

[14] J. K. M. Sanders and D. H. Williams, *J. Amer. Chem. Soc.*, 1971, **93**, 641; G. Montaudo and P. Finocchiaro, *J. Org. Chem.*, 1972, **37**, 3434.

[15] G. Cum, G. Romeo, and N. Uccella, unpublished results.

[16] P. V. Demarco, T. K. Elzey, R. B. Lems, and E. Wenkert, *J. Amer. Chem. Soc.*, 1970, **92**, 5735.

The isolation of compounds (IVa) and (Vb) from the crude products of the reaction between (IIIa) and (Ic) demonstrates the general validity of this cycloaddition pathway. However, the reaction of (IIIb) with (Ia) gave only the adduct (Vc), owing to the low rate of cycloaddition of the nitrone (IIIb).

Further evidence of the vicinal relationship between the two protons in the 1,2-oxazolidine ring of (V) is provided by the n.m.r. spectrum of compound (Vc). The presence of a bulky mesityl group at C-3 induces a change in the stereochemical relationship of the bonds at C-3 and C-4, altering the angular and electronic environments and resulting in a value for $J_{4.5}$ of 6·0 Hz. The molecular ions of compound (Vb) undergo unimolecular decomposition with loss of PhṄHO, as would be predicted.

The molecular geometry of the cycloadduct (Vb) has been clarified by lanthanide shift analysis. As shown in the Table, the derived distances for the various protons allow the assignment of the general structure (V) to the product (Vb). For this compound we would not anticipate the loss of 108 mass units from the molecular ion, as has been experimentally confirmed. Since the alternative structural isomer of (V) has been shown not to be produced, the product must be one of two epimers, on the basis of the known regiospecificity of the $[_{\pi}4_s + _{\pi}2_s]$ cycloaddition reaction.

The stereochemistry of the cycloadducts can be inferred from the lanthanide-induced shift parameters. The isotropic shift produced by adding Pr(fod)$_3$ to the substrates is of particular interest. Shift values are three times greater than those for Eu(fod)$_3$,[13] and the shielding effect results in better resolution of the signals. By following the literature method [17] a linear relationship has been found between $1/\Delta\delta$ and [S], with [L] constant. Since the effect of shift reagents is mainly due to a through-space dipolar interaction, isotropic shifts are proportional to the geometric factor of the pseudo-contact equation. Thus the variation in isotropic shift may be correlated with the distance of the ligand site from the protons of interest. We can neglect any angular dependence since the bonding site is sufficiently distant from the protons under investigation; the use of the 'only distance criterion' [16] is justified by the slope of the straight lines obtained when log Δ is plotted against log R (see Table).

The experimental results allow the assignment of stereochemistry to the adducts (Va and b), with regard to the possible epimeric configuration at C-3. The


(Va,b,d)
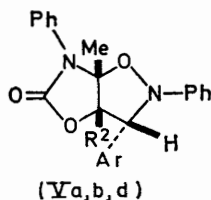
same stereochemistry is produced even when a different dipole, (IIIc), reacts with (IIa). The product (Vd) of

this reaction (see later), again has an n.m.r. spectrum showing no coupling between H-4 and H-5.

In the case of the adduct (Vd), the expected competition between the two carbonyl oxygen atoms as co-ordination sites is observed, and the two contributions to the total isotropic shift have been separated by Hinckley's method.[18] Relative association constants (K) show that the lone pair of the benzoyl group is linked rather than that of the urethane oxygen atoms (Table).

Chemical degradation studies, as well as confirming the structural assignments, have shown some of the chemical properties of the cycloadducts (Scheme 4).
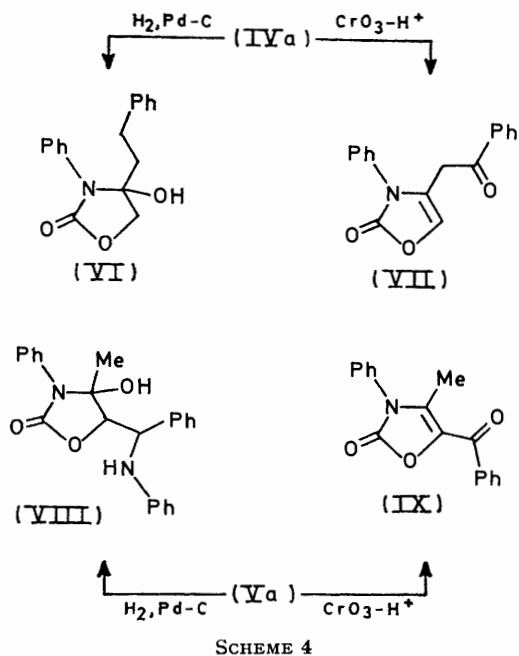
SCHEME 4

Hydrogenolysis of (IVa) gave a product (VI) formed by nitrogen–oxygen bond rupture, followed by carbon–nitrogen cleavage. Oxidation of (IVa) yielded compound (VII). In each case the structure was assigned on the basis of analytical and spectrometric data. Catalytic hydrogenation of (Va) followed a similar path to the reaction of (IVa), yielding the expected amino-alcohol (VIII). Oxidation of (Va) afforded 5-benzoyl-4-methyl-3-phenyl-Δ^4-1,3-oxazolin-2-one (IX). The presence of the benzoyl group at C-5 may be explained only if compound (Va) contains the 1,2-oxazolidine system as already assigned. These studies establish that the 1,3-oxazolidin-2-one systems are always more stable (and therefore less reactive) than the corresponding heterocyclic nuclei linked to them in structures (IV) and (V). The most labile bond in this type of molecule has again been shown to be the oxygen–nitrogen linkage in 1,2-oxazolidine.

Discussion.—With respect to the mechanism of the

[17] D. R. Kelsey, *J. Amer. Chem. Soc.*, 1972, **94**, 1764.
[18] C. C. Hinkley, M. R. Klotz, and F. Patil, *J. Amer. Chem. Soc.*, 1971, **93**, 2417.

reaction under study, we suggest that 4-methylene-1,3-oxazolidin-2-ones (I), which undergo the cycloaddition reaction with the nitrones (IIIa and b) at a temperature slightly above the m.p. of the reaction mixture * (*i.e* 80 °C) rearrange by a thermal 1,3-prototropic shift to 4-methyl-3-phenyl-Δ^4-1,3-oxazolin-2-ones (II) [5] (Scheme 1). This rearrangement should therefore be in competition with the formation of the adduct (IV). Reaction of (IIIa and b) with (II) then yields compound (V).

Evidence of a competitive temperature-dependent process [for the reaction of (IIa) with (IIIa)] involving proton transfer from (I) to (II) is shown in the Figure.

treated at room temperature with the nitrone (IIIc), which has a higher cycloaddition reactivity than (IIIa). The only product isolated was (IVc), as would be predicted for a fast-reacting dipole. The structure (IVc) was assigned by analogy and its sole formation is attributed to the absence of the rearrangement (I) ——> (II) under the reaction conditions. Furthermore, we have obtained by this method the dideuterio-adduct (IVd), whose mass spectrum confirmed the specificity of the rearrangement process occurring in the molecular ions of this type of heterocyclic compound.[1] By analogy with the previous reaction, (IIa) and (IIIc) gave only a product of condensed structure (Vd). When the
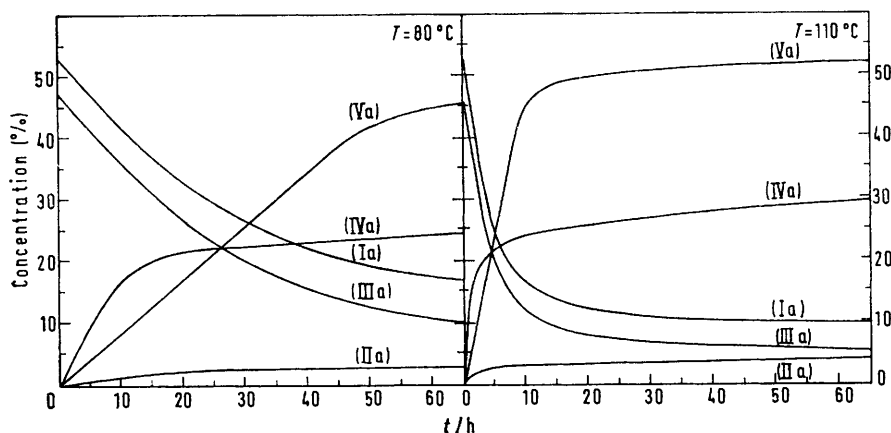

FIGURE Relative rates of formation of compounds (IIa), (IVa), and (Va) in the reaction between 4-methylene-3-phenyl-1,3-oxazolidin-2-one (Ia) and the nitrone (IIIa), at 80 and 110 °C

The data were obtained by n.m.r. analysis of the appropriate signals for each component of the reaction mixture at various times and temperatures. The Figure illustrates that (*a*) (IIa) is formed and maintained in the reaction medium at a low concentration; (*b*) the thermal isomerization reaction is in competition with cycloaddition of (IIIa) to (Ia) and controls the formation of (Va); and (*c*) the condensed adduct (Va) is formed preferentially with respect to the spiro-compound (IVa).

The results obtained when the dipole (IIIa) is used suggest that, at any temperature, the rearrangement reaction is favoured; a considerably greater rate is observed for this relative to the cycloaddition sequence (I) ——> (IV). The rates of the two reactions are in any case of comparable magnitude, since both adducts, (IV) and (V), are always isolated.

In further support of the suggested pathway, compound (Va) was synthesized from (IIIa) and (IIa), the latter being independently obtained from (Ia).

The question then arose as to whether the reactivity of the nitrone used influences the product ratios of the process under investigation. To test this, (Ia) was

dipole (IIIb), of lower reactivity than (IIIa), is used, the isomerization process (I) ——> (II) competes more effectively with spiro-adduct formation, and the only product isolated is (Vc).

EXPERIMENTAL

M.p.s were determined on a Kofler hot-stage apparatus. Analyses were performed on a Perkin-Elmer 240 Elemental Analyser. U.v. spectra were determined for solutions in 95% ethanol with a Zeiss RPQ 20 A spectrometer. I.r. spectra were recorded for Nujol mulls with a Perkin-Elmer 225 instrument. N.m.r. spectra were obtained with a Varian A60 spectrometer, for 10% solutions in [²H]chloroform, [²H₆]acetone, or [²H₆]dimethyl sulphoxide, with tetramethylsilane as internal standard. Experimental paramagnetic shifts were obtained at a probe temperature of 38 °C; 0·8—1·2 × 10⁻³M-solutions of Pr(fod)₃ in dried [²H]chloroform were used, to which the organic material was added to obtain a concentration range of 5—23 × 10⁻³M. Mass spectra were determined on a Varian MAT CH-5 DF double-focusing spectrometer of 'reverse' Nier–Johnson geometry, operating at 70 eV and 3 kV accelerating voltage. Metastable transitions in the second drift region were observed at a nominal 3 kV; the electrostatic analyser voltage was varied according to the DADI technique.[9] Samples were introduced *via* the direct inlet system, the sample probe temperature being in the region of the m.p.s of the products. All samples were purified by t.l.c.

Compound (Ia) was prepared as described previously.[5,19] 4-[²H₂]*Methylene-3-phenyl*-1,3-oxazolidin-2-one (Ib).—

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* These reaction conditions are used because of the low rate of cycloaddition of (IIIa and b); comparison of rates and by-product formation in solvents[4] with those in neat systems shows that there is no improvement when a dilute phase for the reaction is used.

19 P. J. Stoffel and W. D. Dixon, *J. Org. Chem.*, 1964, **22**, 978.

Prop-2-yn-1-ol (0·7 g, 12·5 mmol) was added with stirring to a slurry of sodium hydride (0·93 g; from 80% oil suspension washed with dry petroleum) in dry ether (10 ml). The mixture was heated under reflux for 18 h, then cooled, and [^{2}H$_2$]sulphuric acid (2·8 ml; 30% in D$_2$O) was added with stirring. The ethereal solution was separated, dried (Na$_2$SO$_4$), and evaporated to yield [O-^{2}H$_1$,3-^{2}H$_1$]prop-2-yn-1-ol (0·6 g, 88%; [^{2}H$_2$] >97%). Compound (Ib) was then synthesized according to the method described previously [5] from [O-^{2}H$_1$,3-^{2}H$_1$]prop-2-yn-1-ol (0·40 g) and phenyl isocyanate (0·82 g). The product (0·60 g, 50%; [^{2}H$_2$] >70%) had m.p. 95—97°.

5-*Methyl*-4-*methylene*-3-*phenyl*-1,3-*oxazolidin*-2-*one* (1c).— The procedure used for (Ia) was followed to yield compound (Ic), m.p. 89·5—90·5° (70%) (Found: C, 70·0; H, 5·95; N, 7·2. C$_{11}$H$_{11}$NO$_2$ requires C, 69·85; H, 5·85; N, 7·4%), $\nu_{max.}$ 1770 (CO), 1658, 1414, 1333, 1214, 1099, 1078, 765, and 703 cm^{-1}, δ (CDCl$_3$) 7·6—7·1 (5H, m, ArH), 5·22 (1H, twelve lines, J_{vic} 6·0, $J_{long-range}$ 2·0 Hz, H-5), 4·17 and 4·06 (2H, ddd, J_{gem} 3·0, $J_{l.r.}$ 2·0 Hz, =CH$_2$). and 1·57 (3H, d, J_{vic} 6·0 Hz, 5-Me) (ddd constitutes an AB system which is further split by long-range couplings), m/e 189 ($M^{+\cdot}$, 47%), 145 (18), 144 (31), 130 (100), 119 (5), 118 (8), 117 (6), 104 (21), 103 (30), 91 (8), 89 (3), and 77 (92).

4-*Methyl*-3-*phenyl*-Δ^4-1,3-*oxazolin*-2-*one* (IIa).—This was obtained by isomerization of (Ia) (16 mmol) in dry ether (150 ml) with a catalytic amount of concentrated sulphuric acid (0·5 ml) for 15 h. The solution was washed until neutral, dried (Na$_2$SO$_4$), and evaporated. The product crystallized from methanol to yield compound (IIa),[5] m.p. 57—58° (90%).

4,5-*Dimethyl*-3-*phenyl*-Δ^4-1,3-*oxazolin*-2-*one* (IIb), prepared similarly (90%), had m.p. 79·5—80° (Found: C, 69·8; H, 6·15; N, 7·15. C$_{11}$H$_{11}$NO$_2$ requires C, 69·85, H, 5·85; N, 7·4%), $\nu_{max.}$ 1761 (CO), 1712, 1508, 1188, and 982 cm^{-1}, δ (CDCl$_3$) 7·7—7·2 (5H, m, ArH), 2·08 (3H, dd, J 1·0 Hz, 5-Me), and 1·82 (3H, dd, J 1·0 Hz, 4-Me), m/e 189 ($M^{+\cdot}$, 80%), 118 (100), 104 (5), 103 (9), and 77 (68).

Reactions of the Nitrones (IIIa *and* b) *with Substituted* 4-*Methylene*-3-*phenyl*-1,3-*oxazolidin*-2-*ones* (Ia *and* c).— A mixture of (IIIa or b) (20 mmol) with (Ia or c) (20 mmol) was heated, in a neutral glass tube sealed under nitrogen, at 90—110 °C for several hours. After cooling, a little methanol was added and the precipitate was collected and recrystallized from methanol to give the product (IVa or b); compound (Va, b, or c) was recovered from the mother liquors and recrystallized from acetone–petroleum.

To obtain the data given in the Figure batches of (IIIa) and (Ia) were heated at various temperatures in small sealed tubes and the n.m.r. spectrum of each mixture was determined at various times.

2,3,6-*Triphenyl*-1,8-*dioxa*-2,6-*diazaspiro*[4.4]*nonan*-7-*one* (IVa) (reaction at 100 °C for 48 h; 22% yield) had m.p. 185—185·5° (Found: C, 74·25; H, 5·2; N, 7·65. C$_{23}$H$_{20}$N$_2$O$_3$ requires C, 74·2; H, 5·4; N, 7·5%), $\lambda_{max.}$ 278 (log ε 3·21) and 245 nm (3·86), $\nu_{max.}$ 1764 (CO), 1490, 1395, and 768 cm^{-1}, δ (CDCl$_3$) 7·5—6·7 (15H, m, ArH), 4·93 and 4·38 (2H, dd, gem-AB, $J_{9.9'}$ 9·5 Hz, 9-H$_2$), 4·05 (1H, t, $J_{3.4} = J_{3.4'} = 8·4$ Hz, H-3), and 2·97 and 2·40 (2H, ddd, $J_{4.4'}$ 13·5, $J_{3.4} = J_{3.4'} = 8·4$ Hz, 4-H$_2$) (t and ddd constitute an ABX system), m/e 372 ($M^{+\cdot}$, 2%), 264 (100), 253 (3), 220 (10), 198 (6), 194 (6), 183 (6), 182 (12), 180 (15), 119 (20), 117 (16), 105 (13), 104 (29), 103 (10), 93 (12), 91 (35), and 77 (46).

9-*Methyl*-2,3,6-*triphenyl*-1,8-*dioxa*-2,6-*diazaspiro*[4.4]-

nonan-7-*one* (IVb) (reaction at 85—90 °C for 120 h; 37% yield) had m.p. 160—162° (Found: C, 74·6; H, 5·75; N, 7·3. C$_{24}$H$_{22}$N$_2$O$_3$ requires C, 74·6; H, 5·75; N, 7·25%), $\nu_{max.}$ 1772 (cyclic CO), 1493, 1393, 770, and 701 cm^{-1}, δ (CDCl$_3$) 7·4—6·7 (15H, m, ArH), 5·10 (1H, dd, J_{vic} 6·2 Hz, H-9), 4·07 (1H, t, $J_{3.4} = J_{3.4'} = 8·2$ Hz, H-3), 2·78 and 2·51 (2H, ddd, $J_{4.4'}$ 13·5, $J_{3.4} = J_{3.4'} = 8·2$ Hz, 4-H$_2$), and 1·47 (3H, d, J_{vic} 6·2 Hz, Me) (t and ddd constitute an ABX system), m/e 386 ($M^{+\cdot}$, 7%), 279 (20), 278 (80), 234 (23), 181 (22), 180 (39), 131 (24), 120 (20), 119 (35), 105 (29), 93 (38), 91 (29), 78 (25), and 77 (100).

1-*Methyl*-3,4,8-*triphenyl*-2,6-*dioxa*-3,8-*diazabicyclo*[3.3.0]-*octan*-7-*one* (Va) (reaction at 100° for 48 h; 52% yield) had m.p. 154—155° (Found: C, 73·85; H, 5·45; N, 7·3%), $\lambda_{max.}$ 282 (log ε 2·98) and 237 nm (4·09); $\lambda_{min.}$ 223 nm (4·01), $\nu_{max.}$ 1770 (CO), 1495, 1391, 762, and 701 cm^{-1}, δ (CDCl$_3$) 7·8—6·8 (15H, m, ArH), 5·33 (1H, s, $J_{4.5}$ 0 Hz, H-4), 5·01 (1H, s, $J_{4.5}$ 0 Hz, H-5), and 1·53 (3H, s, Me), m/e 372 ($M^{+\cdot}$, 7%), 263 (100), 253 (3), 220 (6), 198 (5), 197 (4), 196 (5), 182 (14), 181 (10), 180 (18), 174 (4), 119 (17), 118 (17), 105 (11), 104 (12), 103 (4), 93 (19), 91 (61), and 77 (70). Compound (Va) was also prepared similarly from the reaction of (IIIa) with (IIa).

1,5-*Dimethyl*-3,4,8-*triphenyl*-2,6-*dioxa*-3,8-*diazabicyclo*-[3.3.0]*octan*-7-*one* (Vb) (reaction at 90 °C for 135 h; 30% yield) had m.p. 169—171° (Found: C, 74·4; H, 5·7; N, 7·15%), $\nu_{max.}$ 1760 (CO), 1386, 1375, and 756 cm^{-1}, δ (CDCl$_3$) 7·6—6·7 (15H, m, ArH), 5·20 (1H, s, H-4), 1·48 (3H, s, 1-Me), and 1·25 (3H, s, 5-Me), m/e 386 ($M^{+\cdot}$, 8%), 234 (3), 198 (100), 196 (6), 189 (49), 182 (8), 181 (19), 180 (21), 119 (7), 118 (32), 105 (7), 104 (8), 93 (6), 91 (29), and 77 (34). Product (Vb) was similarly synthesized independently from (IIIa) and (IIb).

4-*Mesityl*-1-*methyl*-3,8-*diphenyl*-2,6-*dioxa*-3,8-*diazabicyclo*-[3.3.0]*octan*-7-*one* (Vc) (reaction at 100 °C for 100 h; 20% yield) had m.p. 197—199° (Found: C, 75·5; H, 6·35; N, 6·75. C$_{26}$H$_{26}$N$_2$O$_3$ requires C, 75·35; H, 6·3; N, 6·75%), $\nu_{max.}$ 1767 (CO), 1381, 1368, 1092, 764, and 701 cm^{-1}, δ (CDCl$_3$) 7·7—6·8 (12H, m, ArH), 5·12 (1H, d, $J_{4.5}$ 6·0 Hz, H-4), 4·93 (1H, d, $J_{4.5}$ 6·0 Hz, H-5), 2·38 (6H, s, 2- and 6-mesityl CH$_3$), 2·27 (3H, s, 4-mesityl CH$_3$), and 1·80 (3H, s, Me), m/e 414 ($M^{+\cdot}$, 4%), 307 (24), 306 (100), 295 (5), 224 (17), 223 (5), 222 (13), 208 (3), 207 (6), 206 (5), 146 (3), 144 (3), 119 (7), 118 (19), 105 (5), 104 (6), 93 (7), 91 (7), and 77 (15). Compound (Vc) was also obtained similarly from the reaction of (IIIb) with (IIa).

Reaction Between N-*Phenacylideneaniline* N-*Oxide* (IIIc) *and* 4-*Methylene*-3-*phenyl*-1,3-*oxazolidin*-2-*one* (Ia).—To a solution of (Ia) (1·0 g, 5·7 mmol) in dry benzene (60 ml) was slowly added, with stirring and at 60 °C, the nitrone (IIIc) (1·3 g, 5·8 mmol).[8] The mixture was stirred at the same temperature for 4 h and then left for 18 h at room temperature. The solvent was removed under vacuum and the product recrystallized from acetone–petroleum to give 3-*benzoyl*-2,6-*diphenyl*-1,8-*dioxa*-2,6-*diazaspiro*[4.4]*nonan*-7-*one* (IVc), m.p. 184—186° (80%) (Found: C, 72·15; H, 5·1; N, 6·95. C$_{24}$H$_{20}$N$_2$O$_4$ requires C, 72·0; H, 5·05; N, 7·0%), $\nu_{max.}$ 1754 (cyclic CO), 1681 (benzoyl), 1595, 1488, 1389, 1227, 1208, 950, 755, and 696 cm^{-1}, δ (CDCl$_3$) 7·9—6·7 (15H, m, ArH), 4·92 and 4·50 (2H, dd, gem-AB, $J_{9.9'}$ 10·3 Hz, 9-H$_2$), 4·80 (1H, dd, $J_{3.4}$ 8·6, $J_{3.4'}$ 6·1 Hz, H-3), and 2·93 and 2·62 (2H, ddd, $J_{4.4'}$ 13·3, $J_{3.4}$ 8·6, $J_{3.4'}$ 6·1 Hz, 4-H$_2$) (dd and ddd constitute an ABX system), m/e 400 ($M^{+\cdot}$, 5%), 295 (26), 292 (14), 281 (3), 278 (5), 250 (6), 234 (14), 224 (5), 223 (3), 222 (5), 202 (3), 177 (9), 176 (30), 144 (12), 130 (17),

122 (13), 120 (9), 119 (33), 118 (29), 117 (10), 106 (8), 105 (65), 104 (20), 103 (6), 92 (21), 92 (7), 91 (24), and 77 (100).

3-Benzoyl-2,6-diphenyl[4,4-²H₂]-*1,8-dioxa-2,6-diazaspiro-*[4.4]*nonan-7-one* (IVd) was obtained similarly from (Ib) (0·53 g) and (IIIc) (0·7 g). The product was crystallized from acetone–petroleum; m.p. 184—186° (80%; [²H₂] >97%).

4-Benzoyl-1-methyl-3,8-diphenyl-2,6-dioxa-3,8-diazabicyclo-[3.3.0]*octan-7-one* (Vd).—The procedure described for compound (IVc) was followed, with (IIIb) (1·3 g) and (IIa) (1·0 g) in dry benzene (100 ml). After 24 h the solvent was distilled off under vacuum and the product crystallized from acetone–petroleum to yield compound (Vd), m.p. 137—139° (80%) (Found: C, 71·9; H, 5·05; N, 7·0. C₂₄H₂₀N₂O₄ requires C, 72·0; H, 5·05; N, 7·0%), $\nu_{max.}$ 1761 (cyclic CO), 1689 (benzoyl), 1497, 1377, 1357, 774, 757, 697, and 693 cm⁻¹, δ (CDCl₃) 8·1—6·8 (15H, m, ArH), 5·87 (1H, s, $J_{4.5}$ 0 Hz, H-4), 5·61 (1H, s, $J_{4.5}$ 0 Hz, H-5), and 1·69 (3H, s, Me), *m/e* 400 (*M*⁺·, 5%), 285 (26), 282 (15), 271 (3), 268 (5), 250 (6), 234 (14), 224 (5), 223 (3), 222 (5), 176 (30), 144 (12), 130 (17), 122 (12), 120 (8), 119 (33), 118 (29), 117 (10), 106 (8), 105 (65), 104 (20), 103 (6), 93 (21), 91 (24), and 77 (100).

Hydrogenolysis of the Adducts (IVa) *and* (Va).—A solution of the adduct (1·1 mmol) in ethanol was hydrogenated over 10% palladium–charcoal (0·5 g), at room temperature. Evaporation of the combined filtrate and chloroform washing from the catalyst gave a product which was crystallized from acetone–petroleum.

The cycloadduct (IVa) yielded *4-hydroxy-3-phenyl-4-phenethyl-1,3-oxazolidin-2-one* (VI), m.p. 135—137° (67%) (Found: C, 72·65; H, 6·25; N, 4·8. C₁₇H₁₇NO₃ requires C, 72·05; H, 6·05; N, 4·95%), $\nu_{max.}$ 3300 (OH), 1752 (CO), 1701, 1422, 756, and 695 cm⁻¹, δ ([²H₆]acetone) 7·6—6·7 (10H, m, ArH), 4·53 and 4·29 (2H, dd, $J_{5.5}$, 9·5 Hz, 5-H₂), 3·0 (1H, s, OH), and 2·9—1·9 (4H, m, CH₂·CH₂), *m/e* 283 (*M*⁺·, 21%), 164 (9), 151 (4), 146 (34), 137 (8), 133 (44), 120 (23), 119 (29), 117 (6), 106 (11), 105 (80), 104 (21), 103 (8), 93 (20), 92 (31), 91 (100), 79 (12), 78 (9), and 77 (40).

Compound (Va) gave *5-α-anilinobenzyl-4-hydroxy-4-methyl-3-phenyl-1,3-oxazolidin-2-one* (VIII), m.p. 177—179°

(63%) (Found: C, 74·05; H, 6·05; N, 7·35. C₂₃H₂₂N₂O₃ requires C, 73·8; H, 5·9; N, 7·5%), $\nu_{max.}$ 3423 (NH), 3279 (OH), 1758 (CO), 1412, and 698 cm⁻¹, δ ([²H₆]acetone) 7·7—6·4 (15H, m, ArH), 5·82 and 5·62 (1H + 1H, s + s, NH and OH), 5·26 (1H, d, J_{vic} 9·0 Hz, >CH·NH–), 4·68 (1H, d, J_{vic} 9·0 Hz, H-5), and 1·63 (3H, s, 4-Me) (the two doublets constitute an AB system), *m/e* 374 (*M*⁺·, 2%), 183 (17), 182 (100), 181 (6), 180 (7), 119 (9), 104 (11), 93 (6), 91 (6), and 77 (14).

Oxidative Cleavage of the Adducts (IVa) *and* (Va).—A solution of the adduct (1·34 mmol) in acetone (15 ml) was added with cooling to chromic oxide (0·7 g, 7 mmol) in water (2 ml), followed by sulphuric acid (1 ml; 50%) (slow addition at 5 °C). After 5 h stirring at room temperature the mixture was diluted with water and extracted with portions of ether. The combined extracts were washed until neutral, dried (Na₂SO₄), and evaporated. The product was crystallized from methanol to yield compounds (VII) and (IX) [from (IVa) and (Va), respectively].

4-Phenacyl-3-phenyl-Δ⁴-1,3-oxazolin-2-one (VII) had m.p. 146—148° (decomp.) (53%) (Found: C, 73·3; H, 4·55; N, 5·2. C₁₇H₁₃NO₃ requires C, 73·1; H, 4·7; N, 5·0%), $\nu_{max.}$ 1786 (cyclic CO), 1672 (benzoyl), 1587, 1570, 1208, 1044, 700, and 695 cm⁻¹, δ (CDCl₃) 7·80—7·20 (10H, m, ArH), 6·25 (1H, t, $J_{l.r.}$ 2·1 Hz, H-4), and 5·68 (2H, d, $J_{l.r.}$ 2·1 Hz, CH₂), *m/e* 279 (*M*⁺·, 7%), 236 (18), 235 (100), 234 (71), 206 (26), 204 (18), 118 (11), 115 (16), 93 (26), and 77 (32).

5-Benzoyl-4-methyl-3-phenyl-Δ⁴-1,3-oxazolin-2-one (IX) had m.p. 129—131° (decomp.) (40%) (Found: C, 73·55; H, 4·8; N, 4·9. C₁₇H₁₃NO₃ requires C, 73·1; H, 4·7; N, 5·0%), $\lambda_{max.}$ 312 (log ε 4·22) and 257 nm (3·89), $\lambda_{min.}$ 274 (3·75) and 233 nm (3·66), $\nu_{max.}$ 1770 (cyclic CO), 1648 (conj. benzoyl), 1631, 1370, and 708 cm⁻¹, δ (CDCl₃) 8·3—7·3 (10H, m, ArH) and 2·40 (3H, s, 4-Me), *m/e* 279 (*M*⁺·, 60%), 278 (58), 262 (5), 119 (10), 118 (70), 105 (26), 104 (6), 103 (3), 91 (3), and 77 (100).