Aziridination of β -substituted styrene derivatives with 3-acetoxyaminoquinazolin-4(3*H*)-ones: probing transition state geometry from changes in diastereoselectivity

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Reaction of (S)-3-acetoxyamino-2-[1-(t-butyldimethylsilyloxy)ethyl]quinazolin-4(3H)-one **5** (Q¹NHOAc) with styrene and R(β)-substituted *E*-styrenes (R = SiMe₃, Me, CH₂Cl, CHCl₂) gives the corresponding aziridines diastereoselectively. The diastereoselectivity increases in the same sense from 5 : 1 \rightarrow 20 : 1 as the electron-withdrawing character of R increases [H(Me), CH₂Cl, CHCl₂] but is accompanied by a decrease in yield of aziridine. A similar increase in diastereoselectivity is found in the reaction of 3-acetoxyamino-2-(2,3,3-trimethylpropyl)quinazolin-4(3H)-one **38** (Q⁴NHOAc) with the same β -substituted styrenes.

An explanation for these observations is offered based on a tighter, more symmetrical transition state for the aziridination of styrenes bearing the more electron-withdrawing β -substituents and is supported by SCF calculations.

Introduction

3-Acetoxyaminoquinazolinones 1 (QNHOAc) are ambiphilic aziridinating agents for alkenes: they react in comparable yields with alkenes of grossly different electron availability *e.g.* styrene and *a*, β -unsaturated esters (Scheme 1).¹ In the transition states



(TS[#]s) for aziridination the planes containing alkene and the Q ring are approximately parallel with an attractive (*endo*) overlap of the (Q)C=O with the π -system of the alkene substituent (2, 3).

However, the mechanism of reaction in $TS^{\#} 2$ is thought (2, *j*). However, the mechanism of reaction in $TS^{\#} 2$ is thought to differ from that in $TS^{\#} 3$: in aziridination of styrene, $TS^{\#} 2$, C_{β} -N bond formation is believed to run ahead of N– C_{α} bond formation ² whereas in aziridination of acrylates 3, N– C_{β} bond formation runs ahead of C_{α} -N bond formation *i.e.* the $TS^{\#}$ takes on some Michael addition character.³ In neither case is any intermediate involved *i.e.* the reactions are concerted but asynchronous. The configurations at the sp³-hybridised ⁴ NHOAc chiral centres in 2 and 3 are opposite because attack on this nitrogen is assumed to be $S_N 2$ in character. Thus the ambiphilicity of QNHOAc arises from its ability to respond to the different electron availability of the alkene by a change in mechanism.

Aziridination with QNHOAc 1 is analogous to epoxidation with peroxyacetic acid but QNHOAc 1 is the more versatile reagent because peroxyacids do not react well with electrondeficient alkenes, *i.e.* acrylates.

The location of R, the Q-2 substituent, in TS[#]s 2 and 3 means that with $R = R^*$, a chiral group, diastereoselective aziridination of prochiral alkenes is feasible.^{5a,b} The work described in this paper was initiated as a result of the observation that aziridination of (E)- β -trimethylsilylstyrene with Q¹NHOAc 5, prepared *in situ* by *N*-acetoxylation of Q¹NH₂ 4 with lead tetraacetate (LTA) was more diastereoselective [dr (diastereoisomer ratio) 11 : 1]⁶ than styrene itself (dr 5 : 1) (Scheme 2).⁷

It seemed that the effect of the trimethylsilyl group on the diastereoselectivity must be electronic in origin because in the presumed TS[#] 8 for aziridination of this alkene, little, if any, steric interaction of the trimethylsilyl group with the (Q¹)-2-substituent would be expected. To understand this electronic effect and hence to extend its application to increase diastereoselectivity in aziridination more generally, we have studied the aziridinations of a variety of β -substituted styrenes with Q¹NHOAc and the results are summarised in Scheme 3. The only other homogeneous product isolated from these reactions







was the 3H-quinazolinone **14**, a known decomposition product of Q¹NHOAc.

In the reaction of Q¹NHOAc **5** with (*E*)- β -methylstyrene, both diastereoisomers of aziridine **9** are present as mixtures of *N*-invertomers by NMR spectroscopy in deuteriochloroform of the crude reaction product. Unravelling of the diastereoisomer ratio present was facilitated after separating the aziridine from unchanged β -methylstyrene by chromatography and then by partial separation of the diastereoisomers (13 : 1 ratio after Kieselgel chromatography). The major diastereoisomer was present as a 1.3 : 1 (Q/Ph *cis* : *trans*) ratio of *N*-invertomers and the minor diastereoisomer as a 2.2 : 1 ratio favouring Q/Ph *trans*. This conclusion was arrived at from observation of the chemical shifts of the C*H*Ph aziridine ring protons (Fig. 1): protons *cis* to the quinazolinone ring have been previously shown to be deshielded relative to those which are *trans*.⁸



Fig. 1 Invertomer ratios for diastereoisomeric aziridines 9.

Examination of the crude reaction mixture shows that the diastereoisomer ratio for aziridine 9 is 5 : 1. The enhancement in dr from $5: 1 \rightarrow 13: 1$ above is important because it allows a distinction between signals in the NMR spectrum from both *N*-invertomers of the same diastereoisomer (a ratio which is not affected by chromatography because interconversion is fast on the real timescale in solution) and signals from different diastereoisomers.

Aziridination of (E)- β -chloromethylstyrene using Q¹NHOAc **5** and purification of the crude product **10** using a Chromatotron gave the major diastereoisomer as a crystalline solid (*N*-invertomer ratio 3.5 : 1 favouring Q and Ph *cis*) and the minor diastereoisomer as an oil (*N*-invertomer ratio 2 : 1 favouring Q and Ph *cis*). Re-examination of the crude reaction product showed that the initial diastereoisomer ratio was 10 : 1.

For the (E)- β -dichloromethylstyrene-derived aziridine 11, measurement of the diastereoisomer ratio (20 : 1) and the aziridine *N*-invertomer ratio (7 : 1) in the major diastereoisomer was again facilitated when the latter was obtained as a crystalline solid after silica chromatography. An NMR spectrum of the mother liquor from this crystallisation after evaporation showed it was enriched in the minor diastereoisomer of aziridine 11.

Aziridination of (E)-stilbene gave a 3 : 1 ratio of diastereoisomers of **12**. A small sample of the minor diastereoisomer was separated by column chromatography: the major diastereoisomer was obtained as a crystalline solid. Likewise, methyl cinnamate gave a 3 : 1 ratio of diastereoisomers of aziridine **13** with the major one separable by chromatography. In neither of these cases **12** or **13** was the absolute configuration at the two chiral centres determined.

Stereostructures of aziridines 6, 7 and 9-11

The stereostructure of the major diastereoisomer of aziridine 6 was previously shown to be that having the 2*S*,3*S* configuration by chemical correlation (Scheme 4) together with an X-ray crys-



Scheme 4 Reagents: i, KCN, CsF, CH₃CN.

tal stucture determination⁶ of the minor diastereoisomer of the related aziridine **15**: both of the major diastereoisomers of aziridines **6** and **15** gave the same product **16** by the aziridine–aziridine sequence in Scheme 4.9

X-Ray crystal structures⁷ of the major diastereoisomers of aziridines 10 and 11 revealed that these also had the same absolute configuration at the 2-position as 6. Both crystal structures showed the Q-group *cis* to the phenyl ring and this is presumably the major *N*-invertomer in solution since the chemical shifts of the PhC*H* aziridine ring protons in each case are at higher field than those of the corresponding protons in the minor *N*-invertomers (see above).

For determination of the absolute configuration of the major diastereoisomers of styrene- and (E)- β -methylstyrene-derived aziridines 7 and 9, both were converted to the corresponding (Q)-2-(1-hydroxyethyl) compounds 17 and 18 by desilylation using tetrabutylammonium fluoride (TBAF) (Scheme 5).



Aziridine 17 was obtained from aziridine 7 (dr 5:1) as a 5:1 ratio of diastereoisomers which were separated by Chromatotron chromatography. Similarly, aziridine 9 (dr 5:1) was converted into aziridine 18 (dr 5:1) without any apparent interconversion of diastereoisomers: the major diastereoisomer was separated as a crystalline solid.

Previously we had shown that 3-acetoxyamino-2-(1-hydroxyalkyl)quinazolinones 22-24, prepared *in situ* by acetoxylation of the corresponding 3-aminoquinazolinones 19-21, react with styrene diastereoselectively in the presence of titanium(IV) *tert*butoxide (TTB) to give aziridines 17, 25 and 26 respectively (Scheme 6).^{5a} The major diastereoisomer of aziridine 17 pro-



duced was identical to the major one obtained by desilylation of aziridine 7 in Scheme 5.

Evidence for the same preferred sense of diastereoselectivity in formation of aziridines 17, 25 and 26 came from the excellent correlation in their NMR spectra for the chemical shifts of aziridine ring and RCHOH protons in major and minor diastereoisomers. The absolute configuration for aziridine 26 at the 3-membered ring carbon was shown to be (S) from X-ray crystallography by relating it to the [(S)-tert-leucine-derived] inducing centre in the Q2-substituent. From the correlations above, it follows that the configuration at the phenyl-substituted 3-membered ring carbon in the major diastereoisomer of aziridine 17 and hence aziridine 7 is also (S).^{5a} In this work aziridination of (E)- β -methylstyrene with Q²NHOAc **22** was also carried out in the presence of TTB and aziridine **18** was isolated as a 5 : 1 ratio of diastereoisomers (Scheme 7) with the major one identical to the crystalline major



Scheme 7 Reagents: i, (E)-RCH=CHPh₂, Ti(OBu^r)₄; ii, silica chromatography.

diastereoisomer isolated by desilylation of aziridine **9** (Scheme 5). The diastereoisomer of **18** shown is that which would be formed using our previous $TS^{\#}$ model for aziridination of styrene (see below). Aziridination of (E)- β -methylstyrene with Q³NHOAc **24** in the presence of TTB gave aziridine **27** as a single diastereoisomer from NMR examination of the crude reaction mixture: some aziridine ring-opening to alcohol **29** took place on silica chromatography.

When aziridination of (E)- β -methylstyrene with Q³NHOAc 24 was carried out in the absence of TTB, the diastereoselectivity was, as expected, much reduced (dr 2 : 1). After separation of the minor diastereoisomer by chromatography, it was shown to be absent from the crude reaction product 27 by NMR spectroscopy.

Although the identity in configuration at C-2 in aziridines **18** and **27** could not be confirmed by the ¹H NMR correlation used for aziridines **17** and **26** above, it seems very likely from the correspondence in behaviour of β -methylstyrene and styrene in the aziridinations in Schemes 5–7 that the β -methyl substituent has virtually no effect upon the stereochemistry of these aziridinations and that the configuration at the aziridine ring chiral centres in **9** is accordingly 2*S*,3*S*.

The complete diastereoselectivity in aziridination of (E)- β methylstyrene with Q3NHOAc 24 in the presence of TTB to give aziridine 27 deserves some comment when taken in conjunction with our previous observation that aziridination of a-methylstyrene under the same conditions gave a 5 : 1 ratio of diastereoisomers.^{5a} Our TS[#] model for aziridination of (E)- β methylstyrene that leads to diastereoisomer 27 has the phenyl endo and cis to the Q-ring as in 30. However, the sense of diastereoselectivity would remain unchanged even if some competitive aziridination took place via TS# 31 since the same face of the alkene is being attacked. Attack via TS[#] 31 seems less likely than via 30 in any case because of steric interaction between the N-acetoxy and tert-butyl groups. Attack via analogous TS[#]s 32 and 33 on α -methylstyrene, however, would lead to diastereoisomeric aziridines because opposite faces of the alkene would be involved: the N-acetoxy and tert-butyl groups would be anti in either case (Scheme 8).

Aziridination of β -chloromethylstyrene with Q³NHOAc 24 was also completely diastereoselective giving 28 (Scheme 7).



Prior to obtaining confirmation of the absolute configuation of aziridine **10** by X-ray crystallography, we had attempted to do this by chemical correlation. Desilylation of the major diastereoisomer by TBAF gave two products in a 1.6 : 1 ratio identified as the aziridine **34a** and the imine **35** (Scheme 9a).

Previously we had prepared a diastereoisomer **34b** of aziridine **34a** by intramolecular aziridination of the 3-acetoxyaminoquinazolinone **36** (Scheme 9b).⁴

The NMR spectra of these two aziridines **34a** and **34b** were consistent with their assigned diastereoisomeric relationship particularly in the similarity of chemical shifts and coupling constants for the OCH₂CH unit but in the dissimilarities for the CH₃CH protons arising from their different environments. Since both aziridines **34a** and **34b** have the same absolute configuration for the chiral centre adjacent to the 2-position of the Q-ring they must be epimeric at both aziridine ring chiral centres (aziridination of double bonds by QNHOAc is always stereospecific).

Aziridination using Q⁴NHOAc 38

We also briefly examined aziridination of some of the β -substituted styrene derivatives used above with (racemic) Q⁴NHOAc **38** and the results are summarised in Scheme 10. The X-ray crystal structure of the major diastereoisomer of aziridine **40** (Fig. 2) was obtained. The major diastereoisomer of aziridine **41** was obtained as a crystalline solid.



Fig. 2 The molecular structure of **40** showing the atom label scheme and 30% displacement probability ellipsoids. H atoms are omitted for clarity.

Discussion

Aziridination with Q¹NHOAc 5 of styrene and β -substituted styrenes to give 6, 7, 9–11 all proceed in the same diastereosense to give the same absolute configuration at the phenyl-bearing aziridine C-2 position. As the β -substituent changes from H(Me) \rightarrow CH₂Cl \rightarrow CHCl₂, *i.e.* becomes more electronwithdrawing, there is an increase in diastereoselectivity but a decrease in yield. Aziridination with Q⁴NHOAc **38** shows the same trend of increased diastereoselectivity but reduced yield with the same β -substituent changes if it is assumed that aziridination takes place in the same diastereosense in each case.

Although the changes in activation energy bringing about the changes in diastereoselectivity in these aziridinations are small, it is the trend of increasing dr with substituent electronegativity which is significant. Our explanation for this trend is based on the assumption that the effect of increasing the electron-withdrawing character of the β -substituent reduces the extent by which C_{β} -N bond formation runs ahead of N- C_{α} in the TS[#] for aziridination of these electron-available alkenes (2 in Scheme 1).



Scheme 9

Table 1 Energy levels (hartrees) and calculated orbital coefficients of C_{α} and C_{β} for some of the β -substituted styrenes used in Scheme 3

$\alpha \beta R$							
	НОМО			LUMO			
 R	E	C_{α}	C_{β}	Е	C_{α}	C _β	
Н	-0.3016	0.1794 0.1581	0.2579 0.2344	0.1119	0.1786 0.2993	-0.2415 -0.4325	
Me	-0.2923	0.2058 0.1823	0.2636 0.2421	0.1152	0.1693 0.2910	-0.2569 -0.4225	
CH ₂ Cl	-0.3100	0.1625 0.1403	0.2177 0.1937	0.1004	0.1823 0.3038	-0.2118 -0.3318	
CHCl ₂	-0.3170	0.1518 0.1255	0.2158 0.1986	0.0940	0.1943 0.3237	-0.2098 -0.3260	
 SiH ₃	-0.3064	0.1727 0.1490	0.2587 0.2388	0.0913	0.2238 0.3590	-0.2214 -0.3616	

Ph



Scheme 10 Reagents: i, LTA, CH₂Cl; ii, (E)-RCH=CHPh.

Using *ab initio* SCF calculations and a double zeta basis set (6-319*), the orbital coefficients at C_{α} and C_{β} and HOMO and LUMO energy levels for some of the β -substituted styrenes used in Scheme 3 were calculated (Table 1).

According to our mechanism for electron-available alkenes² the aziridination involves overlap of HOMO_{alkene} and LUMO_{Q'NHOAc} (the N–OAc σ^* orbital) and LUMO_{alkene} with HOMO_{Q'NHOAc} (the *N*HOAc lone pair) with the ordering of HOMO and LUMO levels resembling that in Fig. 3 for styrene.

Since the aziridination is primarily electrophilic attack by $Q^{1}NHOAc$, we have chosen LUMO ($Q^{1}NHOAc$) and HOMO (alkene) for the reaction scheme, a choice illustrated by the fact that $LUMO_{Q'NHOAc}$ -HOMO_{alkene} overlap is larger than $LUMO_{alkene}$ -HOMO_{Q'NHOAc} overlap, in Fig. 3.

It is clear from the Table that the effect of increasing the electron-withdrawing character of the β -substituent from $H \rightarrow CH_2Cl \rightarrow CHCl_2$ is to lower both the HOMO and LUMO levels of the alkene which increasingly favours LUMO_{alkene}-HOMO_{Q'NHOAc} overlap.



In addition, as the electron-withdrawing character of the β -substituent increases, there is in the LUMO_{alkene} a progressive increase in the magnitude of the C_a coefficient and a corresponding decrease in the C_β-coefficient that will increasingly favour bond making at the C_a-position. The same effects, moreover, are brought about by β -substitution of SiH₃ in styrene (as a model for SiMe₃) (Table).

Overall, the effect of favouring increased N–C_a bond formation in the TS[#] will be to make it more symmetrical and tighter with formation of the two 3-membered ring bonds more but not completely synchronous. An increase in diastereoselectivity is expected, *i.e.* in formation of aziridine **11**, because of the increased site selectivity of the three substituents on the inducing Q2-chiral centre. Thus using our previous TS[#] model for this aziridination,² **42** will become favoured over **43** because of the augmented interaction between H_β and CH*Me*OSi in the latter.



There is in $TS^{\#}$ **42**, a stereoelectronic effect which favours the conformation around the Q2–C bond shown with the C–O bond at the chiral centre almost in the plane of the Q ring and

the O–Si bond orthogonal to this plane:¹⁰ the two methyl groups on silicon then direct the methyl and hydrogen on the chiral centre to the sites shown. It is this stereoelectronic effect which is responsible for the superior levels of diastereoselectivity using Q¹NHOAc **5** over Q⁴NHOAc **38** in spite of the better size differentiation in the substituents on the inducing chiral centre in Q⁴NHOAc **38**.

The progressive decrease in yield with increasing electronwithdrawal by the β -substituent in Schemes 3 and 10 is a reflection of the inherent electrophilic character of the QNHOAc species: only in TS[#] **3** with back donation by the oxygen of the α,β -unsaturated ester carbonyl is the nucleophilic reactivity of the QNHOAc brought to the fore in Michael addition to the double bond.

Experimental

For general experimental details, see ref. ¹¹. Unless otherwise indicated, NMR spectra were run at 250 MHz in deuteriochloroform solutions with tetramethylsilane as internal standard. (*E*)- β -Dichloromethylstyrene was prepared by the literature method ¹² and routinely crystallised from light petroleum before use. All calculations were carried out using the standard facilities provided by Gaussian 941.¹³

General procedure 1 for aziridination

The 3-aminoquinazolinone QNH₂ (1 eq.) and acetic acid-free lead tetraacetate (LTA) (1.1 eq.) were added alternately and continuously in very small portions over 15 min. to a vigorously stirred solution of dry dichloromethane (1 cm³ per 100 mg of QNH₂) cooled with a dry ice–acetone bath held at -20 to -25 °C. After stirring for a further 5 min to give a solution of the 3-acetoxyaminoquinazolinone, a solution of the alkene (1.5–3.5 eq.) in dichloromethane (500 mg QNH₂ per 1 cm³) was added and then the temperature of the solution was allowed to rise to ambient stirring throughout. Lead diacetate was separated and (on a 500 mg QNH₂ scale) washed with dichloromethane (15 cm³) the organic solution washed successively with saturated aqueous sodium hydrogen carbonate (15 cm³) and water (15 cm³), dried with magnesium sulfate and the solvent removed by evaporation under reduced pressure.

General procedure 2 for aziridination in the presence of HMDS

A solution of 3-acetoxyaminoquinazolinone at -20 °C was prepared as described above, separated from lead di-acetate at this temperature (on a small scale a Pasteur pipette can be used) and the cold solution added dropwise over 2 min. to a stirred solution of the alkene (1.5–3.5 eq.) in dichloromethane (1 cm³/ 500 mg) containing HMDS (2–3 eq.) maintained at -20 °C (bath temperature). The temperature of the stirred solution was then allowed to rise to ambient and the reaction worked-up as described above.

General procedure 3 for aziridination in the presence of titanium(IV) *tert*-butoxide (TTB)

A cold (-20 °C) solution of 3-acetoxyaminoquinazolinone freed from lead diacetate prepared as described above was added dropwise over 2 min to a stirred solution of the alkene (1.5-3.5 eq.) in dichloromethane $(1 \text{ cm}^3 \text{ per } 500 \text{ mg QNH}_2)$ containing TTB (2 eq.) maintained at -20 °C (bath temperature). After 5 min the cooling bath was removed and the temperature of the stirred solution was allowed to rise to ambient. The reaction mixture was then poured into saturated hydrogen carbonate solution, the gelatinous precipitate produced filtered off (Celite), the organic layer separated, washed with brine, dried and solvent evaporated under reduced pressure.

Aziridination of styrene with Q¹NHOAc 5

General procedure 2 was followed using Q¹NH₂ 4⁹ (0.2 g, 0.63 mmol), LTA (0.31 g, 0.69 mmol), HMDS (0.20 g, 1.25 mmol) and styrene (0.13 g, 1.25 mmol) in dry dichloromethane (2 cm³). After work-up, examination of the residue by NMR spectroscopy indicated two diastereoisomers of aziridine 7 were present in a 5 : 1 ratio from integral comparison of signals at δ 2.71 and 2.65 ppm respectively and comparison with previously reported spectra.⁴

Aziridination of β-methylstyrene with Q¹NHOAc 5

General procedure 2 was followed using Q¹NH₂ 4⁹ (1 g, 3.13 mmol), LTA (1.53 g, 3.45 mmol), HMDS (1 g, 6.28 mmol) and β-methylstyrene (0.74 g, 6.28 mmol) in dry dichloromethane (15 cm³). The crude product was chromatographed over silica with light petroleum–ethyl acetate (10:1) as eluent to give a mixture of *aziridine* 9 diastereoisomers ($R_f 0.30$) as a colourless oil (0.82 g, 60%). (Found: M⁺ 435.234. C₂₅H₃₃N₃O₂Si requires M 435.234) v_{max}/cm^{-1} 1675s and 1600s; m/z (%) 435 $(M^+, 6)$, 247 (72), 132 (100) and 73 (30); δ_H (400 MHz) (d₅-pyridine) (mixture of N-invertomers) major N-invertomer (Ph and Q^1 cis) 0.00 (3H, s, CH₃SiCH₃), 0.06 (3H, s, CH₃-SiCH₃), 0.68 (9H, s, Bu^t), 0.98 (3H, d, J 5.0, azir. CH₃), 1.52 (3H, d, J 6.2, CH₃CHO), 2.87 (1H, dq, J 6.0 and 5.0, azir. H-3), 3.51 (1H, d, J 6.0, azir. H-2), 5.18 (1H, q, J 6.2, CH₃CHO), 6.99-7.67 [8H, m, 6-H, 7-H, 8-H(Q) and CHPh] and 8.20 [1H, dd, J 8.0 and 1, 5-H(Q)]; minor N-invertomer (observable signals) & 1.01 (3H, d, J 5.0, azir. CH₃), 1.64 (3H, d, J 6.2, CH₃CHO), 3.80 (1H, dq, J 5.6 and 5.0, azir. H-3), 4.00 (1H, d, J 5.6, azir. H-2), 5.47 (1H, q, J 6.2, CH₃CHO) and 8.28 [1H, d, J 8.0, 5-H(Q)]. From integral comparison of signals at δ 5.18 and 5.47, the N-invertomer ratio was 1.3 : 1; minor diastereoisomer (mixture of N-invertomers) major N-invertomer (phenyl and Q^1 trans); (observable signals) δ 2.92 (1H, dq, J 5.0 and 6.0, azir. H-3), 4.06 (1H, br d, J 5, azir. H-2) and 5.41 (1H, q, J 6.2, CH₃CHO); minor N-invertomer (observable signal) δ 3.47 (1H, d, J 5.6, azir. H-2). From integral comparison of signals at δ 4.06 and 3.47, the *N*-invertomer ratio was ~2 : 1. The ratio of diastereoisomers present was 5:1 from integral comparison of signals at δ 5.18 + 5.47 : 4.06 + 3.47 in the crude reaction product.

Kieselgel chromatography of the 5 : 1 ratio of diastereoisomers with light petroleum–ethyl acetate as eluent gave a fraction containing the two diastereoisomers in a 13 : 1 ratio from integral comparison of signals *inter alia* at δ 5.18 + 5.47 : 4.06 + 3.47.

Aziridination of (E)-cinnamyl chloride with Q¹NHOAc 5

General procedure 2 was followed using Q¹NH₂ 4⁹ (1 g, 3.13 mmol), LTA (1.53 g, 3.45 mmol), HMDS (1.52 g, 9.40 mmol) and cinnamyl chloride (1.43 g, 9.40 mmol) in dry dichloromethane (15 cm³). Chromatography of the product over silica with light petroleum-ethyl acetate (15:1) as eluent gave the major *aziridine* diastereoisomer 10 (R_f 0.29) as an oil which solidified after trituration with light petroleum and crystallised as a colourless solid (0.75 g, 51%) mp 119-121 °C (from ethanol). $[a]_{D} = -378 (c = 0.5, CHCl_3)$ (Found: C, 63.5; H, 6.9; N, 8.9. C₂₅H₃₂ClN₃O₂Si requires C, 63.85; H, 6.85; N, 8.95%); $\delta_{\rm H}$ (400 MHz) (mixture of *N*-invertomers) major *N*-invertomer (phenyl and Q^1 cis): 0.09 (3H, s, CH₃SiCH₃), 0.11 (3H, s, CH₃SiCH₃), 0.70 (9H, s, Bu'), 0.88 (3H, d, J 6.1, CH₃CHO), 3.76 (1H, dd, J 11.5 and 7.1, CHHCl), 3.78 (1H, d, J 3.9, azir. H-2), 4.13 (1H, m, azir. H-3), 4.48 (1H, dd, J 11.5 and 3.9, CHHCl), 5.05 (1H, q, J 6.1, CH₃CHO), 6.80-7.62 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.24 [1H, dd, J 8.5 and 0.6, 5-H(Q)]; minor N-invertomer (observable signals) δ 1.43 (3H, d, J 6.4, CH₃CHO), 3.24 (1H, m, azir. H-3), 3.61 (1H, dd, J 11.9 and 7.5 CHHCl), 4.54 (1H, d, J 4.6, azir. H-2), 5.43 (1H, q,

Repetition of reaction above and chromatography of the crude product using a Chromatotron with light petroleumethyl acetate (15:1) as eluent, gave a pure sample of minor aziridine 10 diastereoisomer ($R_f 0.29$) as a colourless oil. $[a]_D =$ 54 (c = 1, CHCl₃) (Found: M⁺ 469.195. C₂₅H₃₂ClN₃O₂Si requires M 469.195); $\delta_{\rm H}$ (mixture of N-invertomers) major N-invertomer (phenyl and Q cis) -0.03 (3H, s, CH₃SiCH₃), -0.01 (3H, s, CH₃SiCH₃), 0.83 (9H, s, Bu^t), 1.60 (3H, d, J 6.1, CH₃CHO), 3.69 (1H, d, J 3.9, azir. H-2), 3.77 (1H, dd, J 11.5 and 7.5, CHHCl), 4.33 (1H, dd, J 11.5 and 3.9, CHHCl), 4.40 (1H, m, azir. H-3), 4.95 (1H, q, J 6.1, CH₃CHO), 6.99-7.66 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.22 [1H, d, J 8.5, 5-H(Q)]; minor N-invertomer (observable signals) δ 0.00 (3H, s, CH₃SiCH₃), 0.04 (3H, s, CH₃SiCH₃), 0.85 (9H, s, Bu'), 1.63 (3H, d, J 6.1, CH₃CHO), 3.25 (1H, m, azir. H-3), 3.61 (1H, dd, J 11.5 and 7.5, CHHCl), 4.65 (1H, d, J 3.9, azir. H-2), 5.38 (1H, q, J 6.1, CH₃CHO) and 8.19 [1H, d, J 8.5, 5-H(Q)]. From integral comparison of the signals at δ 4.33 and 4.65, the ratio of major : minor N-invertomers was 2 : 1; an NMR spectrum (400 MHz) of the crude product above showed the ratio of major : minor aziridine diastereoisomers of 10 was 10 : 1 from integral comparison of signals at δ 4.48 + 4.54 : 4.33 + 4.65 ppm; *m*/*z* (%) 469 (M⁺, 0.7), 412 (34), 247 (100), 166 (25), 130 (20), 129 (24), 117 (22) and 73 (27).

Aziridination of (E)- β -dichloromethylstyrene with Q¹NHOAc 5

General procedure 2 was followed using Q¹NH₂ 4⁹ (0.4 g, 1.25 mmol), LTA (0.61 g, 1.38 mmol), HMDS (0.61 g, 3.76 mmol) and β -dichloromethylstyrene (0.68 g, 3.76 mmol) in dry dichloromethane (5 cm³). Flash chromatography of the product over silica with light petroleum-ethyl acetate (15:1) as eluent gave the major aziridine 11 diastereoisomer ($R_{\rm f}$ 0.29) as a colourless solid (0.26 g, 41%) mp 130-132 °C (from ethanol), $[a]_{D} = -366 \ (c = 1, \text{CHCl}_{3}) \ (\text{Found: C, 59.5; H, 6.25; N, 8.4.})$ $C_{25}H_{31}Cl_2N_3O_2Si$ requires C, 59.5; H, 6.2; N, 8.35%); δ_H (mixture of N-invertomers) major N-invertomer (phenyl and Q cis) 0.00 (3H, s, CH₃SiCH₃), 0.02 (3H, s, CH₃SiCH₃), 0.70 (9H, s, Bu'), 0.83 (3H, d, J 6.3, CH₃CHO), 3.96 (1H, d, J 5.4, azir. H-2), 4.48 (1H, dd, J 5.4 and 3.8, azir. H-3), 4.98 (1H, q, J 6.3, CH₃CHO), 6.39 (1H, d, J 3.8, CHCl₂), 6.90-7.70 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.13 [1H, dd, J 7.8 and 1, 5-H(Q)]; v_{max}/cm^{-1} 2950m, 3060m, 2860m, 1670s and 1600s; m/z (%) 503 (M⁺, 0.2), 446 (26), 247 (100), 164 (26), 130 (24), 75 (34) and 73 (65); minor N-invertomer (observable signals) δ 1.58 (3H, d, J 6.3, CH₃CHO), 3.25 (1H, dd, J 5.4 and 3.8, azir. H-3), 5.63 (1H, q, J 6.3, CH₃CHO), 5.81 (1H, d, J 3.8, azir. H-2) and 6.53 (1H, d, J 5.4, CHCl₂). From integral comparison of the signals at δ 4.98 and 5.63, the ratio of major : minor *N*-invertomers was 7 : 1; minor diastereoisomer (observable signal) δ 3.86 (1H, d, J 5.4, azir. H-2). Examination of the NMR spectrum of the crude product showed the ratio of major : minor diastereoisomers of aziridine 11 was 20 : 1 from comparison of the signals at δ 3.96 and 3.86 ppm. A crystal of aziridine 11 suitable for X-ray crystallography was grown by crystallisation from ethanol.

Identification of the major diastereoisomer of aziridine 7: desilylation of aziridine 7

To a solution of the crude aziridine 7 prepared as described above (0.20 g, 0.48 mmol) in THF (3 cm³) at 0 $^{\circ}$ C was added a solution of tetrabutylammonium fluoride (TBAF) in THF (1 M, 0.25 g, 0.96 mmol) and the mixture stirred for 30 min at

0 °C and then at room temp. for 15 min. The reaction mixture was poured into ether (10 cm^3) , the solution washed with water (10 cm³), brine (10 cm³), dried and then evaporated under reduced pressure to give a yellow oil whose NMR spectrum showed the presence of two aziridine 17 diastereoisomers in a ratio 5 : 1 from integral comparison of signals at δ 2.75 and 2.65 ppm respectively. This mixture was separated using a Chromatotron and eluting with light petroleum-ethyl acetate (5:1) to give the major *aziridine* 17 diastereoisomer ($R_r 0.18$) as a colourless oil (0.1 g, 69%). $[a]_{D} = 320$ (c = 0.8, CHCl₃) (Found: M⁺ 307.132. C₁₈H₁₇N₃O₂ requires M 307.132); $\delta_{\rm H}$ 1.51 (3H, d, J 6.3, CH₃CHOH), 2.75 (1H, dd, J 5.0 and 1.9, azir. H-3 trans to Q¹), 3.70 (1H, dd, J7.9 and 1.9, azir. H-3 cis to Q¹), 4.03 (1H, dd, J 7.9 and 5.0, azir. H-2), 4.49 (1H, d, J 7.6, CH₃CHOH), 5.15 (1H, dq, J 7.6 and 6.3, CH₃CHOH), 7.30-7.78 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.22 [1H, dd, J 7.9 and 1, 5-H(Q)]; v_{max}/cm⁻¹ 1670s and 1600s; *m*/*z* (%) 307 (M⁺, 31), 264 (40), 262 (64), 216 (63), 201 (27), 189 (60), 175 (20), 173 (100), 172 (81), 147 (26), 130 (27), 119 (33), 118 (74), 117 (66), 103 (61), 91 (77), 90 (42), 84 (20) and 76 (34).

Further elution with light petroleum–ethyl acetate (5 : 1) gave the minor *aziridine* **17** diastereoisomer also as a colourless oil (0.03 g, 20%). $[a]_D = -94$ (c = 0.5, CHCl₃) (Found: M⁺ 307.132). C₁₈H₁₇N₃O₂ requires *M* 307.132); δ_H 1.50 (3H, d, *J* 6.3, CH₃CHOH), 2.65 (1H, dd, *J* 5.0 and 1.9, azir. H-3 *trans* to Q), 3.49 (1H, dd, *J* 7.9 and 1.9, azir. H-3 *cis* to Q), 4.46 (1H, dd, *J* 7.9 and 5.0, azir. H-2 and d, *J* 7.6, CH₃CHOH), 5.35 (1H, dq, *J* 7.6 and 6.3, CH₃CHOH), 7.38–7.78 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.21 [1H, dd, *J* 7.9 and 1, 5-H(Q)]; *m/z* (%) 307 (M⁺, 22), 264 (25), 262 (38), 216 (77), 201 (29), 189 (39), 174 (21), 173 (73), 172 (58), 134 (72), 130 (21), 119 (56), 118 (49), 115 (36), 105 (55), 104 (26), 103 (56) 92 (71), 91 (100), 90 (31), 78 (37), 77 (42) and 76 (25).

Aziridination of styrene with Q2NHOAc-TTB

General procedure 3 was followed using Q^2NH_2 19^{5b} (0.2 g, 0.98 mmol), LTA (0.48 g, 1.07 mmol) and added to a stirred solution of TTB (0.66 g, 1.95 mmol) and styrene (0.20 g, 1.95 mmol) in dry dichloromethane (2 cm³) maintained at -20 °C (bath temperature). After work-up, examination of the residue by NMR spectroscopy showed the two aziridine 17 diastereo-isomers (0.09 g, 31%) were present in a 6.5 : 1 ratio from integral comparison of signals at δ 2.75 and 2.65 ppm respectively in its NMR spectrum. These major and minor aziridine diastereoisomers were shown to be identical to the major and minor diastereoisomers isolated in the previous experiment by comparison of their NMR spectra.

Identification of the major diastereoisomer of aziridine 9: desilylation of aziridine 9

To a stirred solution of the aziridine 7 (dr 5 : 1) (0.25 g, 0.57 mmol) in THF (2 cm³) at 0 °C was added a solution of TBAF in THF (1 M, 0.18 g, 0.68 mmol) and the mixture stirred for 30 min at 0 °C and then at room temp. for 15 min. The reaction mixture was poured into ether (10 cm³), the solution washed with water (10 cm³), then brine (10 cm³), dried and concentrated under reduced pressure to give a colourless oil. Flash chromatography of the oil over silica with light petroleum-ethyl acetate (10:1) as eluent gave a mixture of aziridine 18 (R_f 0.34) as an oil (0.11 g, 59%) together with unchanged aziridine 9 (0.09 g, 38%). Trituration of the oil with light petroleum gave the major aziridine diastereoisomer 18 as a colourless solid mp 127–128 °C (from ethanol). $[a]_{D} = -59$ (c =0.5, CHCl₃) (Found: C, 71.0; H, 5.95; N, 13.1. C₁₉H₁₉N₃O₂ requires C, 71.0; H, 6.0; N, 13.15%); $\delta_{\rm H}$ (mixture of Ninvertomers) major N-invertomer (phenyl and Q trans) 1.42 (3H, d, J 6.0, CH₃CHOH), 1.45 (3H, d, J 6.6, azir. CH₃), 3.08 (1H, dq, J 6.6 and 5.0, azir. H-3), 3.97 (1H, d, J 5.0, azir. H-2), 4.63 (1H, d, J 6.3, CH₃CHOH), 5.15 (1H, dq, J 6.3 and 6.0,

CH₃CHOH), 6.95–7.78 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.23 [1H, dd, J 7.9 and 1, 5-H(Q)]; minor N-invertomer (observable signals) δ 1.31 (3H, d, J 6.6, azir. CH₃), 1.70 (3H, d, J 6.0, CH₃CHOH), 3.60 (1H, d, J 6.0, CH₃CHOH), 4.28 (1H, m, azir. H-3), 4.92 (1H, m, CH₃CHOH) and 8.12 [1H, d, J 7.9, 5-H(Q)]. From integral comparison of signals at δ 4.63 and 3.60, the N-invertomer ratio of the major aziridine diastereoisomer was 2.7 : 1; v_{max}/cm⁻¹ 1690s and 1600s; m/z (%) 321 (M⁺, 5), 132 (100) and 118 (20). Observable signals from the minor diastereoisomer in the crude reaction product were present for major N-invertomer (phenyl and Q trans) at δ 4.15 (1H, d, J 5.0, azir. H-2) and for the minor N-invertomer at 3.50 (1H, d, J 5.0, azir. H-2) respectively with the ratio of N-invertomers 1.9:1 from comparison of these two signals. The NMR spectrum of the crude product showed the ratio of major : minor diastereoisomers was 5:1 from integral comparison of signals at δ 4.63 + 3.60 : 4.15 + 3.50 ppm.

Aziridination of β-methylstyrene with Q²NHOAc 22–TTB

General procedure 3 was followed using Q^2NH_2 **19**¹⁴ (0.4 g, 1.95 mmol), LTA (0.95 g, 2.15 mmol), TTB (1.33 g, 3.9 mmol) and β -methylstyrene (0.46 g, 3.9 mmol) in dry dichloromethane (6 cm³). An NMR spectrum of the crude product showed two aziridine diastereoisomers present in a 5 : 1 ratio which were identical to the major and minor aziridines **18** respectively in the crude reaction product from the previous experiment.

Aziridination of β-methylstyrene with Q³NHOAc 24–TTB

General procedure 3 was followed using Q³NH₂ 21^{5a} (0.2 g, 0.81 mmol), LTA (0.4 g, 0.90 mmol), TTB (0.55 g, 1.62 mmol) and β -methylstyrene (0.19 g, 1.62 mmol) in dry dichloromethane (3 cm³). An NMR spectrum of the crude product indicated only one aziridine diastereoisomer was present and, after trituration with ethanol, some of this aziridine crystallised out; a further quantity was obtained by Chromatotron chromatography with light petroleum-ethyl acetate as eluent (5:1) to give aziridine 27 (R_f 0.27) as a colourless solid (total 0.14 g, 49%) mp 157–158 °C (from ethanol). $[a]_{D} = 60 (c = 0.5, CHCl_{3})$ (Found: C, 72.35; H, 6.95; N, 11.4. C₂₂H₂₅N₃O₂ requires C, 72.7; H, 6.95; N, 11.55%); $\delta_{\rm H}$ (mixture of N-invertomers) major N-invertomer (phenyl and Q trans): 0.68 (9H, s, Bu^t), 1.32 (3H, d, J 5.4, azir. CH₃), 3.21 (2H, m, azir. H-3 and H-2), 3.64 (1H, d, J 10.4, Bu'CHOH), 4.70 (1H, d, J 10.4, Bu'CHOH), 7.26-7.70 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.20 [1H, dd, J 8.5 and 1.3, 5-H(Q)]; v_{max}/cm^{-1} 1765w, 1680s and 1590s; m/z(%) 364 (MH⁺, 63), 307 (20), 154 (100), 137 (52), 136 (71) and 132 (40); signals from the minor invertomer were observable at δ 0.93 (9H, s, Bu'), 1.65 (3H, d, J 5.4, azir. CH₃). The ratio of *N*-invertomers was 3.6 : 1 from comparison of signals at δ 0.68 and 0.93.

Further elution with light petroleum–ethyl acetate (5 : 1) (Chromatotron) gave an oily ring-opened alcohol **29** (0.035 g, 11%). (Found: M⁺ 382.213. C₂₂H₂₈N₃O₃ requires *M* 382.213); $\delta_{\rm H}$ 0.86 (3H, d, *J* 6.6, NHCHCH₃), 1.03 (9H, s, Bu'), 2.96 (1H, d, *J* 6.6, CHOHPh), 3.62 (1H, d, *J* 10.1, Bu'CHOH), 3.71 (1H, m, CHCH₃), 4.60 (1H, dd, *J* 6.6 and 6.0, CHOHPh), 5.28 (1H, d, *J* 10.1, Bu'CHOH), 6.16 (1H, d, *J* 2.5, NH), 7.33–7.82 [8H, m, 6-H, 7-H, 8-H (Q) and CH(Ph)] and 8.28 [1H, dd, *J* 7.9 and 1.6, 5-H(Q)]; $v_{\rm max}$ /cm⁻¹ 3500m, 1680s, 1610w, 1595s and 1565s; *m*/*z* (%) 382 (M⁺, 0.4), 274 (100), 256 (56), 215 (68), 176 (29), 175 (31) and 147 (22).

The above experiment was repeated, but in the absence of TTB. General procedure 1 was followed using Q^3NH_2 21^{5a} (0.2 g, 0.81 mmol), LTA (0.4 g, 0.90 mmol) and β -methylstyrene (0.19 g, 1.62 mmol) in dry dichloromethane (3 cm³). Examination of the NMR spectrum of the crude product showed two aziridine diastereoisomers were present in a 1.6 : 1 ratio from integration of signals at δ 4.70 : 4.95 + 4.63 with the major one identical to that isolated above. Chromatotron chromatography

of the crude product with light petroleum-ethyl acetate as eluent (5 : 1) gave the minor diastereoisomer of *aziridine* 27 ($R_{\rm f}$ 0.42) as a colourless oil (0.07 g, 23%). (Found: M⁺ 363.194. $C_{22}H_{25}N_3O_2$ requires M 363.194); δ_H major invertomer (phenyl and Q trans): 1.05 (9H, s, Bu'), 1.33 (3H, d, J 5.4, azir. CH₃), 2.94 (1H, dq, J 5.4 and 5.4, azir. H-3), 3.80 (1H, d, J 10.4, Bu'CHOH), 3.88 (1H, d, J 5.4, azir. H-2), 4.95 (1H, d, J 10.4, Bu'CHOH), 6.91-7.76 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.23 [1H, d, J 8.5, 5-H(Q)]; m/z (%) 363 (M⁺, 0.7), 132 (100), 105 (29) and 83 (40); signals from the minor invertomer were observable at δ 0.93 (9H, s, Bu'), 1.68 (3H, d, J 5.4, azir. CH₃), 2.78 (1H, d, J 8.8, Bu'CHOH), 3.55 (1H, d, J 6.0, azir. H-2) and 4.63 (1H, d, J 8.8, Bu'CHOH). The ratio of *N*-invertomers was 2.7 : 1 from comparison of signals at δ 4.95 and 4.63. Signals from this aziridine were absent from the spectrum of the crude product in the aziridination as above carried out in the presence of TTB.

Further elution with light petroleum–ethyl acetate (5 : 1) gave the major *aziridine* diastereoisomer of **27** (R_f 0.31) as a colourless solid (0.09 g, 31%) identical with that isolated previously.

Aziridination of (E)-cinnamyl chloride with Q³NHOAc 24–TTB

General procedure 3 was followed using Q3NH2 215a (0.3 g, 1.21 mmol), LTA (0.59 g, 1.33 mmol), TTB (0.82 g, 2.42 mmol) and cinnamyl chloride (0.37 g, 2.42 mmol) in dry dichloromethane (5 cm³). Crystallisation of the product by addition of ethanol gave aziridine 28 (R_f 0.29) as a colourless solid (0.22 g, 46%) mp 149–151 °C (from ethanol). $[a]_{\rm D} = +190$ (c = 0.5, CH₂Cl₂) (Found: C, 66.15; H, 6.1; N, 10.35. C₂₅H₂₅ClN₃O₂ requires C, 66.4; H, 6.1; N, 10.55%); $\delta_{\rm H}$ (mixture of N-invertomers) major N-invertomer (phenyl and Q cis): 0.75 (9H, s, Bu'), 3.29 (1H, dd, J 11.3 and 9.4, CHHCl), 3.56 (1H, m, azir. H-3), 3.57 (1H, J10.4, Bu'CHOH), 3.66 (1H, d, J 5.0, azir. H-2), 4.30 (1H, dd, J 11.3 and 4.7, CHHCl), 4.81 (1H, d, J 10.4, Bu'CHOH), 7.0-7.80 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.25 [1H, dd, J 7.9 and 1, 5-H(Q)]; v_{max}/cm^{-1} 1660s and 1590s; m/z (%) 398 (M⁺, 1.1), 348 (73), 312 (61), 214 (22), 189 (33), 176 (24), 175 (61), 168 (24), 166 (67), 147 (20), 132 (28), 130 (100), 117 (65), 116 (30), 115 (20), 104 (44), 103 (83), 77 (32), 76 (25) and 57 (33); minor N-invertomer (observable signals): δ 1.00 (9H, s, Bu'), 3.98 (1H, d, J 5.0, azir. H-2), 4.50 (1H, s, br, Bu'CHOH) and 8.02 [1H, dd, J 7.9 and 1, 5-H(Q)]; from integration comparison of the signals at δ 8.25 : 8.02 the ratio of N-invertomers was 4 : 1.

Desilylation of aziridine 10

To a stirred solution of aziridine 10 (0.09 g, 0.19 mmol) in THF (1 cm³) at 0 °C was added a solution of TBAF in THF (1 M, 0.08 g, 0.29 mmol) and the mixture stirred for 30 min at 0 °C and then at room temp. for 15 min. The reaction mixture was poured into ether (5 cm³), the solution washed with water (5 cm³), then brine (5 cm³), dried and concentrated under reduced pressure to give a colourless oil whose NMR spectrum showed the presence of aziridine ether 34a and imine 35 in a 1.6 : 1 ratio from integration comparison of signals at δ 8.11 and 8.37 ppm respectively (see below). Flash chromatography of the product over silica with light petroleum-ethyl acetate (2:1) as eluent gave an oil $(R_f 0.53)$ (0.03 g, 54%). Trituration of this oil with light petroleum gave the cyclic aziridine ether 34a as a colourless solid, mp 171–173 °C (from ethanol). $[a]_{D} = -104$ $(c = 0.8, \text{CHCl}_3)$ (Found: C, 71.2; H, 5.5; N, 13.1. C₁₉H₁₇N₃O₂ requires C, 71.45; H, 5.35; N, 13.15%); $\delta_{\rm H}$ 1.84 (3H, d, J 7.2, CH₃CHO), 3.11 (1H, ddd, J 10.7, 5.3 and 3.5, azir. H-3), 3.27 (1H, d, J 5.3, azir. H-2), 3.58 (1H, dd, J 13.5 and 10.7, CHH), 4.42 (1H, dd, J 13.5 and 3.5, CHH), 5.10 (1H, q, J 7.2, CH₃CHO), 7.22-7.62 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.11 [1H, ddd, J 8.2, 1.6 and 0.6, 5-H(Q)]; v_{max}/cm⁻¹ 1670s and 1590s; m/z (%) 319 (M⁺, 23), 216 (89), 215 (100), 214 (27), 188 (21), 187 (27), 173 (93), 156 (20), 130 (21), 117 (60), 115

(34), 104 (20), 103 (21), 102 (25), 90 (20), 84 (25) and 77 (24). For comparison, signals of the other diastereoisomer **34b** are found at δ 1.75 (3H, d, *J* 7.0, CH₃CHO), 3.25 (1H, ddd, *J* 13.1, 5.3 and 3.6, azir. H-3), 3.4 (1H, d, *J* 5.3, azir. H-2), 3.6 (1H, dd, *J* 13.5 and *ca*. 13, C*H*H), 4.5 (1H, dd, *J* 13.1 and 3.6, CH*H*), 5.6 (1H, q, *J ca*. 7, CH₃CHO), 7.4–7.75 [8H, m, 6-H, 7-H, 8-H(Q) and C*H*(Ph)] and 8.25 [1H, ddd, *J* 7.7 and *ca*. 1, 5-H(Q)].⁴

Further elution of the column using the same solvent mixture gave imine **35** as a colourless oil ($R_f 0.37$) (0.015 g, 23%). (Found: M⁺ 319.132. C₁₉H₁₇N₃O₂ requires *M* 319.132); $\delta_{\rm H}$: 1.67 (3H, d, *J* 6.6, CH₃CHO), 2.85 (2H, m, OCH₂), 3.05 (2H, m, CH₂CN), 5.06 (1H, q, *J* 6.6, CH₃CHO), 7.22–7.77 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.37 [1H, dd, *J* 7.9 and 1.3, 5-H(Q)]; $\delta_{\rm C}$ 17.12 (CH₃), 30.9 (CH₂CH₂), 33.4 (CH₂CH₂), 64.1 (CH₃CHO), 121.3 [CCO(Q)], 125.9–133.3 [4 × CH(Q) and 5 × CH(Ph)], 138.8 [C(Ph)], 144.8 [C=N(Q)], 145.2, 155.6, 157.4 [C–N(Q), N=C(Ph) and CO(Q)]; *m/z* (%) 319 (M⁺, 68), 215 (26), 186 (20), 173 (27), 131 (41), 104 (43), 85 (91), 77 (44), 69 (41) and 57 (100).

Aziridination of stilbene with Q¹NHOAc 5

General procedure 2 was followed using Q¹NH₂ 4⁹ (0.2 g, 0.63 mmol), LTA (0.31 g, 0.69 mmol), HMDS (0.25 g, 1.54 mmol) and styrene (0.14 g, 0.75 mmol) in dry dichloromethane (3 cm³). Flash chromatography of the crude product over silica with light petroleum–ethyl acetate (5 : 1) as eluent gave a pure sample of the minor *aziridine* 12 diastereoisomer (R_f 0.56) as a colourless oil (0.007 g, 2%). δ_H –0.20 (3H, s, CH₃SiCH₃), 0.00 (3H, s, CH₃SiCH₃), 0.95 (9H, s, Bu'), 1.84 (3H, d, *J* 6.3, CH₃CHO), 3.95 (1H, d, *J* 6, azir. H-2 *trans* to Q), 4.88 (1H, d, *J* 6, azir. H-3 *cis* to Q), 4.95 (1H, q, *J* 6.3, CH₃CHO), 7.20–7.84 [13H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.16 [1H, d, *J* 7.8, 5-H(Q)].

Further elution with the same solvent mixture gave major aziridine **12** diastereoisomer ($R_{\rm f}$ 0.48) as an oil which, on trituration with light petroleum, gave a colourless crystalline product (0.053 g, 34%). [a]_D = -599 (c = 0.6, CHCl₃) (Found: M⁺ 497.250. C₃₀H₃₅N₃O₂Si requires *M* 497.250); $\delta_{\rm H}$ 0.00 (3H, s, CH₃SiCH₃), 0.02 (3H, s, CH₃SiCH₃), 0.69 (9H, s, Bu^t), 0.81 (3H, d, *J* 6.3, CH₃CHO), 3.69 (1H, d, *J* 6.0, azir. H-3 trans to Q), 4.61 (1H, d, *J* 6.0, azir. H-2 cis to Q), 5.07 (1H, q, *J* 6.3, CH₃CHO), 6.86–7.55 [13H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.14 [1H, d, *J* 7.8, 5-H(Q)]. From the NMR spectrum of the crude product the ratio of major : minor diastereoisomers was 3 : 1 from integration of signals at δ 5.07 and 4.95 ppm. $v_{\rm max}/{\rm cm}^{-1}$ 1660s and 1600s; m/z (%) 497 (M⁺, 0.7), 247 (47), 195 (15) and 194 (100).

Aziridination of methyl cinnamate with Q¹NHOAc 5

General procedure 1 was followed using Q¹NH₂ 4⁹ (0.3 g, 0.94 mmol), LTA (0.46 g, 1.03 mmol) and methyl cinnamate (0.31 g, 1.88 mmol) in dry dichloromethane (4 cm³). The NMR spectrum of the crude product revealed the presence of diastereoisomers of aziridine 13 (0.15 g, 33%) together with 3H-quinazolinone 14 in a 3 : 1 ratio, from integration of signals at δ 4.00 + 3.96 ppm and 9.28 respectively. Separation by flash chromatography over silica with light petroleum-ethyl acetate (7:1) as eluent gave major *aziridine* 13 diastereoisomer ($R_{\rm f}$ 0.32) as a colourless oil. (Found: M⁺ 479.234. C₂₆H₃₃N₃O₄Si requires M 479.224); $\delta_{\rm H}$ -0.11 (3H, s, CH₃SiCH₃), 0.00 (3H, s, CH₃SiCH₃), 0.70 (9H, s, Bu'), 1.24 (3H, d, J 6.3, CH₃CHO), 3.51 (3H, s, CO₂CH₃), 3.58 (1H, d, J 4.7, azir. H-3 or 2), 4.00 (1H, d, J 4.7, azir. H-2 or 3), 5.03 (1H, q, J 6.3, CH₃CHO), 7.25-7.55 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 7.98 [1H, d, J 7.9, 5-H(Q)]; v_{max}/cm⁻¹ 1760s, 1710s and 1625s; m/z (%) 479 (M⁺, 1), 422 (29), 248 (27), 247 (100) and 75 (22); observable signals from the minor diastereoisomer were present in the crude reaction product at δ -0.18 (3H, s, CH₃Si-CH₃), -0.12 (3H, s, CH₃SiCH₃), 0.55 (9H, s, Bu'), 1.62 (3H, d, J 6.3, CH₃CHO) and 3.96 (1H, d, J 4.7, azir. H-3 or 2). The

NMR spectrum of the crude product showed the ratio of major : minor diastereoisomers was 3 : 1 from integration of signals at δ 4.00 and 3.96 ppm.

Aziridination of (E)-cinnamyl chloride with Q⁴NHOAc 38

General procedure 2 was followed using Q⁴NH₂ 37^{5b} (0.2 g, 0.82 mmol), LTA (0.4 g, 0.90 mmol), HMDS (0.26 g, 1.63 mmol) and cinnamyl chloride (0.25 g, 1.63 mmol) in dry dichloromethane (3 cm³). Flash chromatography of the product over silica with light petroleum-ethyl acetate (12:1) as eluent gave a mixture of the aziridine 40 as a mixture of diastereoisomers ($R_f 0.53$) as a colourless oil (0.21 g, 64%) which crystallised after standing in the freezer (4-5 days); the major aziridine 40 diastereoisomer was obtained on addition of ethanol as a colourless solid, mp 94-96 °C (from ethanol). (Found: C, 69.6; H, 6.75; N, 10.45. C₂₅H₂₆ClN₃O requires C, 69.75; H, 6.6; N, 10.6%); δ_H 0.36 (3H, d, CH₃CHBu^t), 0.88 (9H, s, Bu^t), 3.02 (1H, q, J 6.9, CH₃CHBu^t), 3.73 (1H, dd, J 11.3 and 3.7, CHHCl), 3.78 (1H, d, J 5.6, azir. H-2), 3.96 (1H, ddd, J 7.5, 5.6 and 3.7, azir. H-3), 4.52 (1H, dd, J 11.3 and 7.5, CHHCl), 6.85-7.62 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.25 [1H, dd, J 7.9 and 1.3, 5-H(Q)]; v_{max}/cm⁻¹ 1665s and 1590s; m/z (%) 395 (M⁺, 9), 347 (25), 346 (100), 339 (21), 175 (42), 174 (46), 173 (23), 166 (41), 131 (34), 130 (66), 121 (26), 119 (40), 117 (62), 116 (28), 103 (29), 82 (26), 77 (26), 57 (33) and 51 (37). Observable signals from the minor diastereoisomer of aziridine 40 in the NMR spectrum of the crude reaction product were present at δ 0.73 (9H, s, Bu^t), 1.03 (3H, d, J 6.9 CH₃CHBu^t), 4.33 (1H, dd, J11.3 and 3.7, CHHCl) and 8.21 [1H, d, J7.9, 5-H(Q)]. The NMR spectrum of the crude product showed the ratio of major : minor diastereoisomers present was 2 : 1 from integration of signals at δ 4.52 and 4.33 ppm. An X-ray structure determination was carried out for the major diastereoisomer of aziridine 40 on a crystal obtained from ethanol (see Fig. 2).

Aziridination of (E)-β-dichloromethylstyrene with Q⁴NHOAc 38

General procedure 2 was followed using Q⁴NH₂ 37^{5b} (0.2 g, 0.82 mmol), LTA (0.4 g, 0.90 mmol), HMDS (0.26 g, 1.63 mmol) and β -dichloromethylstyrene (0.18 g, 0.98 mmol) in dry dichloromethane (3 cm³). Trituration of the oily product with light petroleum gave major aziridine 41 diastereoisomer as a colourless solid (0.1 g, 29%) mp 163-165 °C (from ethanol). (Found: C, 64.0; H, 5.9; N, 9.8. C23H25Cl2N3O requires C, 64.2; H, 5.85; N, 9.75%); δ_H 0.28 (3H, d, J 6.6, CH₃CHBu^t), 0.72 (9H, s, Bu^t), 2.90 (1H, q, J 6.6, CH₃CHBu^t), 3.91 (1H, d, J 5.3, azir. H-2), 4.28 (1H, dd, J 5.3 and 3.5, azir. H-3), 6.39 (1H, d, J 3.5, CHCl₂), 6.83-7.50 [8H, m, 6-H, 7-H, 8-H(Q) and CH(Ph)] and 8.07 [1H, dd, J 8.2 and 1.6, 5-H(Q)]; v_{max}/cm⁻¹ 1665s and 1590s; m/z (%) 429 (M⁺, 2), 347 (38), 346 (100), 174 (22), 117 (21) and 116 (23). Observable signals from the minor diastereoisomer of aziridine 41 were present in the NMR spectrum of the crude reaction mixture at δ 2.62 (1H, q, J 6.6, CH₃CHBu^t), 3.81 (1H, d, J 5.3, azir. H-2) and 4.68 (1H, m, azir. H-3). From the NMR spectrum of the crude product, the ratio of major : minor diastereoisomers of aziridine 41 is 3.5 : 1 from integration of signals at δ 3.91 and 3.81 ppm.

Crystal structure determination

Crystal data for 40.† C₂₃H₂₆ClN₃O, M = 395.92, monoclinic, space group P_{2_1}/c , a = 9.750(9), b = 12.881(14), c = 16.715(9) Å, $\beta = 95.70(6)^\circ$, V = 2089(3) Å³, T = 200 K, Z = 4, μ (Mo-K α) = 0.201 mm⁻¹ colourless block, crystal dimensions $0.56 \times 0.53 \times$ 0.43 mm. Full matrix least squares based on F^2 gave $R_1 = 0.056$ for 2156 observed data ($F > 4\sigma(F)$) and $wR_2 = 0.237$ for all 2863 data, GOF = 1.072 for 257 parameters.

[†] CCDC reference number 169151. See http://www.rsc.org/suppdata/ p2/b1/b107327n/ for crystallographic files in .cif or other electronic format.

Data were measured on a Siemens P4 diffractometer with graphite monochromated Mo-K α radiation ($\lambda = 0.7107$ Å) using an ω scan technique. Three standard reflections monitored every 100 scans showed no significant variation in intensity, the reflections were corrected for Lorentz and polarisation effects.

The structure was solved by direct methods and refined by full-matrix least squares on F^2 using the program SHELXTL.¹⁵ All hydrogen atoms were included in calculated positions (C–H = 0.96 Å) using a riding model. All atoms were refined using anisotropic displacement parameters.

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