Imines and Derivatives. Part 24.[1] Nitrone Synthesis by Imine Oxidation using either a Peroxyacid or Dimethyldioxirane

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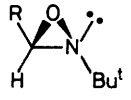
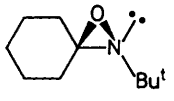
The oxidation of *N*-alkyl imines by *m*-chloroperoxybenzoic acid to yield nitrones was facilitated by (i) the presence of C-aryl substituents, (ii) steric inhibition of attack at the imino C-atom, (iii) electron donating *para*-substituents on the C-aryl substituent, (iv) non-hydroxylic solvents, (v) optimal conjugation between C-aryl substituents and the imino group, and (vi) less bulky *N*-alkyl groups.

The oxidation of *N*-alkyl imines by dimethyldioxirane (DMD) in dichloromethane–acetone solution yielded nitrones without evidence of oxaziridine formation. The yields of isolated nitrones were higher for C,C-diaryl imines and for imines bearing less bulky *N*-alkyl substituents. N–H substituted ketimines were found to yield oximes after reaction with dimethyldioxirane.

The peroxyacid oxidation of imines to yield oxaziridines has been extensively examined by Emmons and other workers.[2,3] To date there have been in excess of two hundred examples of this reaction showing exclusive oxaziridine formation. During the course of studies from these laboratories over the past twenty years[1,4] into the oxidation reaction of imines, oxaziridines have been identified as the 'normal' products from peroxyacid oxidation of imines. However, in a minority of cases, nitrones (imine *N*-oxides) were found to be major products. In this context the peroxyacid oxidation of aza-arenes to *N*-oxides is excluded. A preliminary report of the present work[5] attempted to rationalize the factors which influence the oxaziridine:nitrone ratio obtained after *m*-chloroperoxybenzoic acid (MCPBA) oxidation of imines. Very recently, while the present paper was in preparation, a report has appeared on the oxidation of imines to nitrones using potassium permanganate.[6]



(1) R = Pr^i
(2) R = Bu^t



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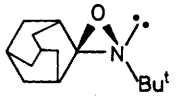

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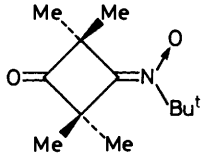

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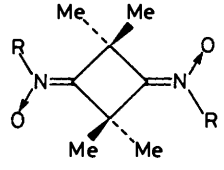
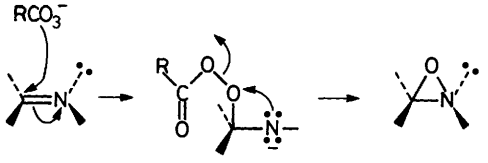


(6) R = Pr^i
(7) R = Bu^t

The peroxyacid oxidation of *N*-alkyl imines derived from alkyl aldehydes or dialkyl ketones has been reported[1,2] to yield oxaziridines exclusively *e.g.* compounds (**1**)–(**4**).[7]

The absence of the nitrone isomers of oxaziridines (**1**)–(**4**) was deduced from ^{1}H NMR analysis of the crude product mixtures and the high isolated yields of oxaziridines. The accepted mechanism for the synthesis of oxaziridines from the peroxyacid–imine reaction proceeds by a two-step process (Scheme 1). The initial step involves nucleophilic attack of the peroxyacid at the imino carbon atom in an orthogonal direction to the imino plane followed by an intramolecular nucleophilic ring closure step. Nucleophilic attack of the peroxyacid to yield oxaziridines is particularly favoured with C-alkyl substituted imines.



Scheme 1.

When orthogonal nucleophilic attack is hindered by non-bonding interactions at the imino carbon then electrophilic attack at the more accessible imino nitrogen atom will occur to yield nitrones. Thus, nitrones (**5**)–(**7**) were formed exclusively by MCPBA oxidation of the corresponding imines under conditions where the corresponding oxaziridines would have been stable and would have been readily detected.[1,8] The bulky *gem*-dimethyl substituents on the cyclobutane ring may thus prevent attack at the imino C-atom and facilitate nitrone (**5**)–(**7**) formation. The latter products may also be preferred due to ring strain in the isomeric oxaziridines. Such observations led to the view that oxaziridine formation was the 'normal' reaction while nitrone formation could be regarded as 'abnormal' with peroxyacid as the oxidizing agent[5] (Scheme 2).

When *N*-alkyl imines derived from aryl aldehydes or diaryl ketones were oxidized with MCPBA, oxaziridines again appeared to be the normal products as shown by the series of

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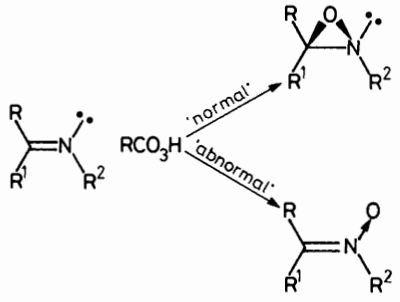
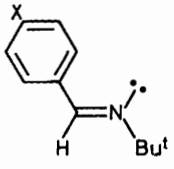
Table 1. Oxidation products of aldimines (**8a–j**) obtained by reaction of MCPBA (0 °C) or DMD (0–5 °C).

Imine (**8**)		Oxaziridine (**9**)			Nitrone (**10**)		
	X	$CDCl_3$[a,b]	CD_3OD[a,b]	Me_2CO–CH_2Cl_2[b,c]	$CDCl_3$[a,b]	CD_3OD[a,b]	Me_2CO–CH_2Cl_2[b,c]
(**a**)	NO_2	100	100	0	0	0	100(23,31)[d]
(**b**)	CN	100	100		0	0	
(**c**)	CF_3	100	100		0	0	
(**d**)	Br	100	100	0	0	0	100(17,56)[d]
(**e**)	Cl	100	100	0	0	0	100(15,47)[d]
(**f**)	F	100	100		0	0	
(**g**)	H	100	100	0	0	0	100(12,36)[d]
(**h**)	Me	91	100		9	0	
(**i**)	OMe	75	93		25	7	
(**j**)	NMe_2	25	50		75	50	

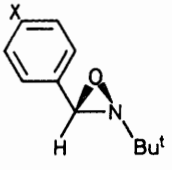
[a] Solvent in which MCPBA oxidation occurred. [b] Relative % ratio of oxaziridine (**9**) to nitrone (**10**) was obtained by 250 and 300MHz ^{1}H NMR analysis of the crude product mixture. [c] Solvent mixture (1:2) in which DMD oxidation occurred. [d] (Isolated yield of nitrone, estimated yield of aldehyde).



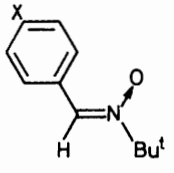
Scheme 2.



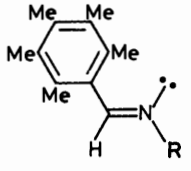
(**8**)



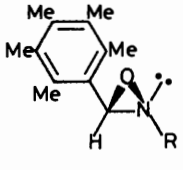
(**9**)



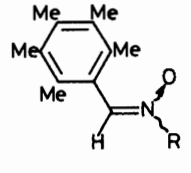
(**10**)



(**11a**) R = Me
(**11b**) R = Bu^t



(**12a**) R = Me
(**12b**) R = Bu^t



(**13a**) R = Me
(**13b**) R = Bu^t

para-substituted aldimine (**8a–i**) oxidation products (**9a–i**) and (**10a–i**) indicated in Table 1.

Only when an electron donating *para*-substituent was present in the imines [*e.g.* (**8h–j**)] was a significant proportion of nitrone formed [*e.g.* (**10h–j**)]. Unfortunately the latter category of imines (**8h–j**) yielded the least stable of the oxaziridine products [*e.g.* (**9h–j**)]. The observed proportion of nitrone (**10j**) may be slightly magnified due to a minor degree of spontaneous isomerization of the least stable oxaziridine (**9j**).[9] From the limited results in Table 1 it is clear that nitrones are more readily formed when the *para*-substituted aryl ring can conjugate with the imino bond thus rendering the N-atom more susceptible to electrophilic attack by the peroxyacid. The extra 'push-pull' delocalisation energy will stabilize the nitrone product, but is lost on oxaziridine formation (see Figure).

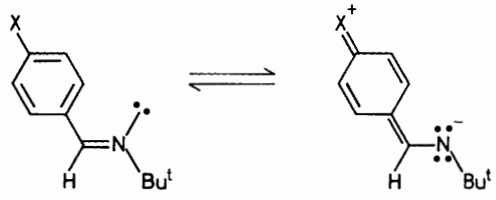


Figure.

A further trend to emerge from Table 1 was the increased proportion of oxaziridines (**9h, i** and **j**) formed in a hydroxylic solvent. This has previously been observed and accounted for by intermolecular hydrogen bonding between the imino N-atom and the solvent hydroxyl group.[10a,b] The latter type of bonding thus inhibits oxidative attack at the N-atom and leads to oxaziridine formation. An increased proportion of oxaziridine found after MCPBA oxidation in MeOH (relative to chlorinated hydrocarbon solvents) was consistently observed in a wide range of imines (Tables 1–3).

The efficiency of π-orbital overlap between the C-aryl and imino groups may be diminished by the addition of one or more C-aryl *ortho*-substituents. Previous studies[13] have indicated that the proportion of nitrone relative to oxaziridine products increases with *ortho*-substitution. In the present study, MCPBA oxidation of the pentamethylbenzaldehyde-derived imines (**11a, b**) yielded both *trans*-oxaziridines (**12a, b**) and nitrones (**13a, b**) (Table 2). The proportion of *E*- and *Z*-isomers of nitrone (**13a**) produced varied with oxidant and solvent. Thus, the *Z*-isomer was found as the major component using MCPBA as oxidant in CH_2Cl_2 (52%) or MeOH (78%). Under similar oxidation conditions imine (**11b**) yielded only the *Z*-isomer of nitrone (**13b**). The higher proportion of pentasubstituted nitrones (**13a**) and (**13b**) formed [relative to the unsubstituted or monosubstituted nitrones (**10a–j**)] may be accounted for by (i) steric inhibition of attack of peroxyacid at the imino carbon atom due to the pentasubstituted aryl group adopting a non-conjugated orthogonal conformation (**11a, b**), and (ii) steric inhibition of resonance between the *ortho*-substituted aryl ring

Table 2. Oxidation products obtained from imines (**11a, b**) and (**14a, b**) using MCPBA (0 °C) or DMD (0–5 °C).

Imine	Oxaziridine (%)				Nitrone (%)			
		CH_2Cl_2[a,b]	MeOH[a,b]	Me_2CO–CH_2Cl_2[b,c]		CH_2Cl_2[a,b]	MeOH[a,b]	Me_2CO–CH_2Cl_2[b,c]
(**11a**)[d]	(**12a**)	0	69	0	(**13a**)	100[d]	31[d]	100(71,28)[d,e]
(**11b**)	(**12b**)	19	91	0	(**13b**)	81[f]	9[f]	100(65,30)[e]
(**14a**)	(**15a**)	92	100	0	(**16a**)	8	0	
(**14b**)	(**15b**)	93	100	0	(**16b**)	7	0	100(39,24)[e]

[a] Solvent in which MCPBA oxidation occurred. [b] Relative % ratio of oxaziridine:nitrone was determined by 250 or 300MHz ^{1}H NMR analysis of the crude product mixture. [c] Solvent mixture (1:2) in which DMD oxidation occurred. [d] Mixture of *E* and *Z*-isomers (see references 11 and 12). [e] (Isolated yield of nitrone, estimated yield of aldehyde or ketone). [f] Only *Z*-isomer obtained.

Table 3. Oxidation products of ketimines (**17a–g**) obtained by reaction of MCPBA (0 °C) or DMD (0–5 °C).

Imine (**17**)		Oxaziridine (**18**)			Nitrone (**19**)		
	R	$CDCl_3$[a,b]	CD_3OD[a,b]	Me_2CO–CH_2Cl_2[b,c]	$CDCl_3$[a,b]	CD_3OD[a,b]	Me_2CO–CH_2Cl_2[b,c]
(**a**)	Me	53(66)[d]	100(100)[d]	0	47(34)[d]	0(0)[d]	100(91,5)[e]
(**b**)	Et	65(82)[d]	100	0	35(18)[d]	0	100(92,9)[e]
(**c**)	CH_2Bu^t	80	100		20	0	
(**d**)	Pr^i	70(88)[d]	100	0	30(12)[d]	0	100(31,12)[e]
(**e**)	Bu^t	<2(72,[d] >98)[f]	0(>98)[d]	0	>98(28,[d] <2[f])	100(<2)[d]	100(4,14)[e]
(**f**)	Ph			0			100(43)[e]
(**g**)	H			0			100(90,2)[e,g]

[a] Solvent in which MCPBA oxidation occurred. [b] Relative % ratio of oxaziridine:nitrone was determined by 250 or 300MHz ^{1}H NMR analysis of the crude product mixture. [c] Solvent in which DMD oxidation occurred (1:2). [d] MCPBA oxidation at −45 °C and analysis by ^{1}H NMR spectroscopy at a probe temperature of −20 °C. [e] (Isolated yield of nitrones, estimated yield of ketone). [f] MCPBA oxidation at −40 °C in $CDCl_3$ and analysis by ^{1}H NMR spectroscopy at a probe temperature of −25 °C [−50 °C for (**17e**)]. [g] The oxime tautomer of nitrone (**19g**) was isolated.

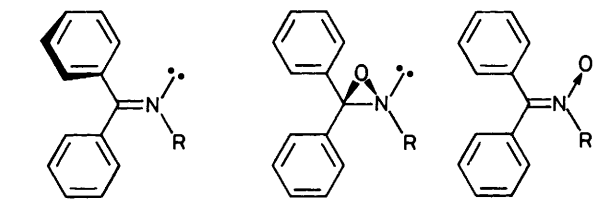
and the C=N bond in the nitrone product. The lower proportion of nitrone (**13b**) relative to nitrone (**13a**) may be rationalized in terms of increased steric hindrance of attack of the imino *N*-atom by the peroxyacid due to the proximity of the bulky t-butyl group.

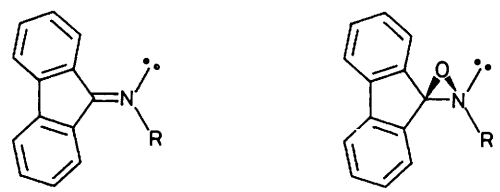
The oxidation of diaryl imines (**14a, b**) by MCPBA was found (Table 2) to yield mainly the corresponding oxaziridines (**15a, b**) with only small amounts (0–7%) of the corresponding nitrones (**16a, b**).

Imines derived from fluorenone (**17a–e**) showed a marked increase in the proportion of nitrone formation (**19a–e**) relative to oxaziridines (**18a–e**) found after MCPBA oxidation in $CDCl_3$ (Table 3). The enhanced tendency towards *N*-oxidation in the fluorenyl imines may be associated with the increased conjugation in these compounds between the C=N bond and the two essentially coplanar aryl rings. This conjugation energy is lost in oxaziridine formation, but is retained and probably increased in nitrone formation. The conjugation energy is less in the diphenyl imines (**14**) and nitrones (**16**) as the aryl rings will be twisted out of the C=N plane due to steric interactions. There may be a tendency towards nitrone formation in (**14a, b**) as compared with (**8a**).

The proportion of oxaziridines (**18**) formed from MCPBA oxidation of imines (**17**) appeared to increase with the increasing bulk of the *N*-alkyl substituents. The neopentyl (**17c**) and t-butyl (**17e**) groups, however, initially appeared to deviate from this trend. Although the neopentyl group is normally considered to be smaller (*A* value, 2.0) than an isopropyl group (*A* value, 2.15) on the basis of *A* values,[14] the effective size of this moiety is strongly conformation-dependent. In the imine (**17c**) (from a consideration of Dreiding models) it appears to adopt a preferred conformation with a greater steric requirement which hinders attack at the imino N-atom.

Initial oxidations of imine (**17e**) with MCPBA in either $CDCl_3$ or CD_3OD solvent at 0 °C indicated that virtually no oxaziridine [<2 or 10% (**18e**)] had been formed. When, however, the oxidations were carried out at −40 °C in $CDCl_3$ or at

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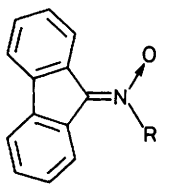

(19)

−50 °C using $CFCl_3$ as solvent in an NMR tube and analysed at −50 °C using low temperature ^{1}H NMR spectroscopy, the proportion of initially formed oxaziridine (**18e**) dramatically increased to 96% and >98% respectively. On warming the

samples of oxaziridine (**18e**) to ambient temperature in the NMR probe a spontaneous isomerization to the corresponding nitrone (**19e**) was observed ($t_{\frac{1}{2}}$ *ca.* 5 min at room temperature). The spontaneous isomerization of oxaziridine (**18e**) may be a result of ring and steric strain in the latter, allied to increased stabilization of the nitrone product (**19e**) due to conjugation. This apparently 'abnormal' production of nitrone (**19e**) from peroxyacid oxidation of imine (**17e**) at 0 °C has thus been described as 'pseudo-abnormal'.[12] When the anomalous oxidation behaviour of imine (**17c**) (due to the increased steric effects of the preferred conformation) and the spontaneous isomerization of oxaziridine (**18e**) to nitrone (**19e**) are taken into account, imines (**17a–e**) provide a suitable probe for the effect of *N*-alkyl substituent size upon the oxaziridine:nitrone ratio of products.

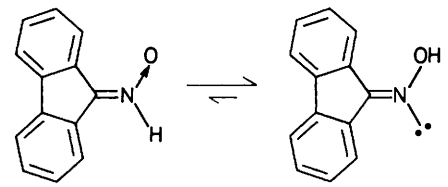
While fast, spontaneous thermal isomerization of oxaziridine (**18e**) to the corresponding nitrone (**19e**) clearly occurs, on the basis of kinetic studies of the thermal isomerization of oxaziridines (**9a–j**) and (**18a–d**)[9] to the nitrone isomers, it would appear that only in the case of oxaziridine (**9j**) could any significant degree of isomerization occur during synthesis at 0 °C. The results in Tables 1–3 from MCPBA oxidation of imines confirm that this is not a generally applicable method for the synthesis of nitrones.

An alternative type of electrophilic oxidant was thus sought which would produce a nitrone exclusively from an imine precursor. Dimethyldioxirane (DMD) has recently[15] been shown to behave as an electrophilic oxidant capable of producing sulphoxides from sulphides, epoxides from olefins, *N*-oxides from tertiary amines and nitro compounds from primary amines. Based upon this proven oxidizing power of dimethyldioxirane it was examined as a potential oxidant for the production of nitrones from imines.*

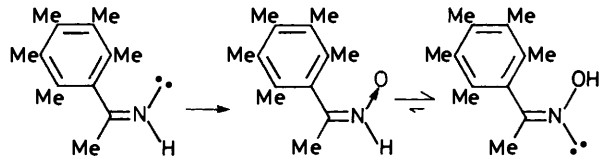
Dimethyldioxirane was obtained as an acetone solution after trap-to-trap distillation from the reaction of Oxone ($2KHSO_5 \cdot KHSO_4 \cdot K_2SO_4$) with $NaHCO_3$ in aqueous acetone solution as previously reported by Murray *et al.*[15] While the DMD appeared to be relatively stable when stored in acetone solution at −70 °C, it deteriorated over a period of several hours at ambient temperature and thus oxidations were carried out over two hours at 0 °C using a 10% excess of DMD. The aldimines (**8a**, **d**, **e** and **g**) were found to react with dimethyldioxirane to yield the corresponding nitrones (**10a**, **d**, **e** and **g**) in relatively low isolated yields (12–23%). Attempts to increase the yields by addition of a greater excess of dimethyldioxirane were unsuccessful. The major by-products of this oxidation procedure appeared to be the parent aldehydes (31–56% yield, Table 1). When oxaziridine (**9a**) was stirred with dimethyldioxirane under similar conditions to those used in nitrone formation, no reaction occurred. This observation suggested that oxaziridines are not involved at any stage in the DMD oxidation of imines (**8a**, **d**, **e** and **g**) to the corresponding nitrones (**10a**, **d**, **e** and **g**). Previous attempts to form nitrones (**10a**, **d**, **e** and **g**) by peroxyacid oxidation of the imine precursors (**8a**, **d**, **e** and **g**) were unsuccessful (Table 1). The aldehyde by-products obtained from attempted oxidation of imines (**8a**, **d**, **e** and **g**) by DMD could have arisen by imine hydrolysis since the acetone solution contained water. However, when a 0.5 molar quantity of DMD in acetone was added to nitrone (**10a**) and stirred for 1 h, it was observed that 50% of the nitrone had been converted to *p*-nitrobenzaldehyde. This result suggests that the relatively low yields of nitrones (**10a**, **d**, **e** and **g**) may be accounted for by further reaction with DMD. The optimal yields of nitrones (**10a**, **d**, **e** and **g**) were found after *ca.* 2 h by HPLC analysis of the reaction products.

The yields of isolated nitrones (**13a**), (**13b**), (**16b**), (**19a**), (**19b**) and (**19d**) obtained after DMD oxidation of the corresponding imines (**11a**), (**11b**), (**14b**), (**17a**), (**17b**) and (**17d**) were much better (31–92%) although aldehyde (28–30%) or ketone (5–24%) byproducts were still observed. The isolated yields of nitrones appeared to be optimal for *N*-methyl substituted aldimines *e.g.* (**11a**) ⟶ (**13a**) (71%; *Z*:*E*, 94:6) or ketimines *e.g.* (**17a**) ⟶ (**19a**) (91%). When account is taken of the unreacted imine remaining after DMD oxidation of the diarylketimines (**14b**), (37%), (**17d**), (57%) and (**17e**), (72%) then the isolated yields of all diarylketonitrones obtained by this route are much better.

In order to examine further the general applicability of DMD as an oxidant of imines, compounds (**17f**), (**17g**) and (**21**) were examined.



(**19g**) (**20**)



(**21**) (**22**) (**23**)

The *N*-phenyl nitrone (**19f**) was isolated in 43% yield after DMD oxidation of imine (**17f**). The yield obtained was in accord with those found for *N*-alkyl imines (**17a**, **b**, **d**, and **e**) in terms of size of the *N*-substituent if the *N*-phenyl group is considered to have steric requirements similar to those of *N*-methyl or *N*-ethyl groups.

Imines bearing an N–H substituent are generally unstable and readily hydrolyse. Imines (**17g**) and (**21**), being among the more stable known examples of N–H substituted imines, were selected as substrates for DMD oxidation. The major products isolated (**20**) (90%) and (**23**) (39%) were the corresponding oximes. It is probable that the isomeric nitrones (**19a**) and (**22**) were the initial products and that these were isolated as the more stable oxime tautomers (**20**) and (**23**).

Dimethyldioxirane thus appears to be capable of oxidizing a wide range of imines to yield the corresponding nitrones (**10a**), (**10d**), (**10e**), (**10g**), (**13a**), (**13b**), (**16b**), (**19a**), (**19b**), (**19d–g**) and oximes (**20**) and (**23**) without oxaziridine formation. At present, a major synthetic limitation in this reagent is the relatively low yield obtained during synthesis and the rather unstable nature of the reagent and of some nitrone products under the reaction conditions.

Experimental

^1H NMR spectra were obtained using Bruker 90 and 250 MHz and General Electric 300 MHz spectrometers with $CDCl_3$ as solvent unless stated otherwise.

Imines (**8a–j**),[16] (**11a**),[11] (**11b**),[12] (**14a, b**),[17] (**17a, b, d,** and **e**),[18] (**17f**)[19] and (**17g**)[20] have been prepared by the literature

* The oxidation of secondary amines with DMD to give nitrones in good yield has recently been reported (R. W. Murray and M. Singh, *J. Org. Chem.*, in the press). We thank Professor Murray for a preprint of this work.

methods. Imines (**17c**) and (**21**) were prepared by similar synthetic routes to those reported previously,[18] (**17c**) m.p. 65–66 °C (MeOH) (Found: C, 86.7; H, 7.7; N, 5.6. $C_{18}H_{19}N$ requires C, 86.7, H, 7.7; N, 5.6%); δ_H(250 MHz), 1.11 (9 H, s, Bu^t), 3.80 (2 H, s, CH_2), and 7.1–7.9 (8 H, m, Ar). (**21**) m.p. 81–82 °C (Found: C, 82.2; H, 10.2; N, 7.4. $C_{13}H_{19}N$ requires C, 82.5; H, 10.1; N, 7.4%); δ_H(250 MHz) 2.16 (6 H, s, Me), 2.20 (6 H, s, Me), 2.24 (3 H, s, Me), 2.29 (3 H, s, Me), and 9.0 (1 H, br s, NH).

Oxaziridines (**9a–j**),[16] and (**15a, b**)[21] were found to have identical spectral characteristics and physical properties to those reported. (**12a**) m.p. 102–106 °C (Found: *M*, 205.1467. $C_{13}H_{19}NO$ requires *M*, 205.1467); δ_H(250 MHz): 2.18 (6 H, s, Me), 2.21 (3 H, s, Me), 2.24 (6 H, s, Me), 2.95 (3 H, s, NMe), and 4.69 (1 H, s, CH). (**12b**) m.p. 60–69 °C (Found: C, 77.7; H, 10.2; N, 5.8. $C_{16}H_{25}NO$ requires C, 77.7; H, 10.2; N, 5.7%); δ_H(90 MHz): 1.18 (9 H, s, Bu^t), 2.08 (6 H, s, Me), 2.11 (3 H, s, Me), 2.20 (6 H, s, Me), and 4.94 (1 H, s, CH). (**18a**) m.p. 39–44 °C (Found: *M*, 209.0841 $C_{14}H_{11}NO$ requires *M*, 209.0841); δ_H(90 MHz): 3.12 (3 H, s, Me), and 7.17–7.80 (8 H, m, Ar). (**18b**) m.p. 76–78 °C (Found: C, 80.5; H, 5.9; N, 6.1. $C_{15}H_{13}NO$ requires C, 80.7; H, 5.9; N, 6.3%); δ_H(250 MHz): 1.23 (3 H, t, *J* 7 Hz, CH_2Me), 3.25 (2 H, m, CH_2Me), and 7.13–7.80 (8 H, m, Ar). (**18c**) m.p. 49–51 °C (Found: C, 81.4; H, 7.0; N, 5.0. $C_{18}H_{19}NO$ requires C, 81.5; H, 7.2; N, 5.3%); δ_H(250 MHz): 1.02 (9 H, s, Bu^t), 2.84 (1 H, d, J_{AB} 13.4 Hz, H_A), 3.07 (1 H, d, J_{AB} 13.2 Hz, H_B), and 7.11–7.70 (8 H, m, Ar). (**18d**) m.p. 88–90 °C (Found: C, 81.1; H, 6.4; N, 5.9. $C_{16}H_{15}NO$ requires C, 81.0; H, 6.4; N, 5.9%); δ_H(250 MHz) 0.82 (3 H, d, *J* 6.5 Hz, Me), 1.45 (3 H, d, *J* 6.1 Hz, Me), 3.29 (1 H, m, C*H*Me$_2$), and 7.05–7.7 (8 H, m, Ar). (**18e**) Too unstable to be isolated in neat state. δ_H(250 MHz, $CFCl_3$, −50 °C): 1.36 (9 H, s, Bu^t), and 7.26–7.96 (8 H, m, Ar).

Nitrones (**10a, g**),[22] (**10i**),[10a] (**13a, b**),[12] (**16a**),[23] (**16b**),[24] (**19a, b,** and **d**),[25] (**19e**),[18] (**19f**),[26] and oxime (**19g**)[27] obtained by imine oxidation were found to be indistinguishable from authentic samples. (**10d**) m.p. 61–62 °C (benzene–pentane) (Found: C, 51.7; H, 5.7; N, 5.3. $C_{11}H_{14}NOBr$ requires C, 51.6; H, 5.5; N, 5.5%) δ_H(90MHz): 1.61 (9 H, s, Bu^t), 7.4 (1 H, s, CH=N), 7.45 (2 H, d, *J* 8 Hz, Ar), and 8.05 (2 H, d, *J* 8 Hz, Ar). (**10e**) m.p. 68–69 °C (benzene–pentane) (Found: C, 62.2; H, 6.9; N, 6.7. $C_{11}H_{14}NOCl$ requires C, 62.4; H, 6.8; N, 6.6%); δ_H(250 MHz) 1.61 (9 H, s, Bu^t), 7.39 (2 H, d, *J* 8.7 Hz, Ar), 7.54 (1 H, s, CH=N), and 8.26 (2 H, d, *J* 8.7 Hz, Ar). (**10h**) m.p. 72–74 °C (benzene–pentane) (Found: C, 75.4; H, 9.0; N, 7.2. $C_{12}H_{17}NO$ requires C, 75.4; H, 9.0; N, 7.3%); δ_H(250 MHz) 1.60 (9 H, s, Bu^t), 2.37 (3 H, s, Me), 7.22 (2 H, d, *J* 8.1 Hz, Ar), 7.51 (1 H, s, CH=N), and 8.19 (2 H, d, *J* 8.3 Hz, Ar). (**10j**) m.p. 132–134 °C (benzene–pentane) (Found: C, 70.7; H, 9.2; N, 12.5. $C_{13}H_{20}N_2O$ requires C, 70.9; H, 9.2; N, 12.7%); δ_H(250 MHz): 1.59 (9 H, s, Bu^t), 3.02 (6 H, s, NMe_2), 6.69 (2 H, d, *J* 8.0 Hz, Ar), 7.40 (1 H, s, CH=N), and 8.21 (2 H, d, *J* 8.0 Hz, Ar). (**19c**) m.p. 75–79 °C (benzene–pentane) (Found: *M*, 265.1476. $C_{18}H_{19}NO$ requires *M*, 265.1467); δ_H(90 MHz): 1.21 (9 H, s, Bu^t), 4.39 (2 H, s, CH_2), 7.1–7.7 (7 H, m, Ar), and 8.91–8.93 (1 H, m, Ar). (**23**) m.p. 105–107 °C (aq. MeOH) (Found: C, 76.1; H, 9.5; N, 6.8. $C_{13}H_{19}NO$ requires C, 76.1; H, 9.3; N, 6.9%); δ_H(250 MHz), 2.09 (3 H, s, Me), 2.13 (3 H, s, Me), 2.17 (3 H, s, Me), 2.19 (3 H, s, Me), 2.20 (3 H, s, Me), and 2.22 (3 H, s, Me).

Typical MCPBA Oxidation Procedure for Imines.—The imine (0.02M) in CH_2Cl_2 (or CH_3OH) (30 ml) was cooled to 0 °C in an ice-bath. MCPBA (0.024M) was dissolved in the same solvent (30 ml) and added dropwise to a vigorously stirred solution. After stirring the mixture at 0 °C for 1–2 h the reaction was terminated, filtered and poured into water. Dichloromethane (100 ml) was added and the organic layer was separated. The aqueous layer was further extracted (CH_2Cl_2 × 2) and the combined CH_2Cl_2 extracts were washed (1M Na_2SO_3, 2M $NaHCO_3$) dried ($MgSO_4$) and concentrated to yield the oxaziridine/nitrone product in 80–90% isolated yield. The oxaziridine:nitrone ratio (from ^{1}H NMR analysis) was found to be similar on smaller scale oxidations using $CDCl_3$ or CD_3OD as solvent and an NMR tube as reaction vessel.

Typical Dimethyldioxirane Oxidation Procedure for Imines.—Dimethyldioxirane was prepared as an acetone solution according to the literature procedure.[15] Thus, using acetone (320 ml, 4.35 mol), water (440 ml), sodium hydrogen carbonate (240 g) and potassium peroxymonosulphate (500 g, 0.813 mol) the product dimethyldioxirane was obtained after distillation as an acetone solution (250–275 ml). The latter solution was analysed by iodometric titration and was found to be consistently within the range 0.077–0.085M.

Imine (0.1 g) in dichloromethane solution and pre-dried dimethyldioxirane (10% excess) were stirred together [CH_2Cl_2–Me_2CO (2:1)] at ice-bath temperature for 2 h. Removal of the solvent under reduced pressure gave products which were analysed by ^{1}H NMR spectroscopy and purified by preparative TLC using chloroform–hexane (1:1) as eluant. The nitrone products were recrystallized and identified by comparison with an authentic sample. Each reaction was repeated several times to ensure reproducibility. Monitoring the progress of the reaction by HPLC [Zorbax Sil 250 mm × 4.6 mm, methanol–hexane (1:99)] indicated that the proportion of aldonitrone products (**10a, d, e,** and **g**) present decreased when the oxidation was allowed to proceed beyond 2 h.

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