Intramolecular Reactions of *N*-Nitrenes with Alkenes

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Oxidation of 2-but-1-enyl- and 2-(1-phenylbut-1-enyl)-3-aminoquinazolin-4(3*H*)-ones (**8**) and (**10**), respectively, generates the corresponding *N*-nitrenes which are trapped intramolecularly by the double bonds. The results from competitive intramolecular trapping of the *N*-nitrene by different double bonds in 3-aminoquinazolones bearing bifurcated chains in position 2 [*e.g.* (**25**), (**26**), (**27**), and (**28**)] indicate that these intramolecular nitrene additions are non-concerted and, as in the corresponding intramolecular addition to aromatic rings, proceed *via* 7-membered transition states with the nitrene functioning as an electrophile.

Singlet carbenes react with alkenes to give cyclopropanes and for concerted reaction, the carbene is required, it is thought, to function as the antarafacial component in a $\pi_{2s} + \omega_{2a}$ addition.[1] Experimental evidence for this 'unnatural' approach of the carbene (Figure 1), where the geometry of the predicted transition state differs substantially from that of the product, is not easily obtained and since the early work of Skell and Doering and their co-workers[2] essentially the problem has been surrendered to the theoretical chemists.[3]†

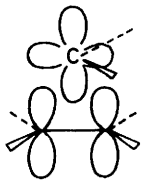


Figure 1.

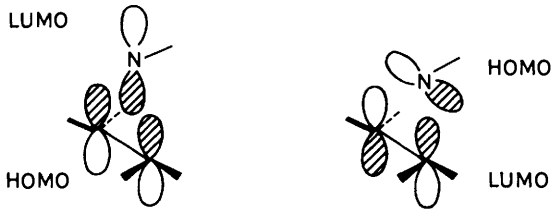
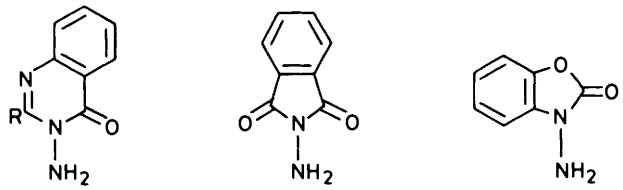


Figure 2.

For the analogous addition of singlet nitrenes to alkenes to give aziridines, a simple application of frontier molecular orbital theory suggests that the transition state shown in Figure 2 may obtain, when the HOMO of the sp-hybridised nitrene is considered to be the filled p-orbital and the LUMO the empty p-orbital.

One possible means by which descriptions of either of the preferred transition state geometries above might be obtained experimentally would be from a study of intramolecular reactions of carbenes or nitrenes with double bonds. Thus, using the intramolecularity of the addition, some control over the approach geometry of the interacting components could be exercised by design of the molecular framework. From the effect of changes in this framework upon the characteristics of the cycloaddition, and in particular upon its *concertedness*, an ideal configuration for the atoms participating in the reaction could be deduced. This strategy is a variation on that used in other concerted cycloadditions in recent years where invariably the preferred transition state geometry is known and intramolecularity is used to control the regioselectivity and/or accelerate the rate of reaction.

As a preliminary to a solution of this problem for the particular case of nitrenes, we have studied the intramolecular trapping of *N*-nitrenes, generated by oxidation of *N*-aminoquinazolones (**1**).[5]



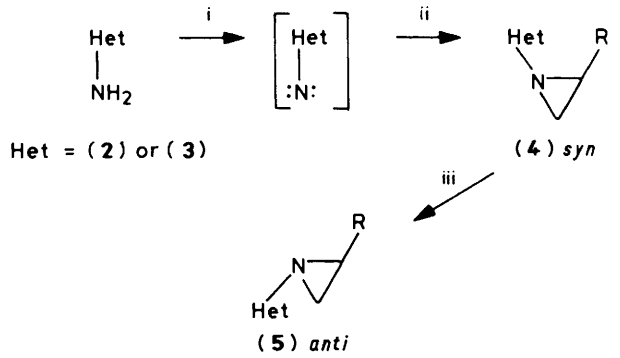
(**1**) (**2**) (**3**)

N-Aminoquinazolones (**1**) belong to a family of *N*-amino-heterocyclic compounds which includes *N*-aminophthalimide (**2**)[6] and *N*-aminobenzoxazolone (**3**)[7] whose oxidation generates *N*-nitrenes having singlet ground states. A further property of these reactive, non-isolable *N*-nitrene intermediates relates to the stereochemistry of the kinetically formed aziridines from their reactions with alkenes.[8] It has been shown that, for the cases of (**2**) and (**3**), oxidation in the presence of alkenes bearing π-electron-containing substituents, *e.g.* styrenes, 1,3-dienes, or acrylates, results in the formation of the aziridines (**4**), in which the heterocycle and substituent are *syn*: only on raising the temperature subsequent to the reaction is the thermodynamically more stable *anti*-aziridine (**5**) formed by inversion at nitrogen (Scheme 1).

This property is of obvious relevance to the question of transition-state geometry in the reaction of these *N*-nitrenes with alkenes and suggests that in this geometry, the heterocycle and substituent are close enough for an attractive interaction to operate. We will refer to this interaction as a secondary one by comparison with the primary interaction of nitrene and alkene (which results in bonds being formed) although there is evidence to suggest that without it, there is little if any addition of the nitrene to some alkenes. Whether this secondary interaction is orbital symmetry controlled or due to other factors is, at present, unknown.

We find that the *N*-nitrene derived by oxidation of 3-amino-2-

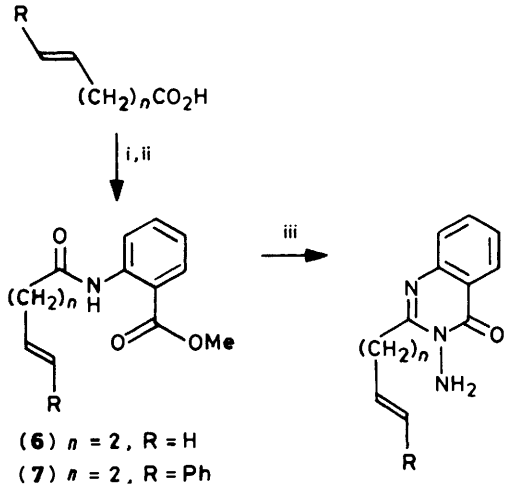
† Recent work has shown that in several cases of singlet carbene additions to alkenes, a complex between the two components is formed reversibly with a rate-determining step in which this complex is converted into cyclopropane. The implications of these findings on the question of concertedness in the cycloaddition remain to be assessed.[4]



Scheme 1. *Reagents:* i, LTA, < -20 °C; ii, $\overset{R}{=}$ (R = Ph, CO_2R, >C–C<); iii, *ca.* 0 °C

methylquinazolone (**1**; R = Me) also exhibits this *syn*-selectivity in its addition to styrene. The significant rate of inversion of the *syn*-aziridine to the *anti*-form even at -20 °C (Scheme 1) makes for experimental difficulty in demonstrating that the *syn*-aziridine is *stereospecifically* formed [as is the case with nitrenes derived from oxidation of (**2**) and (**3**)] but we believe this is probably the case.

The choice of *N*-aminoquinazolones for a study of intramolecular *N*-nitrene additions was based on the ready incorporation of the double bond into the side-chain at position 2 when assembly of the quinazolone ring is carried out *via* the appropriate carboxylic acid (Scheme 2).

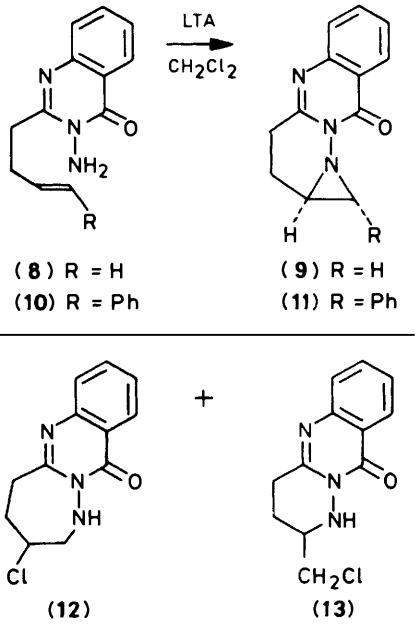


Scheme 2. *Reagents:* i, $SOCl_2$; ii, methyl anthranilate; iii, NH_2NH_2, EtOH

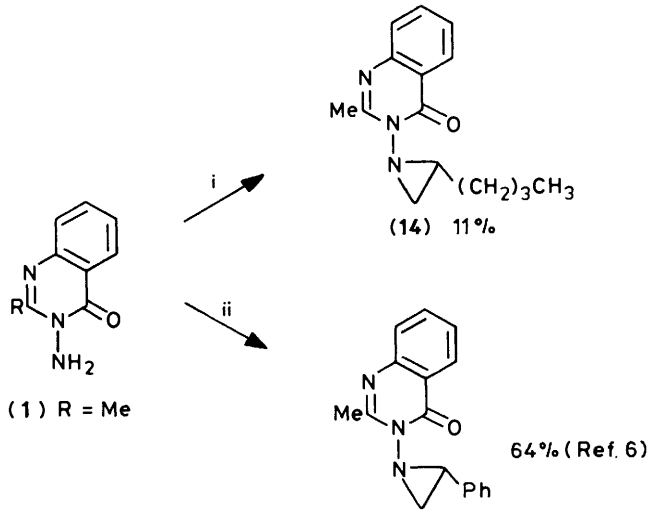
To avoid complications due to the secondary effect referred to above, we first looked for nitrene addition within quinazolones with $n = 2$ in Scheme 2 in which no interaction between quinazolone and phenyl ring is possible when the alkene is *trans*-substituted as in (**10**).

Oxidation of the *N*-aminoquinazolone (**8**) bearing a terminally unsubstituted double bond gave the aziridine (**9**) in 50% yield.

N.m.r. spectroscopy shows the disappearance of olefinic protons in the product and there is no NH stretching band in the i.r. region. The presence of an aziridine ring was supported by its ready ring-opening with hydrogen chloride in ether to give a mixture of the two chlorides (**12**) (32%), m.p. 174—176 °C and (**13**) (11%), m.p. 143—146 °C.



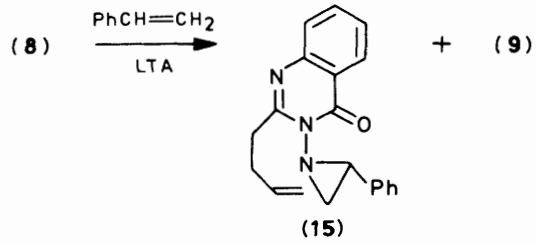
The respectable yield of aziridine (**9**) is in contrast to the poor yields obtained from intermolecular addition of *N*-nitrenes to mono-alkyl-substituted alkenes, *e.g.* the oxidation of (**1**; R = Me) in the presence of an excess of hexene gives the aziridine (**14**) in only 11% yield (Scheme 3).



Scheme 3. *Reagents:* i, $Me(CH_2)_3CH{=}CH_2$, LTA; ii, $PhCH{=}CH_2$, LTA

Oxidation of the same quinazolone (**1**; R = Me) in the presence of an excess of styrene proceeds in better yield (Scheme 3) the result either of a smaller HOMO(alkene)–LUMO(nitrene) separation or perhaps of a favourable secondary interaction between the phenyl group and heterocycle. However, any such intramolecular interaction between these latter two groups is precluded in oxidation of the quinazolone (**10**) bearing a terminal styrenoid double bond and yet the aziridine (**11**) is produced in 85% yield.

It is important to establish that in these intramolecular reactions, the intermediate which is being trapped by the double bond is the nitrene and not some species *en route* to the latter in oxidation of the amino group. When the oxidation of (**8**) was

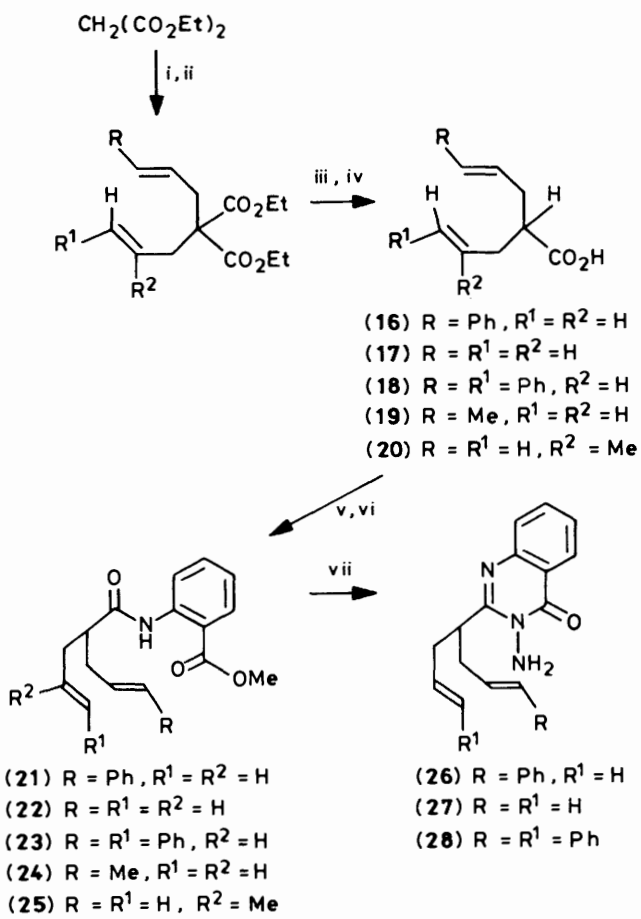


Scheme 4.

carried out on the presence of 3 mole equivalents of styrene, the aziridines (**9**) and (**15**) were obtained in a ratio of *ca.* 3:1 (Scheme 4).

Increasing the concentration of styrene three-fold changes this ratio to 1:1 and a crystalline sample of aziridine (**15**) was isolated by chromatography in 30% yield. Our interpretation of these results is that at least half the oxidation of (**8**) proceeds *via* the same nitrene intermediate in both inter- and intra-molecular trapping by alkenes.

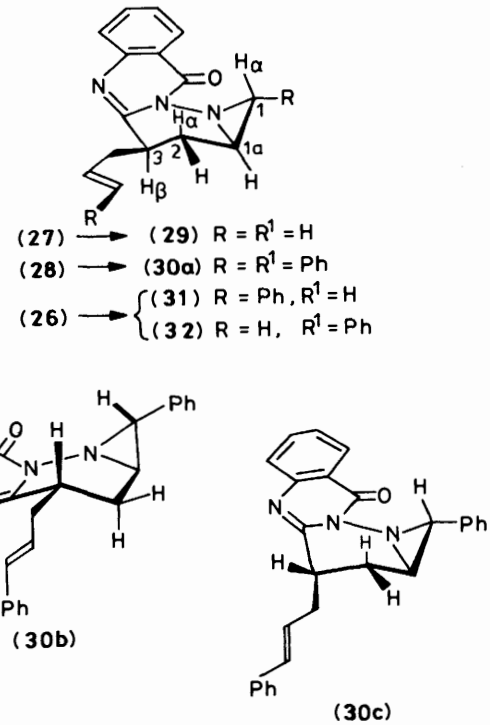
In the addition of aminoquinazolones (**8**) and (**10**), the presence of small amounts of unidentified by-product(s) was inferred from the n.m.r. spectra of the crude products which still contained minor amounts of olefinic signals. The higher yield of aziridine (**11**) is more a reflection of its ease of isolation (isolated yields quoted). To estimate the relative reactivity of the two double bonds in (**8**) and (**10**) directly, we synthesised the quinazolone (**26**) by the route outlined in Scheme 5. For comparison purposes, we also synthesised (**27**) and (**28**) *via* the intermediates shown.



Scheme 5. *Reagents:* i, NaOEt, RCH=CHCH$_2$Cl(Br); ii, NaOEt, R^{1}CH=C(R^2)CH$_2$Cl(Br); iii, NaOH, EtOH; iv, heat, 160 °C; v, SOCl$_2$; vi, methyl anthranilate; vii, NH$_2$NH$_2$–EtOH

These quinazolones bearing bifurcated chains at position 2 and their amide precursors were obtained as oils whose structures were confirmed by spectroscopy. The branching of the chain in amides (**21**)—(**23**) has a retarding effect upon the rates of their reaction with hydrazine: whereas in the synthesis of (**8**) and (**10**) (Scheme 2) quinazolone ring formation is accomplished by heating under reflux with hydrazine in ethanol, it is necessary to heat (**21**)—(**23**) to 120 °C in a sealed tube [with complete exclusion of oxygen to avoid generation of di-imide and consequently, reduction of the double bond(s)]. The simplest interpretation of the steric effect of branching in the chain and the fact that starting material is recovered using conditions which are sufficient for cyclisation when branching is absent, is that attack of hydrazine takes place initially on the amide carbonyl group. It is clear from the n.m.r. spectra of the amides (**21**)—(**23**) that the conformation of this group is as shown where hydrogen bonding between the NH and ester carbonyl is present and the benzene ring proton *ortho* to the NH is deshielded by the amide carbonyl group.

Oxidation of (**27**) or (**28**) gave, in each case, a single aziridine (**29**) (94%) and (**30a**) (89%), respectively.* It is noteworthy that in the case of (**30a**), three chiral centres (excluding the aziridine nitrogen) are created stereospecifically in the reaction.



We have carried out a complete analysis of the 400 MHz ^{1}H n.m.r. spectrum of (**30a**) which was simplified by the presence of a single conformation of the tetrahydropyridazine ring. The most important features of this analysis are as follows. (i) The aziridine ring in (**30a**) is *trans*-substituted, *i.e.* nitrene addition to the double bond is stereospecific with the configuration of

* The aziridine (**30a**) is (1α,1aβ,3α)-1,1a,2,3-tetrahydro-1-phenyl-3-(1-phenylprop-1-enyl)-9*H*-azirino[1′,2′:2,3]pyridazino[6,1-*b*]quinazolin-9-one. As a result of an omission of a carbon in the side-chain in diagrams of these aziridines in our earlier communication (ref. 5), the compounds have been wrongly formulated in *Chem. Abstr.* (1981, **95**, 132794h).

substituents on the double bond retained in the aziridine. (ii) 2αH Is shielded (δ 1.54) relative to 2β-H (δ 2.90) and its assignment is confirmed by observation of a substantial direct n.O.e. from 1α-H. (iii) The coupling constant between 2α-H and 3β-H (*J* 12.8 Hz) defines the configuration at the carbon bearing the allyl side-chain which is, therefore, *cis*- to the aziridine ring carbon C-1. (iv) As expected, the two allylic methylene protons in the side chain, which are diastereoisotopic, have very different chemical shifts (δ 2.62 and 3.28).

The hypothetical alternative stereoisomeric structures (**30b**) and (**30c**) were easily dismissed. Thus, 3α-H did not show the n.O.e. which would be anticipated as a result of its close proximity to 1α-H in structure (**30b**). Further, the observed *trans*-diaxial vicinal coupling to the upfield proton at δ 1.54 would demand that the latter should correspond to 2β-H. The observation of a direct n.O.e. between 1α-H and 2β-H is incompatible with structure (**30b**) where such an interaction would be impossible. The conformer (**30c**) would have 3-H in a pseudo-equatorial position; the corresponding dihedral angles between 3-H and 2α-H (*ca.* 50°) and between 3-H and 2β-H (*ca.* 70°) are not in accord with the observed coupling constants (12.8 and 3.8 Hz) which, in fact, fit well with the axial/axial and axial/equatorial relationships respectively in (**30a**).

The higher energies of (**30b**) ('boat'; 1α-H,3α-H interaction) and (**30c**) ('axial' side chain at C-3) are presumably reflected at the transition states leading to these hypothetical structures and therefore the formation of a single diastereoisomer (**30a**) in the reaction is not surprising (*vide infra* for a discussion of the transition state for nitrene addition).

Oxidation of the aminoquinazolone (**26**) and examination of the spectrum of the crude reaction product by n.m.r. spectroscopy revealed the presence of both aziridines (**31**) and (**32**) in a *ca.* 1:1 ratio as judged by the integration ratios of the signals due to alkene protons on the intact allyl side-chains in these compounds. Clean separation of these two isomers was achieved by alumina chromatography and both were obtained as crystalline solids in *ca.* 25% yields.

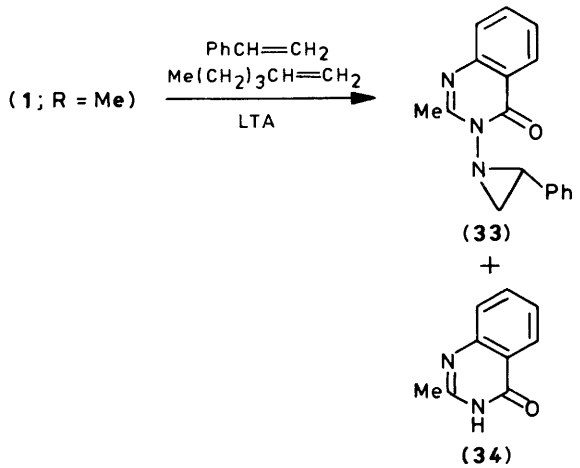
This lack of discrimination by the nitrene in reaction with the alkene double bonds in (**26**) is striking, particularly when contrasted with a competition reaction between hexene and styrene for the nitrene from oxidation of 2-methyl-3-aminoquinazolone (**1**; R = Me) (Scheme 6).

Only the aziridine (**33**) from addition of the nitrene to styrene was detectable in the crude reaction product, together with the de-amination product (**34**) of the starting material (**1**; R = Me), even when the concentration of hexene was five times that of styrene.

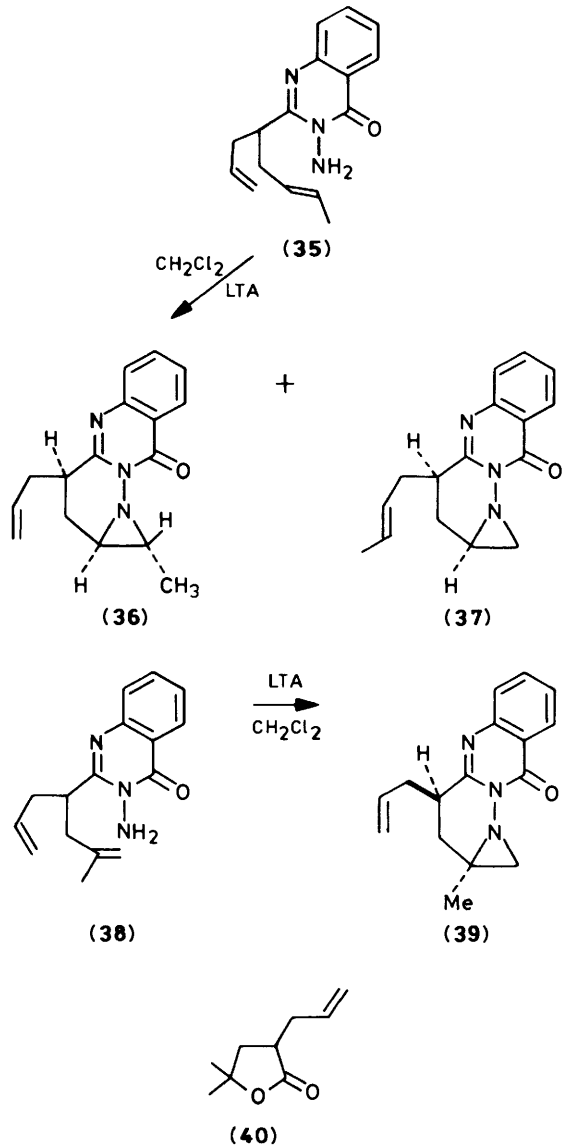
To account for these gross differences in relative double-bond reactivity in inter- and intra-molecular reactions requires either that a different mechanism is operating in each case or that the same mechanism (concerted nitrene cycloaddition?) operates and the equalisation of rates of addition within (**26**) is the result of a geometrically-enforced deprivation of the secondary interaction referred to earlier in addition of the nitrene to the styrenoid double bond.

Further competition experiments using similar bifurcated quinazolones strongly suggest that the mechanisms of inter- and intra-molecular nitrene addition are different. Thus the reactivity of a methyl-substituted *versus* an unsubstituted double bond is critically dependent upon the placement of the methyl group: whereas oxidation of (**35**) gave a 1:1 ratio of aziridines (**36**) and (**37**) [*cf.* oxidation of (**26**)], oxidation of (**38**) gave exclusively the aziridine (**39**) from addition to the β-methyl-substituted double bond.

In each case the isolated aziridine appeared to be a single stereoisomer and although we have proved this only in the cases of (**30a**) and (**39**), we presume that all have a *cis*-relationship between the (substituted) allyl side-chain and the aziridine ring carbon-1.

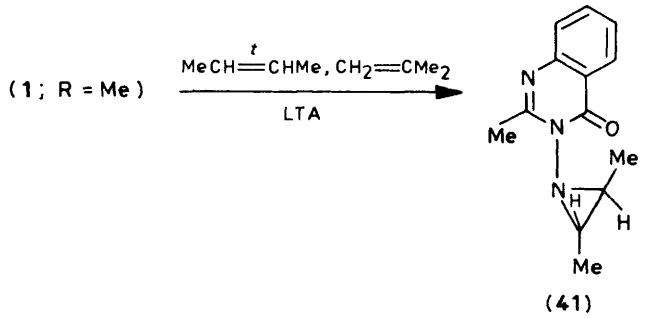


Scheme 6.



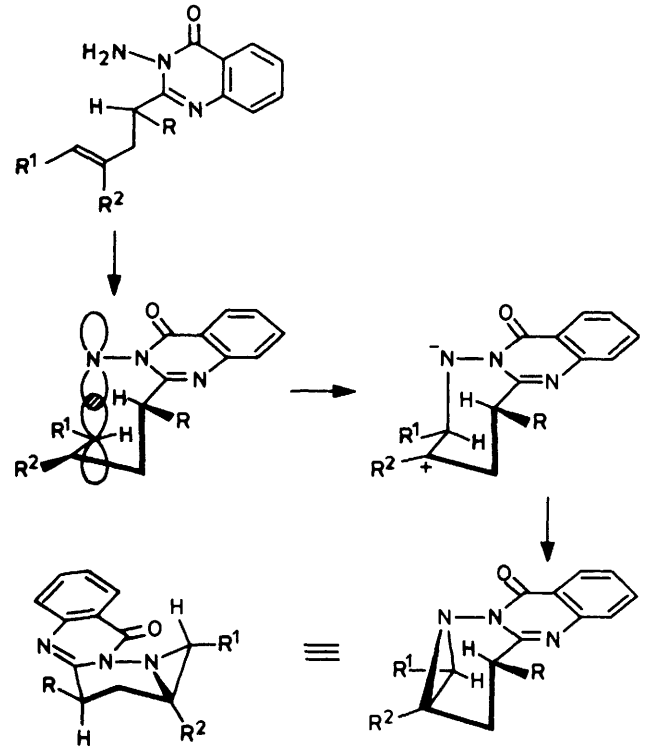
The synthesis of (**35**) and (**38**) followed the route shown in Scheme 5 except that decarboxylation to give the acid (**20**) (Scheme 5) was accompanied by some lactonisation [to give (**40**)]. Acid chloride formation in this case had to be carried out using oxalyl chloride and the sodium salt of the acid.

Again the results from these intramolecular reactions are at variance with those obtained by oxidation of (**1**; R = Me) in the presence of a 1:1 ratio of *trans*-but-2-ene and 2-methylpropene (Scheme 7) where only signals from the aziridine (**41**), the addition product to the former, are observed in the n.m.r. spectrum of the crude reaction mixture.



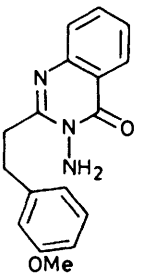
Scheme 3

We suggest that these intramolecular nitrene additions are not fully concerted and proceed *via* (a) intermediates having dipolar character and (b) 7-membered transition states (Scheme 8).



Scheme 8.

We have previously reported[9] that intramolecular trapping of the *N*-nitrene from oxidation of *N*-amino-2-arylethylquinazolones [*e.g.* (**42**)] is very sensitive to the methoxy substitution pattern in the aryl ring and have rationalised this reactivity using analogous intermediates to those in Scheme 8.



(**42**)

The preferential attack on the β-methyl-bearing double bond in the oxidation of (**38**) becomes clear since a tertiary carbocation is generated. A 1:1 ratio of attack on the two different double bonds in both (**26**) and (**35**) is understandable since secondary carbocations are being generated in all cases. In the 7-membered transition state (Scheme 8) it can be seen that R occupies a quasi-equatorial position and unfavourable interaction with the nitrene nitrogen is minimised.

It is clear that the preferred transition state geometry for fully concerted intramolecular nitrene cycloaddition cannot be accommodated in the substituted quinazolone framework used in this work. From an examination of models it is apparent that a transition state closely resembling that shown in Figure 2 is not accessible in this system and that the limited length of the carbon chain directs electrophilic attack of the nitrene to the terminal alkene carbon as shown in Scheme 8.

Concerted nitrene addition should be preferred when quinazolones in Scheme 2 with sufficiently large values of *n* are used. A description of the transition state geometry for concerted nitrene addition to double bonds should therefore be available (with the aid of models) from a determination of the value of *n* at which a changeover from non-concerted to concerted reaction takes place. The role (if any) played by the secondary effect in bringing about concerted addition remains to be determined.

Experimental

For descriptions of instrumentation and general experimental details see ref. 8. N.m.r. spectra were determined using a Varian EM 390 (90 MHz) and Bruker WH-400 (400 MHz) spectrometers in $CDCl_3$ solution unless otherwise indicated. Pent-4-enoic acid was prepared by the method of Conrad and Bischoff,[10] b.p. (Kugelrohr) 85—87 °C/0.7 mmHg (lit.,[10] 186—187 °C); 5-phenylpent-4-enoic acid was similarly prepared, m.p. 87.5—90 °C (lit.[11] 90 °C); 2-prop-2-enylpent-4-enoic acid (**17**) was obtained by decarboxylation of the propanedioic acid,[10] m.p. 131—135 °C (lit.,[10] 132—133 °C) and used directly; 2-(3-phenylprop-2-ene)-5-phenylpent-4-enoic acid (**18**), m.p. 88—90 °C (from ethyl acetate–light petroleum) was similarly obtained from decarboxylation of the propanedioic acid, itself prepared by cinnamylation of diethyl malonate [12] followed by hydrolysis following the method of Conrad and Bischoff,[10] 5-phenyl-2-prop-2-enylpent-4-enoic acid (**16**) was similarly obtained and distilled, b.p. (Kugelrohr) 186 °C/0.5 mmHg; 2-prop-2-enylhex-4-enoic acid (**19**) was similarly obtained from decarboxylation of the dioic acid itself prepared by successive alkylation of diethyl propanedioate with allyl chloride and but-2-enyl chloride followed by hydrolysis of the diester [13] and used directly; 4-methyl-2-prop-2-enylpent-4-enoic acid (**20**) was similarly prepared from the propanedioate[14] but decarboxylation of the dioic acid gave a mixture of the required acid and the lactone, 5,5-dimethyl-3-prop-2-enyltetrahydrofuran-2-one (**40**). The acid was freed from the lactone by dissolving the

mixture in dichloromethane, extracting the solution with dilute aqueous sodium hydroxide, and separating the basic layer; the latter was then acidified with hydrochloric acid. The mixture was then extracted with dichloromethane, and the extract dried and evaporated to give the acid (**20**) as a colourless liquid (57%); this was used directly; δ 11.05 (s, CO_2H), 5.7 (ddt, *J* 17, 10, and 6 Hz, C*H*=CH_2), 4.6—5.2 (m, 2 × C=CH_2), 2.65 (m, *H*CCO_2H), 2.5—2.1 (m, 2 × CH_2), and 1.7 (s, CH_3).

General Procedure for Synthesis of 3-*Amino*-2-(2-*alkenylethyl*)- *and* 3-*Amino*-2-(*hepta*-1,6-*dien*-4-*yl*)*quinazolin*-4(3H)-*ones: Methyl* N-*Pent*-4-*enoyl- and N*-(2-*Substituted pent*-4-*enoyl*)-*anthranilates*.—The appropriate acid (0.02 ml) and thionyl chloride (12 ml) were set aside for 2 h until bubbles had ceased to be observable (an i.r. spectrum on a small sample at this time after removal of thionyl chloride showed $\nu_{max.}$ CO at 1 785 cm^{-1} only). Excess of thionyl chloride was removed by evaporation under reduced pressure and the residual acid chloride diluted with dry ether (10 ml) and added dropwise but briskly with stirring to methyl anthranilate (0.045 mol) dissolved in dry ether (150 ml). The mixture was set aside overnight after which the insoluble hydrochloride was separated off and the ether solution washed with dilute hydrochloric acid (2M; 4 × 25 ml) and water, dried, and evaporated. The following amides were obtained in this manner: Methyl *N*-(5-phenylpent-4-enoyl)anthranilate (**7**) (47%) as colourless crystals, m.p. 83—85 °C (from ethanol) $\nu_{max.}$ 3 300m, 1 700s, and 1 600 cm^{-1}; δ 11.02 br (s, NH), 8.70 (dd, *J* 8 and 1 Hz, ArH *ortho* to NH), 8.00 (dd, *J* 7 and 2 Hz, ArH *ortho* to C=O), 7.50 (ddd, *J* 8, 8, and 2 Hz, ArH *meta* to NH), 7.10 (ddd, *J* 8, 7, and 1 Hz, ArH *meta* to C=O), 7.25 (m, 5 × ArH), 6.30 (m, C*H*=C*H*), 3.80 (s, OMe), and 2.80 (m, 2 × CH_2); methyl *N*-pent-4-enoylanthranilate (**6**) (50%) as colourless crystals, m.p. 26—27 °C (from ethanol–ether); $\nu_{max.}$ 3 300m, 1 685s, and 1 600s cm^{-1}; δ 11.00br (s, NH), 8.66 (dd, *J* 8 and 1 Hz, ArH *ortho* to NH), 7.99 (dd, *J* 7 and 2 Hz, ArH *ortho* to C=O), 7.50 (ddd, *J* 8, 8, and 2 Hz, ArH *meta* to NH), 7.04 (ddd, *J* 8, 7, and 1 Hz, ArH *meta* to C=O), 5.82 (m, C*H*=CH_2), 5.04 (m, CH=CH_2), 3.80 (s, OMe), and 2.45 (m, 2 × CH_2); methyl *N*-(2-prop-2-enylpent-4-enoyl)anthranilate (**22**) as a colourless oil (65%); $\nu_{max.}$ 3 305m, 1 695s, and 1 600s cm^{-1}; δ(CCl_4) 11.0br (s, NH), 8.68 (dd, *J* 8 and 1 Hz, ArH *ortho* to NH), 7.88 (dd, *J* 7 and 2 Hz, ArH *ortho* to C=O), 7.43 (ddd, *J* 8, 8, and 2 Hz, ArH *meta* to NH), 6.90 (ddd, *J* 8, 7, and 1 Hz, H *meta* to C=O), 5.70 (m, 2 × C*H*=CH_2), 5.2—5.0 (m, 2 × CH=CH_2), 3.80 (s, OMe), and 2.5—2.3 (m, CH_2C*H*CH_2); methyl *N*-[5-phenyl-2-(3-phenylprop-2-enyl)-pent-4-enoyl]anthranilate (**23**) as a colourless oil (45%); $\nu_{max.}$ 3 305m, 1 690s, and 1 600s cm^{-1}; δ(CCl_4) 10.92br (s, NH), 8.68 (dd, *J* 8 and 1 Hz, Ar H *ortho* to NH), 7.89 (dd, *J* 7 and 2 Hz, ArH *ortho* to C=O), 7.46 (ddd, *J* 8, 8, and 2 Hz, H *meta* to NH), 7.20 (m, 10 × ArH), 6.95 (ddd, *J* 8, 7, and 1 Hz), ArH *meta* to CO), 6.30 (m, 2 × C*H*=C*H*), 3.75 (s, OMe), and 2.75—2.5 (m, CH_2C*H*CH_2); methyl *N*-(5-phenyl-2-prop-2-enylpent-4-enoyl)anthranilate (**21**) as a colourless oil (65%); $\nu_{max.}$ 3 300m, 1 685s, and 1 600s cm^{-1}; δ(CCl_4) 10.95br (s, NH), 8.70 (dd, *J* 8 and 1 Hz, ArH *ortho* to NH), 7.95 (dd, *J* 7 and 2 Hz, ArH *ortho* to C=O), 7.0—7.5 (m, 7 × ArH), 6.32 (m, C*H*=C*H*Ph), 5.90 (m, C*H*=CH_2), 5.15 (CH=CH_2), 3.80 (s, OMe), and 2.55 (m, CH_2C*H*CH_2); methyl *N*-(2-prop-2-enylhex-4-enoyl)anthranilate (**24**) as a low-melting solid (94%); $\nu_{max.}$ 3 300m, 1 700s, and 1 600s cm^{-1}; δ 11.0br (s, NH), 8.7 (d, *J* 8 Hz, ArH *ortho* to NH), 7.9 (d, *J* 8 Hz, ArH *ortho* to C=*O*), 7.5 (dd, *J* 8 and 8 Hz, ArH *meta* to NH), 7.0 (dd, *J* 8 and 8 Hz, ArH *meta* to C=O), 4.9—6.0 (m, 5 × olefin H), 3.9 (s, OMe), 2.7—2.1 (m, CH_2C*H*CH_2), and 1.6 (3 H, m). Methyl *N*-(4-methyl-2-prop-2-enylpent-4-enoyl)anthranilate (**25**) was obtained by the following route.[15] 4-Methyl-2-prop-2-enylpent-4-enoic acid (1 g) was added to a solution of sodium (0.15 g) in dry ethanol (25 ml). After 15 min, the solution was evaporated under reduced pressure to give a colourless oil which solidified on trituration with ether. This sodium salt was separated, dried in an oven (100 °C), and then suspended in dry benzene and treated with 4 drops of dry pyridine. Oxalyl chloride (3 ml) was added to the ice-cooled reaction mixture and after 3 min the solution was evaporated under reduced pressure. The residual acid chloride was added in ether to methyl anthranilate as described above and the amide (**25**) isolated as an oil (95%); $\nu_{max.}$ 3 300m, 1 700s, and 1 600s cm^{-1}; δ 11.1br (s, NH), 8.7 (d, *J* 8 Hz, ArH *ortho* to NH), 7.9 (d, *J* 8 Hz, ArH *ortho* to C=O), 7.5 (dd, *J* 8 and 8 Hz, ArH *meta* to NH), 7.0 (dd, *J* 8 and 8 Hz, H *meta* to C=O), 6.0—4.7 (m, 5 × olefin H), 3.9 (s, OMe), 2.7—2.1 (m, CH_2C*H*CH_2), and 1.7br (s, CH_3).

3-*Amino*-2-*but*-1-*enylquinazolin*-4(3H)-*ones* (**8**) *and* (**10**).—The corresponding amide above (0.02 mol) and hydrazine hydrate (0.1 mol) were dissolved in methanol (50 ml) and heated under reflux overnight under nitrogen. Cooling the mixture in ice gave the following as colourless crystals: 3-*amino*-2-*but*-3-*enylquinazolin*-4(3H)-*one* (**8**) (90%), m.p. 105—106 °C (from ethanol) [Found: C, 67.0; H, 6.1; N, 19.5. $C_{12}H_{13}N_3O$ requires C, 67.0; H, 6.1; N, 19.5%]; $\nu_{max.}$ 3 320m, 1 675s, and 1 605s cm^{-1}; δ 8.18 (d, *J* 8 Hz, 5-ArH), 7.6—7.2 (m, 3 × ArH), 5.92 (m, 2-H), 5.00 (m, 2 × 1-H), 4.76 br (s, NH_2), 3.04 (m, 2 × 4-H), and 2.56 (m, 2 × 3-H); *m/z* 215, 200, 198, 185, 175, 160, 144, 119, 90, and 76; 3-*amino*-2-(1-*phenylbut*-3-*enyl*)*quinazolin*-4(3H)-*one* (**10**), (83%), m.p. 117.5—118.5 °C (from ethanol) (Found: C, 74.4; H, 5.9; N, 14.6. $C_{18}H_{17}N_3O$ requires C, 74.2; H, 5.9; N, 14.4%); $\nu_{max.}$ 3 320m, 1 665s, and 1 600s cm^{-1}; δ 8.18 (d, *J* 8 Hz, 5-QuinazH), 7.7—7.1 (m, 8 × ArH), 6.35 (m, C*H*=C*H*), 4.81br (s, NH_2), 3.04 (m, 2 × 4-H), and 2.70 (m, 2 × 3-H).

3-*Amino*-2-*hepta*-1,6-*dien*-4-*ylquinazolin*-4(3H)-*ones and* (**35**).—The corresponding amide (0.01 mol) and hydrazine hydrate (95%; 0.05 mol) were dissolved in ethanol (25 ml) and, after 3 freeze–thaw cycles to eliminate oxygen, the mixture was sealed *in vacuo* in a Carius tube. After being heated at 120 °C overnight in an oven and then cooled, the tube was opened and the solution evaporated under reduced pressure. The residue was dissolved in chloroform (20 ml) and the solution washed with water, dried, and evaporated; the product was purified by Kieselgel chromatography using light petroleum–ethyl acetate (10:1), as eluant. The following were obtained using this method: 3-amino-2-(1,7-diphenylhepta-1,6-dien-4-yl)quinazolin-4(3*H*)-one (**28**) as a colourless oil (65%); $\nu_{max.}$ 3 305m, 1 685s, and 1 600s cm^{-1}; δ(CCl_4) 8.15 (d, *J* 8 Hz, 5-Quinaz.H), 7.6—7.0 (m, 13 × ArH), 6.25 (m, 1-, 2-, 6-, 7-H), 4.85br (s, NH_2) 3.89 (q, *J* 7 Hz, 4-H), and 2.66 (m, 2 × 3-H, 2 × 5-H); *m/z* 407, 316, 290 (base), 273, 160, 145, 119, 91, 77, and 76; 3-amino-2-(hepta-1,6-dien-4-yl)quinazolin-4(3*H*)-one (**27**) as a colourless oil (85%); $\nu_{max.}$ 3 300, 1 695s, and 1 600s cm^{-1}; δ(CCl_4) 8.20 (d, *J* 8 Hz, 5-Quinaz.H), 7.7—7.2 (m, 3 × ArH), 5.82 (m, 2-, 6-H), 4.92br (s, NH_2), 5.00 (m, 2 × 1-H, 2 × 7-H), 3.80 (q, *J* 7 Hz, 4-H), and 2.50 (m, 2 × 3-H, 2 × 5-H); 3-amino-2-(1-phenylhepta-1,6-dien-4-yl)quinazolin-4(3*H*)-one (**26**) as a colourless oil (50%), $\nu_{max.}$ 3 305m, 1 690s, and 1 595s cm^{-1}; δ(CCl_4) 8.18 (d, *J* 8 Hz, 5-Quinaz.H), 7.7—7.1 (m, 8 × ArH), 6.28 (m, 1-, 2-H), 5.80 (m, 6-H), 4.98 (m, 2 × 7-H), 4.80 br (s, NH_2), 3.85 (m, 4-H), and 2.9—2.5 (m, 2 × 3-H, 2 × 5-H); *m/z* 331, 290 (base), 240, 201, 170, 117, 91, 83, and 77; 3-amino-2-(2-methylhepta-1,6-dien-4-yl)quinazolin-4(3*H*)-one (**38**), as an oil (73%); δ 8.15 (d, *J* 8 Hz, 5-Quinaz.H), 7.7—7.2 (m, 3 × ArH), 5.8 (m, 6-H), 5.2—4.6 (m, 2 × 1-H, 2 × 7-H), 4.9br (s, NH_2), 2.8—2.2 (m, 2 × 3-H, 2 × 5-H), and 1.75 (s, Me); 3-amino-2-(octa-1,6-dien-4-yl)quinazolin-4(3*H*)-one (**35**), as a colourless oil (65%); $\nu_{max.}$ 3 300m, 1 670s, and 1 610 cm^{-1}; δ 8.2 (d, *J* 8 Hz, 5-Quinaz.H), 7.9—7.2 (m, 3 × ArH), 5.8 (m, 2-H), 5.4 and 5.1—4.8 (m,

2 × 1-, 6-, 7-H), 4.9br (s, NH_2), 3.75 (m, 4-H) and 2.7—2.2 (m, 2 × 3-H, 2 × 5-H).

Oxidation of 2-Substituted 3-Aminoquinazolin-4(3H)-ones with Lead Tetra-acetate.—Method (a). The foregoing quinazolone (1 mol equiv.) was dissolved or suspended in the specified volume of dichloromethane and stirred magnetically at room temperature. Powdered lead tetra-acetate (LTA) (1 mol equiv.) was added in portions over 5 min and the reaction mixture stirred for a further 10 min. Precipitated lead di-acetate was separated off and the solution washed with aqueous sodium hydrogen carbonate and water; it was then dried and evaporated.

Method (b). Small portions of powdered LTA (7.7 mmol in total) and quinazolone (7.8 mmol in total) were added alternately to magnetically stirred dichloromethane (25 ml) over 15 min. Lead diacetate was separated off and the solution treated as in Method (*a*).

Oxidation of the quinazolone (**10**) *by Method (a).* The quinazolone (0.39 g) was oxidised using LTA (0.8 g) and dichloromethane (5 ml) to give the *aziridine* (**11**) (0.29 g, 76%), m.p. 165.5—167 °C (from ethanol) (Found: C, 74.6; H, 5.2; N, 14.6. $C_{18}H_{15}N_3O$ requires C, 74.7; H, 5.2; N, 14.5%); $\nu_{max.}$ 1 680s and 1 600s cm^{-1}; δ 8.20 (d, *J* 7 Hz, 8-H), 7.6—7.2 (m, 8 × ArH), 3.2—2.7 (m, 1α-, 1β-, 1aβ-, 2β-H, 2 × 3-H), and 1.8 (m, 2α-H); *m/z* 289, 186 (base), 161, 131, 118, 90, and 77.

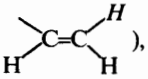
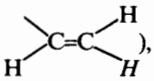
Oxidation of the quinazolone (**8**) *by Method (a).* The quinazolone (0.2 g) was oxidised using LTA (0.4 g) in dichloromethane (2 ml) to give the *aziridine* (**9**) (0.1 g, 50%), m.p. 164—166 °C (from ethanol) (Found: C, 67.4; H, 5.3; N, 19.9. $C_{12}H_{11}N_3O$ requires C, 67.6; H, 5.2; N, 19.7%); $\nu_{max.}$ 1 670s and 1 600s cm^{-1}; 8.24 (d, *J* 8 Hz, 8-H), 7.8—7.3 (m, 3 × ArH), 2.9—2.8 (m, 1α-, 1aβ-, 2β-H, 2 × 3-H), 1.96 (dd, *J* 7 and 2 Hz, 1α-H), and 1.76 (m, 2α-H); *m/z* 213, 185 (base), 156, 130, 102, 90, 84, and 76.

Oxidation of the quinazolone (**27**) *by Method (a).* The quinazolone (0.5 g) was oxidised using LTA (0.87 g) in dichloromethane (5 ml) to give the *aziridine* (**29**) (0.4 g, 89%), m.p. 137—139 °C (from acetonitrile) (Found: C, 70.9; H, 6.2; N, 16.8. $C_{15}H_{15}N_3O$ requires C, 71.1; H, 6.0; N, 16.6%); $\nu_{max.}$ 1 680s and 1 605s cm^{-1}; δ 8.18 (d, *J* 8 Hz, 8-H), 7.8—7.2 (m, 3 × ArH) 5.94 (m, C*H*=CH_2), 5.18 (m, CH=CH_2), 3.2—2.1 (m, 1β-, 1aβ-, 2β-, 3β-, CH_2CH=C), 1.86 (dd, *J* 6 and 1 Hz, 1α-H), and 1.40 (m, 2α-H).

Oxidation of the quinazolone (**28**) *by Method (a).* The quinazolone (0.5 g) was oxidised using LTA (0.5 g) in dichloromethane (5 ml). Trituration of the resulting gum with ether yielded the *aziridine* (**30a**) (0.4 g, 94%) which gave colourless crystals from ethanol, m.p. 212.5—213 °C (Found: C, 79.8; H, 5.8; N, 10.3. $C_{27}H_{23}N_3O$ requires C, 80.0; H, 5.7; N, 10.4%); $\nu_{max.}$ 1 680s and 1 590s cm^{-1}; δ (400 MHz) 8.28 (d, *J* 8 Hz, 8-H) 7.7—7.2 (m, 13 × ArH), 6.57 (d, *J* 16 Hz, C=C*H*Ph), 6.41 (ddd, *J* 16, 7.7, and 6.5 Hz, CH_2C*H*=CHPh), 3.28 (ddd, *J* 14.2, *ca.* 6.5 and *ca.* 5.1, HC*H*CH=CHPh), 3.18 (dddd, *J* 12.8, 7.7, 5.1, and 3.8, 3β-H), 3.16 (ddd, *J* 8.5, 7.7, and 4.5 Hz, 1aβ-H), 3.08 (d, *J* 4.5 Hz, 1α-H), 2.90 (ddd, *J* 13.4, 7.7 and 3.8 Hz, 2β-H), 2.62 (ddd, *J* 14.2, 7.7, and 7.7 Hz, H*C*HCH=CHPh), and 1.54 (ddd, *J* 13.4, 12.8, and 8.5 Hz, 2α-H); *m/z* 405 (base), 314, 288, 223, 196, 184, 173, 117, 91, and 77.

Oxidation of the quinazolone (**26**) *by Method (a).* The quinazolone (0.24 g) was oxidised using LTA (0.32 g) in dichloromethane (20 ml). An n.m.r. spectrum showed the crude reaction mixture to contain equal proportions of the two aziridines (**31**) and (**32**). Chromatography on alumina and elution with light petroleum–ethyl acetate (2:1) gave the *aziridine* (**31**) (0.06 g, 25%), m.p. 145—147 °C (from ethanol) (Found: 76.6; H, 5.8; N, 12.8. $C_{21}H_{19}N_3O$ requires C, 76.6; H, 5.8; N, 12.8%); $\nu_{max.}$ 1 680s and 1 605s cm^{-1}; δ 8.24 (d, *J* 8 Hz, 8-H), 7.6—7.2 (m, 8 × ArH), 5.95 (m, C*H*=CH_2), 5.18 (m, CH=CH_2), 3.2—2.9 (m, 1α-, 1aβ-, 3β-H, *H*CHC=C), 2.38 (m, 2β-H, HC*H*C=C), and 1.55 (m, 2α-H). Further elution with ethyl acetate gave (**32**) (0.05 g, 21%), m.p. 137—140 °C (from ethanol) (Found: C, 76.6; H, 5.8; N, 12.8. $C_{21}H_{19}N_3O$ requires C, 76.6; H, 5.8; N, 12.8%); $\nu_{max.}$ 1 685s and 1 600s cm^{-1}; δ 8.25 (d, *J* 8 Hz, 8-H), 7.7—7.2 (m, 8 × ArH) 6.46 (m, C*H*=C*H*Ph), 3.3—1.8 (m, 1α-, 1β-, 1aβ-, 2β-, 3β-H, CH_2CH=CHPh), and 1.32 (m, 2α-H).

Oxidation of the quinazolone (**35**) *by Method (b).* The quinazolone (2.1 g) was oxidised using LTA (3.4 g) and dichloromethane (25 ml). N.m.r. examination of the crude reaction mixture revealed the presence of the aziridines (**36**) and (**37**) in a 1:1 ratio. Trituration with dry ether gave the *aziridine* (**37**) which crystallised from ethanol as colourless plates (0.56 g, 26%), m.p. 146.5—147.5 °C (Found: C, 71.75; H, 6.4; N, 15.9. $C_{16}H_{17}N_3O$ requires C, 71.9; H, 6.4; N, 15.7%); $\nu_{max.}$ 1 690s and 1 590 cm^{-1}; δ 8.2 (d, *J* 8 Hz, 8-H), 7.8—7.2 (m, 3 × ArH), 5.7—5.5 (m, C*H*=C*H*), 3.2—2.3 (m, 1α-, 1β-, 1aβ-, 2β-, 3β-H, CH_2C=C), *ca.* 1.25 (m, 2α-H), and 1.7 (d, *J* 5 Hz, CH_3). Chromatography of the residue on neutral alumina after removal of (**37**) and elution with light petroleum–ethyl acetate (5:2) gave the *aziridine* (**36**) as an oil (0.8 g, 38%); δ 8.0 (d, *J* 8 Hz, 8-H), 7.5—7.1 (m, 3 × ArH), 5.8 (m, C*H*=CH_2), 5.1—4.8 (m, CH=CH_2), 3.0—2.1 (m, 1α-, 1aβ-, 2β-, 3β-H, CH_2C=C), *ca.* 1.2 (m, 2α-H), and 1.3 (d, *J* 6 Hz, CH_3).

Oxidation of the quinazolone (**38**) *by Method (b).* The residue after evaporation of the dichloromethane was crystallised to give the *aziridine* (**39**) (64%), m.p. 153—155 °C (from ethanol) (Found: C, 71.7; H, 6.4; N, 15.8. $C_{16}H_{17}N_3O$ requires C, 71.9; H, 6.4; N, 15.7%); $\nu_{max.}$ 1 670 and 1 590 cm^{-1}; δ (400 mHz) 8.31 (ddd, *J* 8, 1, and 1 Hz, 8-H), 7.72 (ddd, *J* 8.1, 7, and 1 Hz, 6-H), 7.68 (ddd, *J* 8.1, 1, and 1 Hz, 5-H), 7.44 (ddd, *J* 8, 7, and 1 Hz, 7-H), 5.99 (dddd, *J* 16.9, 10.3, 8.1, and 6.2 Hz, C*H*=CH_2), 5.20 (dd, *J* 16.9 and 1 Hz ), 5.17 (dd, *J* 10.3 and 1 Hz, ), 3.15 (ddd, *J* 14, 6.2 and 4.4 Hz, HC*H*CH=CH_2), 2.95 (dddd, *J* 12.5, 8.5, 4.4 and 3.7 Hz, 3β-H), 2.82 (d, *J* 2.2 Hz, 1β-H), 2.44 (dd, *J* 13.6 and 3.7 Hz, 2β-H), 2.38 (ddd, *J* 14, 8.5, and 8.1 Hz, HC*H*CH=CH_2), 1.98 (d, *J* 2.2 Hz, 1α-H), 1.70 (s, Me), and 1.37 (dd, *J* 1.36 and 12.5 Hz, 2α-H).

Oxidation of 3-Amino-2-methylquinazolin-4(3H)-one (**1**; R = Me) *in the Presence of Styrene at Low Temperature.*—The quinazolinone (**1**; R = Me) (0.05 g) and styrene (0.89 g) were added to deuteriochloroform (0.5 ml) and magnetically stirred at −22 °C to −28 °C. Powdered LTA (0.126 g) was added over 15 min and the solution stirred for a further 20 min at this temperature; it was then cooled to −50 °C, filtered, and tetramethylsilane added. N.m.r. spectra were run at −26 °C, −19 °C, and −10 °C with no intermediate warming of the solution. At −26 °C 81% of the *syn*-invertomer (**4**; Het = 3,4-dihydro-3-oxoquinazolin-3-yl, R = Ph) and 19% *anti*-invertomer (**5**; Het = 3,4-dihydro-3-oxoquinazolin-3-yl, R = Ph) were present: after 9 min at −19 °C, 37% of the latter was present; at −10 °C after 27 min no *syn*-invertomer [(**4**); Het = 3,4-dihydro-3-oxoquinazolin-3-yl, R = Ph] was detectable. The *syn*-aziridine included the following signals: δ 3.92 (dd, *J* 7.5 and 6 Hz, C*H*Ph), 3.80 (dd, *J* 6 and 2 Hz, azirid. ring H *cis* to Ph), 3.52 (dd, *J* 7.5 and 2 Hz, azirid. ring H *trans* to Ph), 2.40 (s, Me); for the *trans*-aziridine the corresponding signals were at δ 3.26 (dd, *J* 8.5 and 6 Hz), 2.82 (dd, *J* 6 and 2.5 Hz), 2.98 (*J* 8.5 and 2.5 Hz), and 2.58 (s).

Oxidation of the Quinazolone (**8**) *in the Presence of Styrene.*—The procedure described earlier, Method (*a*), was carried out using the quinazolone (**8**) (0.5 g), LTA (1.0 g), and di-

chloromethane (5 ml) containing styrene (1.2 g). Examination of the crude reaction product showed that the ratio of aziridines (**15**):(**9**) was 1:3. A further experiment using the same quantities of reagents but twice the amount of styrene (2.4 g) indicated that this ratio was 1:1. Chromatography on alumina and elution with light petroleum–ethyl acetate (1:1) gave the *aziridine* (**15**) (0.2 g, 30%), m.p. 66—67 °C (from ethanol) (Found: C, 75.55; H, 6.05; N, 13.35. $C_{20}H_{19}N_3O$ requires C, 75.7; H, 6.05; N, 13.25%); $\nu_{max.}$ 1 680s and 1 600s cm $^{-1}$; 8.15 (d, *J* 8 Hz, Quinaz.H *ortho* to CO), 7.7—7.2 (m, 8 × ArH), 5.66 (m, C*H*=CH_2), 4.79 (m, CH=CH_2), 3.62 (dd, *J* 6 and 8 Hz, C*H*Ph), 3.12 (dd, *J* 8 and 3 Hz, Azirid. ring H *trans* to Ph), 3.00 (m, Quinaz.-CH_2), 2.76 (dd, *J* 6 and 3 Hz, Azirid. ring H *cis* to Ph), and 2.55 (m, CH_2CH=CH_2).

Oxidation of (**1**; R = Me) *in the Presence of Hexene.*—The oxidation procedure described earlier, Method (*a*), was carried out using (**1**; R = Me) (1 g) and LTA (2.56 g) in dichloromethane (10 ml) containing hexene (2.4 g). After separation of lead diacetate, solid potassium carbonate (1 g) was added and the mixture stirred for 2 min; it was then filtered and the solvent removed by evaporation under reduced pressure. N.m.r. spectroscopy showed the product to be a mixture of 2-methylquinazolin-4(3*H*)-one (**34**) and (**14**) in the ratio 3:1 respectively. Chromatography on alumina, with light petroleum–ethyl acetate (1:1) as eluant gave the *aziridine* (**14**) (0.15 g), m.p. 66—67 °C (from ethanol) (Found: C, 70.0; H, 7.4; N, 16.3. $C_{15}H_{19}N_3O$ requires C, 69.7; H, 7.4; N, 16.3%); $\nu_{max.}$ 1 665s and 1 600s cm^{-1}; δ 8.2 (d, *J* 8 Hz, Quinaz.H *ortho* to CO), 7.7—7.2 (m, 3 × ArH), 2.72 (s, Quinaz.Me + m, NC*H*CH_2), 2.42 (dd, *J* 8.5 and 2 Hz, Azirid. ring H *trans* to butyl), 2.20 (dd, *J* 6 and 2 Hz, Azirid. ring H *cis* to butyl), 2.08 [m, $CH_2(CH_2)_2CH_3$], and 1.6—0.8 (m, $CH_2CH_2CH_3$).

Reaction of the Aziridine (**9**) *with Hydrogen Chloride in Ether.*—The aziridine (**9**) (0.8 g) was suspended in a saturated solution of HCl in dry ether (20 ml) at 0 °C and stirred magnetically at this temperature for 1 h and then at room temperature overnight. A colourless solid was separated off and added to aqueous sodium carbonate solution and the solution extracted with chloroform. The chloroform solution was dried, the solvent removed under reduced pressure, and the residue chromatographed on alumina. Elution with light petroleum–ethyl acetate (2:1) gave the *chloride* (**12**) (0.3 g, 32%) as colourless needles, m.p. 174—176 °C (from ethanol) (Found: C, 57.7; H, 4.9; N, 17.1. $C_{12}H_{12}N_3O$ requires C, 57.7; H, 4.8; N, 16.8%); $\nu_{max.}$ 3 260m, 1 665s, and 1 600s cm $^{-1}$; δ 8.2 (d, *J* 8 Hz, Quinaz.H *ortho* to CO), 7.8—7.3 (m, 3 × ArH), 6.84br (s, NH), 4.29 (m, C*H*Cl), 3.6—3.1 (m, NCH_2, Quinaz.CH_2), and 2.4—2.2 (m, CH_2CH_2CHCl); *m/z* 251/249, 216/214, 188, 187 (base), 160, 130, 102, 90, and 77.

Further elution with light petroleum–ethyl acetate (1:1) gave the chloride (**13**) (0.1 g, 11%) as colourless crystals, m.p. 143—146 °C (from ethanol); $\nu_{max.}$ 3 240m, 1 665s, and 1 600s cm $^{-1}$; δ 8.2 (d, *J* 8 Hz, Quinaz.H *ortho* to CO), 7.8—7.2 (m, 3 × ArH), 6.84 br (s, NH), 3.54 (m, CH_2Cl and NC*H*), 3.0 (m, Quinaz-CH_2), and 2.15 (m, CH_2CH_2CHN); *m/z* 251/249, 200 (base), 185, 183, 160, 120, and 77.

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References

1 'Conservation of Orbital Symmetry,' ed. R. B. Woodward and R. Hoffmann, Academic Press, Weinheim, 1970; R. Hoffmann, *J. Am. Chem. Soc.*, 1968, **96**, 1475.
2 P. S. Skell and M. S. Cholod, *J. Am. Chem. Soc.*, 1968, **91**, 7131; W. E. Doering and W. C. Henderson, *ibid.*, 1958, **80**, 5774.
3 N. G. Rondan, K. N. Houk, and R. A. Moss, *J. Am. Chem. Soc.*, 1980, **102**, 1770 and references therein.
4 N. J. Turro, G. F. Lehr, J. A. Butcher, R. A. Moss and W. Guo, *J. Am. Chem. Soc.*, 1982, **104**, 1754; B. Giese, W. B. Lee, and C. Neumann, *Angew. Chem., Int. Ed. Engl.*, 1982, **21**, 310.
5 Preliminary Communication: R. S. Atkinson, J. R. Malpass, K. L. Skinner, and K. L. Woodthorpe, *J. Chem. Soc., Chem. Commun.*, 1981, 549.
6 D. J. Anderson, T. L. Gilchrist, D. C. Horwell, and C. W. Rees, *J. Chem. Soc. C*, 1970, 576.
7 R. S. Atkinson and C. W. Rees, *J. Chem. Soc. C*, 1969, 772.
8 R. S. Atkinson and J. R. Malpass, *J. Chem. Soc., Perkin Trans. 1*, 1977, 2242.
9 R. S. Atkinson, J. R. Malpass, and K. L. Woodthorpe, *J. Chem. Soc., Perkin Trans. 1*, 1982, 2407.
10 M. Conrad and C. A. Bischhoff, *Annalen*, 1880, **204**, 170.
11 E. Erlenmeyer and A. Kreutz, *Ber.*, 1905, **38**, 3505.
12 F. J. McCarty, P. D. Rosenstock, J. P. Paolini, D. D. Micucci, L. Ashton, W. W. Bennetts, and F. P. Palopoli, *J. Med. Chem.*, 1968, **11**, 534.
13 I. G. Farbenind, D. R. P. 489, 251; *Beilstein* 2, II, 677.
14 E. Lobba *Bol. Dep. Eng. Quim.* (*Esc. Politec., Univ. Sao Paulo*), 1964, **19**, 44 (*Chem. Abstr.*, 1966, **64**, 4932a).
15 G. Stork and F. H. Clarke, *J. Am. Chem. Soc.*, 1961, **83**, 3114.

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