Stereospecificity in the Rearrangement Reactions of an *N*-Phosphinoyl-*O*-sulfonylhydroxylamine with Methylamine and *tert*-Butylamine: Retention of Configuration at Phosphorus as Evidence for the Initial Formation of a Phosphonamidic Sulfonic Mixed Anhydride[1]

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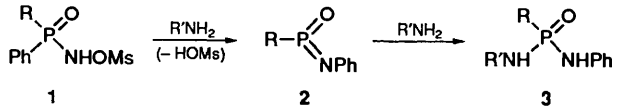
Reaction of the *N*-phosphinoyl-*O*-sulfonylhydroxylamine PhMeCH(Ph)P(O)NHOMs **10** with RNH_2 (R = Me or Bu^t) results in migration of the phenyl group from phosphorus to nitrogen which leads to the rearrangement product PhMeCHP(O)(NHPh)NHR. Using samples of **10** enriched in one diastereoisomer (80:20) or the other (3:97), the reaction with neat RNH_2 proceeds with a high degree of stereospecificity, thereby ruling out the possibility of a free metaphosphonimidate intermediate. For the $MeNH_2$ reaction, the relative configurations of substrate and product, deduced from their X-ray crystal structures, show the sense of the stereospecificity to be retention of configuration at phosphorus; for the Bu^tNH_2 reaction, indirect evidence leads to the same conclusion. Retention of configuration is thought to result from initial base-induced rearrangement to the phosphonamidic sulfonic mixed anhydride PhMeCHP(O)(NHPh)OMs, with inversion of configuration at phosphorus; this then undergoes nucleophilic substitution with RNH_2 to give the observed product. The nucleophilic substitution can have an associative $S_N2(P)$ mechanism (inversion of configuration at phosphorus) but also a dissociative elimination–addition mechanism. The latter is responsible for departures from complete stereospecificity; these are small with $MeNH_2$ and neat Bu^tNH_2, but large with Bu^tNH_2 at high dilution.

N-Phosphinoylhydroxylamines such as $Ph_2P(O)NHOH$ are the phosphorus analogues of hydroxamic acids and when suitably activated they undergo a Lossen-like rearrangement with base. Thus, for example, the *O*-methylsulfonyl derivative **1** (R = Ph) reacts with $MeNH_2$ or Bu^tNH_2 to give the phosphonic diamide **3** (R′ = Me or Bu^t) in which a phenyl group has migrated from phosphorus to nitrogen.[2] Alkyl groups migrate much less readily than phenyl, so the unsymmetrical substrates **1** (R = alkyl) still give only the phenyl-migration products **3**.[3] Alkyl groups will migrate if there is no competing phenyl group but they do so only with reluctance.[4] Rearrangement may proceed by way of a monomeric metaphosphonimidate **2** (Scheme 1)



1 2 3

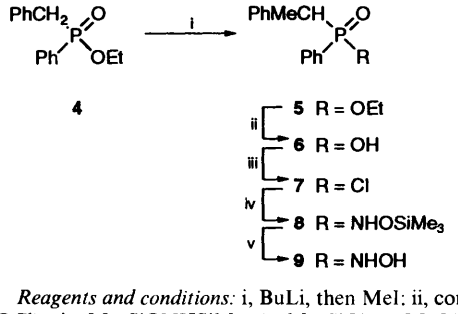
Scheme 1

analogous to the isocyanate formed in a Lossen rearrangement,[5] although such a 3-coordinate P^V species is likely to have only a fleeting existence.[6] Some results accord well with the formation of an intermediate of high reactivity/low selectivity but others point to a product-forming species more discriminating than a metaphosphonimidate.[7] The present stereochemical study was undertaken with a view to establishing as firmly as possible whether or not the rearrangement proceeds *via* a metaphosphonimidate.

From the point of view of the P atom, the overall rearrangement **1**→**3** is essentially just a substitution: the Ph group in the substrate is replaced by R′NH in the product. When the substrate is chiral (R ≠ Ph), this will occur either stereospecifically (inversion *or* retention of configuration at phosphorus) or non-stereospecifically (inversion *and* retention). Using a single enantiomer of **1**, a metaphosphonimidate intermediate should, by reaction at the two faces, give the product **3** as a mixture of enantiomers, *i.e.* reaction should be non-stereospecific. In practice this straightforward approach presents serious problems, both in obtaining the substrate **1** as a single enantiomer and, if there is stereospecificity, relating the configurations of the substrate and product. The situation should be eased somewhat if the alkyl group R in **1** is made chiral, so that both the substrate and product exist as diastereoisomers, not just enantiomers. So long as it does not migrate, the alkyl group will merely be a spectator of the chemistry taking place at the P atom and, by virtue of its chirality, it should be able to distinguish between inversion and retention of configuration. We therefore decided to aim for the 1-phenylethyl compound **1** (R = PhMeCH), with a view to examining stereochemically the behaviour of its diastereoisomers. Since we sought only information on relative configurations there was no need to use optically active materials; racemates would serve just as well.

Results and Discussion

Preparative Work.—The chiral benzylphosphonate **4** (δ_P 40.1) was prepared by heating benzyl chloride with $PhP(OEt)_2$ (Arbusov reaction).[8] A second chiral centre was then introduced by methylation of the benzylic phosphonate carbanion, giving **5** as a mixture of diastereoisomers (δ_P 43.0 and 42.4). The



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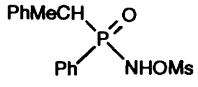
Scheme 2 *Reagents and conditions:* i, BuLi, then MeI: ii, conc. HCl, heat; iii, $(COCl)_2$; iv, $Me_3SiONHSiMe_3$ ($-Me_3SiCl$); v. MeOH

chirality at phosphorus was lost on hydrolysis (**6**; δ_P 44.8) but was regained when the acid **6** was treated with oxalyl chloride: the phosphinic chloride **7** was formed as a 47:53 mixture of diastereoisomers (δ_P 59.6 and 59.2). It was possible, by crystallisation, to obtain a sample of **7** enriched in one diastereoisomer (δ_P 59.6; *ca.* 90%) but separation at this stage was not pursued; the stereochemical integrity of **7** seemed certain to be compromised (chloride ion exchange) during the course of its subsequent reactions. The reaction with $Me_3SiONHSiMe_3$ did not proceed readily (high concentration in CH_2Cl_2; 24 h at 35 °C) but eventually it gave the *O*-silyl-*N*-phosphinoylhydroxylamine **8** as an almost equal mixture of diastereoisomers [δ_P 41.7 and 40.7; by-product 33.7 (10–20%)]. The highfield diastereoisomer proved to be relatively insoluble in CH_2Cl_2; simply by filtering the reaction mixture it was possible to obtain a solution enriched in one diastereoisomer and a solid that was very largely the other. Removal of the silyl protecting group then gave corresponding samples of the *N*-phosphinoylhydroxylamine **9** and these with $MeSO_2Cl$–Et_3N (0 °C; CH_2Cl_2 solution) gave methanesulfonate (mesylate) **10**: sample A, diastereoisomer ratio 80:20, major component $\delta_P(CDCl_3)$ 39.6, $\delta_H(CDCl_3)$ (in part) 8.45 (d, J_{PH} 7, NH), 3.10 (s, SO_2Me) and 1.70 (dd, J_{PH} 16, J_{HH} 7.5, PhCH*Me*); sample B, diastereoisomer ratio 3:97, major component $\delta_P(CDCl_3)$ 38.1, $\delta_H(CDCl_3)$ (in part) 7.14 (d, J_{PH} 4, NH), 2.70 (s, SO_2Me) and 1.55 (dd, J_{PH} 18, J_{HH} 7.5, PhCH*Me*).



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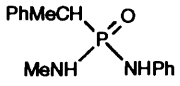

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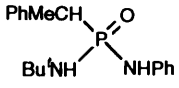

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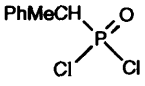

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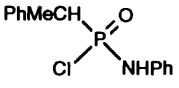

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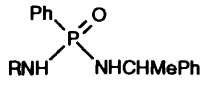

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Degree of Stereospecificity.—Both samples of the mesylate **10** were treated with $MeNH_2$ (large excess; no solvent) at *ca.* −5 °C and the reaction mixtures were examined by NMR spectroscopy (^{31}P and ^1H after washing with water). In each case the product was seen to be a mixture of the same two compounds (δ_P 26.2 and 25.7), but in very different proportions, *i.e.* ratio 79:21 from sample A (80:20) and 7:93 from sample B (3:97). Crystallisation of the 7:93 mixture afforded a pure sample of the major component (product B). For this the ^1H NMR spectrum showed that an NHMe group had been acquired by the P atom (*Me*NH: δ 2.59, dd, J_{PH} 11.5, J_{HH} 5.5) and implied that the 1-phenylethyl group remained attached to phosphorus (PhCH*Me*: δ 1.62, dd, J_{PH} 17.5, J_{HH} 7.5), while the mass spectrum suggested an NHPh group (*m/z* 93, $PhNH_2^+$, 40%). These features point to the phosphonic diamide structure **11** for product B. The ^1H NMR spectrum of the 79:21 product mixture contained small signals attributable to product B and similar but larger signals at higher field for the major component (product A), *i.e.* *Me*NH: δ 2.51, dd, J_{PH} 11.5, J_{HH} 6 and PhCH*Me*: δ 1.56, dd, J_{PH} 17.5, J_{HH} 7.5. This implies a different diastereoisomer of the same structure **11** for product A.

With Bu^tNH_2 the two samples of the methanesulfonate also gave mixtures of two products [$\delta_P(CDCl_3)$ 22.75 and 22.5], ratio 75:25 from sample A (80:20) and 10:90 from sample B (3:97). Spectroscopically these products differed from those above in that the NH*Me* signals had been replaced by NH*Bu*^{t} singlets, δ 1.19 (product A) and 1.305 (product B). Apparently the two products were the diastereoisomers of phosphonic diamide **12**.

When the mesylate **10** rearranges, either the Ph group or the PhMeCH group can, in principle, migrate. So that no doubt should remain, authentic samples of the phenyl migration products **11** and **12** were prepared from the phosphonic dichloride **13**, *via* the *N*-phenylphosphonamidic chloride **14**. Apart from the diastereoisomer ratios, these were essentially identical (^1H and ^{31}P NMR) with the rearrangement products. Authentic samples of the alternative rearrangement products **15** were also prepared, from $PhP(O)Cl_2$, 1-phenylethylamine, and $MeNH_2$ [**15** (R = Me), δ_P 20.2 and 19.8] or Bu^tNH_2 [**15** (R = Bu^t), δ_P 17.3 and 16.5]; peaks corresponding to these were not present in the spectra of the mesylate rearrangement products (1% would have been detected). Like simple alkyl groups,[3] 1-phenylethyl seems unable to compete with phenyl in migration from phosphorus to nitrogen. Our concern was therefore only with phenyl migration and, in particular, its consequences for the stereochemistry at the P atom.

If rearrangement is completely stereospecific the diastereoisomer ratio of the product should mirror exactly that of the substrate, *i.e.* 80:20 for sample A or 3:97 for sample B. If it is totally non-stereospecific, the product from both samples of substrate should be exactly the same mixture of stereoisomers, although for diastereoisomers the ratio is unlikely to be exactly 50:50 and may be different for the $MeNH_2$ and Bu^tNH_2 reactions. Our measured stereoisomer ratios (Table 1; ratios ± 1.0%) using the neat amines imply that rearrangement is largely stereospecific, but not entirely so, and that the departure from complete stereospecificity is greater for Bu^tNH_2 than for $MeNH_2$. The behaviour of the individual stereoisomers of the substrate can easily be deduced from the results in Table 1 for the stereoisomer mixtures. If S_A and S_B are the principal stereoisomers in substrate samples A and B, and P_A and P_B are the principal stereoisomers in the corresponding product samples, then

$$MeNH_2: 100\ S_A \longrightarrow 98\ P_A + 2\ P_B$$

$$100\ S_B \longrightarrow 96\ P_B + 4\ P_A$$

$$Bu^tNH_2: 100\ S_A \longrightarrow 92\ P_A + 8\ P_B$$

$$100\ S_B \longrightarrow 92.5\ P_B + 7.5\ P_A$$

Mechanistically, the observation of stereospecificity is very significant since it establishes beyond doubt that the rearrangement does not proceed *via* a free (liberated) metaphosphonimidate. There may be a minor pathway involving a free metaphosphonimidate, and this might be responsible for the small departures from complete stereospecificity, but the principal pathway must be something different. To understand what this could be, it is essential to know the sense of the stereospecificity: is the configuration at the P atom inverted or retained when the phenyl group migrates? There is no straightforward and dependable chemical method of correlating the stereostructures of the mesylate **10** and its rearrangement product **11** or **12** so it was necessary to resort to X-ray crystallography.

Sense of Stereospecificity.—Pure samples (> 99% by NMR spectroscopy) of the principal diastereoisomer of substrate sample B and its $MeNH_2$ rearrangement product were obtained by recrystallisation, and were used to grow single crystals

Table 1 Stereochemical experiments. Diastereoisomer ratio (and estimated yield) of the phosphonic diamide rearrangement product from the reaction of Ph(PhMeCH)P(O)NHOMs (sample A or sample B) with $MeNH_2$ or Bu^tNH_2 (neat or in CH_2Cl_2)[a]

	$MeNH_2$		Bu^tNH_2	
$[RNH_2]$	A (80:20)	B (3:97)	A (80:20)	B (3:97)
Neat	79:21 (>98%)	7:93 (96%)	75:25 (≥98%)	10:90 (95%)
1.0 mol dm^{-3}	82:18 (90%)	8:92 (85%)	67:33 (85%)	30:70 (80%)
0.1 mol dm^{-3}	83:17 (75%)	8:92 (57%)	57:43 (65%)	41:59 (50%)

[a] Yield refers to the percentage of the ^{31}P NMR spectrum of the reaction mixture (including by-products) accounted for by the phosphonic diamide rearrangement product

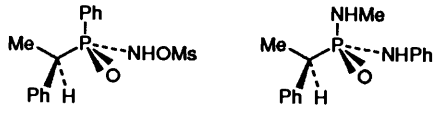
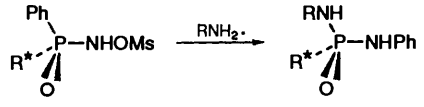


Fig. 1 Relative configuration at carbon and phosphorus



R* = PhMeCH

Scheme 3

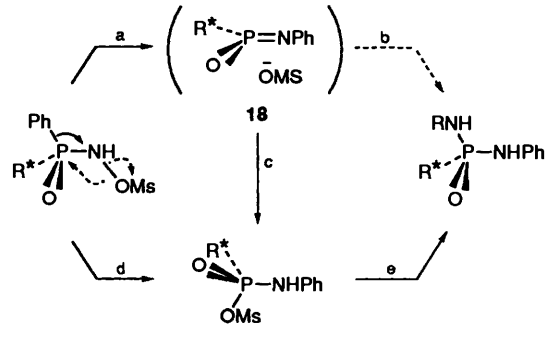
suitable for X-ray analysis. From the resulting crystal structures the configuration at phosphorus was deduced, relative to the configuration of the chiral alkyl group, for both the substrate and the product (Fig. 1).[1] The result was unambiguous: the nucleophile ($MeNH_2$) takes the place of the migrating phenyl group with retention of configuration at phosphorus (Scheme 3, R = Me). For the Bu^tNH_2 reaction the same sense of stereospecificity would obviously be expected but evidence was needed. It was obtained by treating a sample of the phosphonamidic chloride **14** having a predominance of one diastereoisomer (70% highfield δ_P) with $MeNH_2$ and with Bu^tNH_2. In each case the predominant diastereoisomer of the product **11** or **12** formed by substitution corresponded (^{31}P and ^1H NMR spectroscopy) to the predominant diastereoisomer of the same compound formed by the rearrangement of mesylate sample A. Provided that the substitution reactions with the two amines are stereospecific in the same sense, regardless of whether it is inversion (probable) or retention, then the rearrangement reactions of the mesylate with the two amines must also have the same sense of stereospecificity, *i.e.* there is retention of configuration at phosphorus with Bu^tNH_2 as well as with $MeNH_2$ (Scheme 3, R = Me or Bu^t).

Mechanistic Interpretation of Stereochemistry.—One possible explanation of the stereochemistry is that rearrangement proceeds *via* a 5-coordinate phosphorane intermediate like that formed in nucleophilic substitution.[9] If the amine (RNH_2) attacks opposite the NHOMs group (*i.e.* adjacent to phenyl) to form the phosphorane **16**, the product that results from phenyl

16 **17**

migration will have RNH in the space originally occupied by phenyl, *i.e.* there will be retention of configuration at phosphorus. Any competing attack opposite the Ph group will give the phosphorane **17** and thence the rearrangement product with inverted configuration at phosphorus. A small departure from complete retention is therefore easily accounted for. Attractive though it is, an associative mechanism of this type has previously been rejected on the grounds that the rearrangement is insensitive to steric effects.[3] In particular, the rearrangement of the mesylate **1** with $MeNH_2$ is practically as fast when R = Pr^i as it is when R = Me,[3] whereas the nucleophilic substitution reaction of PhRP(O)Cl with H_2O is 750 times slower when R = Pr^i.[10] As a check on the behaviour of the mesylate **10** the rearrangement was carried out using competing amines. For steric reasons Bu^tNH_2 is much less reactive than $MeNH_2$ in substitution at a phosphoryl centre; $Ph_2P(O)Cl$, for example, in competition experiments gives only the product derived from $MeNH_2$ (NHMe:NHBu^t product ratio ≥200:1).[7] In contrast to this, when **10** was treated with an equimolar $MeNH_2$–Bu^tNH_2 mixture (large excess; no solvent) a substantial amount of the Bu^tNH_2 rearrangement product was formed, the NHMe:NHBu^t ratio being 86:14. It does not seem possible that Bu^tNH_2 could compete to such an extent if rearrangement were proceeding associatively *via* phosphoranes such as **16** and **17**.*

Returning to our original picture of the mechanism (Scheme 1), it is true that a free metaphosphonimidate is incompatible with stereospecificity. But what if the metaphosphonimidate never becomes free (liberated)? When the Ph group migrates from phosphorus on one side of the molecule (or its conjugate base), the sulfonate group is presumably released from nitrogen on the other (Scheme 4, step a). One face of the resulting



Scheme 4

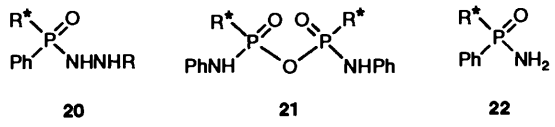
metaphosphonimidate will then be more open to attack than the other (see **18** in Scheme 4). If the metaphosphonimidate reacts immediately with the nucleophile (RNH_2), before it can diffuse away from the sulfonate anion, the product will be formed preferentially with retention of configuration at phosphorus (step b). For neat amine this certainly seems reasonable, since the nucleophile concentration is necessarily very high. It seems

* A referee has pointed out that a simple substitution in which chlorine is the leaving group is a poor model for a substitution in which phenyl is the leaving (migrating) group.

less plausible, however, in the light of the observation (see below) that the rearrangement is no less stereospecific when a dilute solution of $MeNH_2$ is used. There is no charge on the metaphosphonimidate to keep it close to the sulfonate anion, and it is hard to imagine it reacting with a low concentration of the nucleophile more quickly than it diffuses away and becomes free.

The question of diffusion need not arise if the sulfonate bonds covalently to the P atom when it is displaced from nitrogen. In this case the initial product of rearrangement is a phosphonamidic sulfonic mixed anhydride **19** (Scheme 4); it may still be formed *via* the metaphosphonimidate (path a,c) but some concertedness seems quite likely, with the O–P bond beginning to form before the O–N bond is completely broken (path d). The observed rearrangement product, the phosphonic diamide, results from a subsequent reaction of the mixed anhydride with the amine nucleophile (step e).

We hoped that by extending our investigation of the mesylate **10** from neat amine to relatively dilute solutions we would be able to clarify the mechanistic detail. Substrate samples A (80:20) and B (3:97) were therefore treated with both $MeNH_2$ and Bu^tNH_2 as 1.0 and 0.1 mol dm^{-3} solutions in CH_2Cl_2. The diastereoisomer compositions of the resulting rearrangement products are shown in Table 1, together with the neat-amine results for comparison. In contrast to the neat-amine rearrangements, side reactions were much in evidence, especially at the lowest amine concentration. Two types of by-product were firmly identified, namely phosphinic hydrazide **20** (2 diastereoisomers; nucleophilic displacement of sulfonate without rearrangement) and phosphonamidic anhydride **21** (several diastereoisomers; rearrangement with involvement of traces of moisture); in addition, there was some evidence for phosphinic amide **22** (2 diastereoisomers; reductive displacement of sulphonate without rearrangement). The by-products had little direct impact on the stereochemical measurements, but their formation is still of consequence because it affects the two diastereoisomers of the substrate to different extents. The one more seriously depleted by side reactions is the minor component of sample A (80:20) and the major component of sample B (3:97). In consequence, the phosphonic diamide rearrangement product will actually have been formed from substrate enriched (sample A) or depleted (sample B) in its major diastereoisomer (>80% for A, <97% for B). The results in Table 1 therefore exaggerate the stereospecificity in the case of sample A (at face value >100% with $MeNH_2$) and understate it in the case of sample B. In reality, the rearrangement could well be completely stereospecific with $MeNH_2$ at very low concentrations. If that is so, the phosphonamidic sulfonic anhydride must obviously be formed with complete stereospecificity, and there seems no reason why the situation should be different with other amines or with neat $MeNH_2$. We therefore propose the following tentative interpretation, while acknowledging that it is not proven.



20 **21** **22**

R*= PhMeCH

1. The substrate initially undergoes base-catalysed rearrangement to a phosphonamidic sulfonic mixed anhydride; this rearrangement is completely stereospecific (inversion of configuration at phosphorus) and is probably concerted (Scheme 4, path d).

2. The observed rearrangement product is derived from the phosphonamidic sulfonic anhydride by nucleophilic substitution (step e).

3. With an unhindered amine ($MeNH_2$) the substitution reaction of the anhydride is largely or exclusively $S_N2(P)$ (first order in amine; stereospecific inversion of configuration). At higher concentrations a preassociative elimination–addition (EA) mechanism (second order in amine) plays a more important part; this is not completely stereospecific, albeit largely so at high amine concentrations, and it discriminates poorly between competing amines.[11,12] It is responsible for the appreciable but not large departure from complete stereospecificity with neat $MeNH_2$, and also for the substantial amount of the Bu^tNH_2 rearrangement product formed in the $MeNH_2$–Bu^tNH_2 competition experiment.

4. With a hindered amine (Bu^tNH_2) substitution of the phosphonamidic sulfonic anhydride is very largely EA, because $S_N2(P)$ is sterically much retarded. At high amine concentrations preassociative EA (second order in amine) is dominant. This is largely stereospecific (at high amine concentrations) so the phosphonic diamide is still formed with rather high stereospecificity. In this case, however, the stereospecificity is reduced at lower amine concentrations and the change is quite dramatic (Table 1). How much of the reduction is due to preassociative EA becoming less stereospecific at lower amine concentrations and how much due to simple EA (totally non-stereospecific; first order in amine) become more important we cannot say. Whatever the underlying reason, it seems likely that in the limit (if side reactions can be contained) the rearrangement with a hindered amine will be totally non-stereospecific at high dilution.

Experimental

M.p.s were determined using a Kofler hot-stage apparatus and are uncorrected. ^1H NMR spectra were recorded at 90 MHz on a Varian EM 390 spectrometer or (where indicated) at 300 MHz on a Bruker AM-300 (Me_4Si internal standard; coupling constants, *J*, given in Hz), and ^{31}P NMR spectra (^1H decoupled) were recorded at 36.2 MHz on a JEOL JNM-FX90Q spectrometer (positive chemical shifts downfield from external 85% H_3PO_4). Routine mass spectra were obtained in EI or (where indicated) CI mode on a VG 16-B or Kratos Concept spectrometer and high resolution spectra were recorded by the SERC Mass Spectrometry Service at Swansea. GLC analyses were performed using a Philips PU 4500 chromatograph (helium carrier gas; flame-ionisation detector) fitted with an OV 1701 widebore capillary column (1 μm film; 15 m × 0.53 mm) and TLC analyses were performed on silica gel 60 F_{254} (0.2 mm layer on aluminium foil). Amines were dried over KOH, CH_2Cl_2 was distilled from CaH_2, and THF was distilled from sodium–benzophenone. Light petroleum refers to the fraction with b.p. 60–80 °C unless otherwise indicated and ether to diethyl ether. Diethyl phenylphosphonite, b.p. 60–62 °C at 0.05 mmHg, was prepared from phenylphosphonous dichloride (reaction with EtOH–pyridine in light petroleum) and was converted into ethyl benzyl(phenyl)phosphinate, $\delta_P(CDCl_3)$ 40.1, by heating with benzyl chloride.[8]

Ethyl Phenyl(1-phenylethyl)phosphinate **5**.—A solution of ethyl benzyl(phenyl)phosphinate **4** (7.6 g, 29.1 mmol) in THF (50 cm^3) was stirred at −70 °C (bath temp.) while a solution of butyllithium in hexane (2.5 mol dm^{-3}; 12 cm^3, 30 mmol) was added dropwise over 20 min. After a further 30 min at −70 °C, iodomethane (8.3 g, 60 mmol) in THF (10 cm^3) was added dropwise, the mixture was allowed to warm slowly to room temperature, and solvent was evaporated. The residue was dissolved in ether (70 cm^3) and the solution was washed with water (50 cm^3 then 20 cm^3), dried, and concentrated to give the

crude *title ester* **5** (7.2 g, 90%) as a mixture of diastereoisomers, $\delta_P(CH_2Cl_2)$ 43.0 and 42.4. A small portion was distilled, b.p. 130 °C (oven temp.) at 0.3 mmHg; $\delta_P(CDCl_3)$ 44.3 and 43.4 (major), ratio 47:53 (impurity at 47.1, *ca.* 5%); $\delta_H(CDCl_3$; 300 MHz) 7.61–7.04 (10 H, m), 4.19–3.76 (2 H, m), 3.29 and 3.23 (major) (total 1 H; both dq, J_{PH} 18 or 17, J_{HH} 7.5, PC*H*Me), 1.595 and 1.50 (major) (total 3 H; both dd, J_{PH} 17 or 17.5, J_{HH} 7.5, PCH*Me*), and 1.31 and 1.20 (major) (total 3 H; both t, J_{HH} 7); *m/z* 274 (M^+, 40%), 170 (M^+ – PhCH=CH_2, 40), 169 (M^+ – PhCHMe, 30), 142 (M^+ – PhCH=CH_2 – C_2H_4, 20), 141 (M^+ – PhCHMe – C_2H_4, 100) and 105 ($PhCHMe^+$, 50); ν_{max}(film)/cm^{-1} 1220 (P=O) (Found: M^+, 274.1123. $C_{16}H_{19}O_2P$ requires *M*, 274.1123). The bulk of the product was used without purification.

Phenyl(1-phenylethyl)phosphinic Acid **6**.—The crude ester **5** (7.0 g, 25.7 mmol) was stirred and heated (bath temp. 140 °C) with conc. hydrochloric acid (25 cm^3) for 14 h. The mixture was diluted with water and the product was extracted into CH_2Cl_2 and dried. Evaporation of the solvent gave a syrup, which on trituration with ether followed by crystallisation from CH_2Cl_2–ether yielded the phosphinic acid **6** (4.1 g, 65%), m.p. 136–137 °C (from ethyl acetate) (lit.,[13] 133–135 °C); $\delta_P(CH_2Cl_2)$ 44.8; $\delta_H(CDCl_3)$ 12.90 (s, OH), 7.6–7.0 (5 H, m). 7.08 (5 H, br s), 3.10 (1 H, dq, J_{PH} 18, J_{HH} 7) and 1.42 (3 H, dd, J_{PH} 17, J_{HH} 7); ν_{max}(Nujol)/cm^{-1} 2650, 2250, 1660 (all br, OH), 1170 (P=O) and 950 (Found: C, 68.0; H, 5.9. Calc. for $C_{14}H_{15}O_2P$: C, 68.3; H, 6.1%).

Phenyl(1-phenylethyl)phosphinic Chloride **7**.—The phosphinic acid **6** was stirred in CH_2Cl_2 (*ca.* 2 cm^3 per mmol) and oxalyl chloride (2 mol equiv.) was added. When reaction was complete (δ_P 58.8 and 58.5, diastereoisomers) the volatile material was evaporated; remaining traces of oxalyl chloride were removed by repeated addition and evaporation of solvent followed by pumping at 0.4 mmHg (≥2 h). The crude *phosphinic chloride* **7** was obtained as a mixture of diastereoisomers (47:53), $\delta_P(CDCl_3)$ 59.6 and 59.2; $\delta_H(CDCl_3$; 300 MHz) 7.7–6.9 (10 H, m), 3.58 and 3.57 (total 1 H; both dq, J_{PH} 14.5, J_{HH} 7.5), and 1.80 (major) and 1.63 (total 3 H; both dd, J_{PH} 20 or 21, J_{HH} 7.5); ν_{max}(Nujol)/cm^{-1} 1225 (P=O). A portion crystallised from ether–light petroleum (b.p. 40–60 °C) gave a sample [90% the lowfield (^{31}P NMR) diastereoisomer] with m.p. 108–111 °C; *m/z* 266 and 264 (M^+, 25%), 162 and 160 (M^+ – PhCH=CH_2, 12) and 105 ($PhCHMe^+$, 100) (Found: M^+ 264.0471. $C_{14}H_{14}ClOP$ requires *M*, 264.0471). The bulk of the material was used without purification.

N-[*Phenyl*(1-*phenylethyl*)*phosphinoyl*]-O-*trimethylsilyl-hydroxylamine* **8**.—(a) *N,O*-Bis(trimethylsilyl)hydroxylamine (1.95 g, 11 mmol)[4] was added to a stirred solution of the phosphinic chloride **7** (2.26 g, 8.6 mmol) in CH_2Cl_2 (7.7 cm^3) (slight effervescence). The vessel was stoppered in such a way that any excess pressure would be released, and the temperature was maintained at *ca.* 35 °C for 24 h. Some solid precipitated (see below) but was not removed. All volatile material was evaporated (no heat) and (to remove the last traces of Me_3SiCl) light petroleum was added to, and evaporated from, the residue. Washing with ether afforded the solid *title compound* **8** (1.63 g, 57%) as a mixture of comparable amounts of the two diastereoisomers, $\delta_P(CH_2Cl_2)$ 41.7 and 40.7.

(b) In a similar experiment the precipitated solid was filtered off and washed with ether; it was found to be very largely the highfield diastereoisomer of the hydroxylamine **8** (18%). A portion crystallised from CH_2Cl_2–light petroleum (b.p. 40–60 °C) had m.p. 140–142 °C (decomp.); $\delta_P(CDCl_3)$ 42.0; $\delta_H(CDCl_3$; 300 MHz) 7.96–7.88 (2 H, m), 7.61–7.26 (8 H, m), 5.30 (1 H, s, NH), 3.72 (1 H, dq, J_{PH} 12, J_{HH} 7.5), 1.45 (3 H, dd, J_{PH} 17, J_{HH} 7.5) and −0.11 (9 H, s); *m/z* 333 (M^+, 30%), 318 (M^+ – Me, 15), 120 (80) and 105 ($PhCHMe^+$, 100); ν_{max}(Nujol)/cm^{-1} 3130 (NH), 1185 (P=O) and 850 (several maxima) (Found: C, 60.85; H, 7.4; N, 4.05. $C_{17}H_{24}NO_2PSi$ requires C, 61.2; H, 7.25; N, 4.2%). The filtrate contained both this diastereoisomer and the other in a ratio 1:2.5, together with a by-product (δ_P 34.0, *ca.* 20%); evaporation of volatile material and washing of the residue with ether–light petroleum gave a solid that was desilylated as described below.

N-[*Phenyl*(1-*phenylethyl*)*phosphinoyl*]*hydroxylamine* **9**.—(a) The *N*-phosphinoyl-*O*-silylhydroxylamine **8** (1.63 g, 4.9 mmol) from (a) above was dissolved in CH_2Cl_2 (24 cm^3) and methanol (1.2 cm^3, 6 mol equiv.) was added. The reaction was monitored by ^{31}P NMR spectroscopy [δ_P 43.7, 42.5 (diastereoisomers)→42.1, 40.2]. After 86 h all volatile material was removed under reduced pressure and the residue was triturated with ether to give the *N*-phosphinoylhydroxylamine **9** (1.24 g, 97%) as a mixture of diastereoisomers (*ca.* 1:1), $\delta_P(CDCl_3)$ 41.9 and 40.1.

(b) The two silylated materials from (b) above were similarly desilylated (complete in *ca.* 24 h) and the residues were triturated with ether to give two samples of the N-*phosphinoylhydroxylamine* **9**; sample B (from the precipitated material), very largely one diastereoisomer, m.p. 130–132 °C (decomp.) after crystallisation from chloroform–light petroleum; $\delta_P(CDCl_3)$ 40.1; $\delta_H(CDCl_3$; 300 MHz) 8.1 (br, OH), 7.73–7.37 (5 H, m), 7.20 (5 H, m), 5.96 (1 H, d, J_{PH} 9, NH), 3.41 (1 H, dq, J_{PH} 15, J_{HH} 7.5) and 1.43 (3 H, dd, J_{PH} 17, J_{HH} 7.5); *m/z* 261 (M^+, 5%), 245 (40), 141 (45), 140 (100) and 105 ($PhCHMe^+$, 65); ν_{max}(Nujol)/cm^{-1} 3160 (NH), 1155 (P=O) and 1115; sample A (from the filtrate), a mixture of diastereoisomers, $\delta_P(CDCl_3)$ 41.9 and 40.1 (ratio *ca.* 4.5:1). A small sample of the major diastereoisomer of sample A was obtained by crystallisation from CH_2Cl_2, m.p. 142.5–144.5 °C (decomp.); $\delta_H(CDCl_3$ 8.50 (1 H, br s, OH), 7.55–7.0 (10 H, m), 6.30 (1 H, d, J_{PH} 11.5, NH), 3.72 (1 H, dq, J_{PH} 19.5, J_{HH} 7.5) and 1.57 (3 H, dd, J_{PH} 16.5, J_{HH} 7.5); *m/z* 261 (M^+, 6%); ν_{max}(Nujol)/cm^{-1} 3260, 3220 (NH), 1170 (P=O) and 1120 (Found: C, 64.4; H, 6.3; N, 5.55. $C_{14}H_{16}NO_2P$ requires C, 64.4; H, 6.2; N, 5.4%).

N-[*Phenyl*(1-*phenylethyl*)*phosphinoyl*]-O-*methylsulfonyl-hydroxylamine* **10**.—A suspension of the *N*-phosphinoylhydroxylamine **9** (sample B) (496 mg, 1.90 mmol) in CH_2Cl_2 (8 cm^3) was stirred and cooled in ice. Triethylamine (192 mg, 1.90 mmol) was added, followed immediately by methanesulfonyl chloride (300 mg, 2.60 mmol). After 20 min, the mixture was allowed to warm to room temperature. It was diluted with CH_2Cl_2 (12 cm^3) and washed with water (2 × 4 cm^3), some solid that separated being redissolved by addition of more solvent and warming. The warm solution was dried and concentrated. Crystallisation of the residue from CH_2Cl_2–light petroleum afforded the *methanesulfonate* **10** (sample B) (97% one diastereoisomer) (395 mg, 61%), $\delta_P(CDCl_3)$ 38.1; $\delta_H(CDCl_3$; 300 MHz) 7.92–7.85 (2 H, m), 7.69–7.52 (3 H, m), 7.45–7.30 (5 H, m), 7.14 (1 H, d, J_{PH} 4, NH), 3.63 (1 H, dq, J_{PH} 12, J_{HH} 7.5), 2.70 (3 H, s) and 1.55 (3 H, dd, J_{PH} 18, J_{HH} 7.5) [small peaks at 3.14 (s) and 1.725 (dd) due to other diastereoisomer (3%)]; *m/z* 339 (M^+, 2%), 324 (M^+ – Me, 2), 245 (25), 141 (40), 140 (95) and 105 ($PhCHMe^+$, 100); *m/z* (CI) 340 (M + H^+, 40) and 246 (M + H^+ – $MeSO_3H$, 100); ν_{max}(Nujol)/cm^{-1} 3060 (NH) and 1185 (P=O). A portion further purified by recrystallisation from CH_2Cl_2–light petroleum had m.p. 177–179 °C (decomp.) (Found: C, 53.1; H, 5.3; N, 4.1. $C_{15}H_{18}NO_4PS$ requires C, 53.1; H, 5.35; N, 4.1%). Crystallisation of this from CH_2Cl_2 gave the sample for single crystal X-ray analysis.[1]

Samples of the *N*-phosphinoylhydroxylamine **9** having other

diastereoisomer compositions were similarly converted into the methanesulfonates. In particular, sample A gave the methanesulfonate **10** (sample A) as a 4:1 mixture of diastereoisomers, m.p. 154–157.5 °C; $\delta_P(CDCl_3)$ 39.6 (major) and 38.4; $\delta_H(CDCl_3)$ (major component) 8.45 (1 H, d, J_{PH} 7, NH), 7.63–6.85 (5 H, m), 7.12 (5 H, br s), 3.66 (1 H, dq, J_{PH} 15, J_{HH} 7.5), 3.10 (3 H, s) and 1.70 (3 H, dd, J_{PH} 16, J_{HH} 7.5) [smaller peaks at 2.73 (s) and 1.52 (dd) due to other diastereoisomer (20%)]; *m/z* (CI) 340 ($M + H^+$, 35%) and 246 (100); ν_{max}(Nujol)/cm^{-1} 3020 (NH) and 1180 (P=O).

1-*Phenylethylphosphonic Dichloride* **13**.—A mixture of triethyl phosphite (19.9 g, 120 mmol) and 1-bromoethylbenzene (11.1 g, 60 mmol) was stirred in a gentle stream of nitrogen, and the flask (fitted with an air condenser) was placed in an oil bath pre-heated to 160 °C. The temperature was raised during 15 min to 175 °C at which it was maintained for 2 h. Volatile material was removed under reduced pressure (20 then 0.2 mmHg) with gentle warming, and the crude diethyl 1-phenylethylphosphonate [$\delta_P(CDCl_3)$ 30.0] was hydrolysed by stirring with conc. hydrochloric acid (50 cm^3) at 120 °C (bath temp.) for 7 h (some decomposition occurred when heating was prolonged). When cool, the aqueous layer was decanted off and the residue was extracted with boiling water (2 × 30 cm^3). The combined aqueous portions were evaporated to dryness, ethanol was added and evaporated to remove remaining water, and the anhydrous solid was crystallised from EtOAc–light petroleum to give 1-phenylethylphosphonic acid (6.39 g, 57%), m.p. 151–152 °C (lit.,[14] m.p. 153–154.5 °C); $\delta_P(CDCl_3)$ 34.6 (broad). The phosphonic acid was stirred in thionyl chloride (20 mol equiv.) containing a catalytic amount of DMF (0.03 mol equiv.) at 90 °C (bath temp.) until reaction was complete [*ca.* 3 h; product $\delta_P(SOCl_2)$ 54.1]. Volatile material was removed and the residue was maintained at ≤0.2 mmHg for 1.5 h. The resulting phosphonic dichloride **13**[15] was used without further purification.

N-*Phenyl*-P-(1-*phenylethyl*)*phosphonamidic Chloride* **14**.—1-Phenylethylphosphonic dichloride **13** (2.27 g, 10.2 mmol) was stirred (powerful magnet) with aniline (1.90 g, 20.4 mmol) in benzene (6 cm^3) at 25 °C for 24 h, during which time much solid was precipitated. The mixture was diluted with benzene (10 cm^3) and the insoluble material ($PhNH_3Cl$) was filtered off. The filtrate was reduced in volume, diluted with ether, and stored overnight, when crystals of one of the diastereoisomers of the *phosphonamidic chloride* **14** (0.98 g, 34%) were obtained, m.p. 146–148 °C [from CH_2Cl_2–light petroleum (b.p. 40–60 °C)]; $\delta_P(CDCl_3)$ 42.3; $\delta_H(CDCl_3$; 300 MHz) 7.27 (5 H, br s), 7.3–7.15 (2 H, m), 7.07–6.98 (3 H, m), 5.75 (1 H, br d, J_{PH} 9.5, NH), 3.65 (1 H, dq, J_{PH} 17, J_{HH} 7.5) and 1.78 (3 H, dd, J_{PH} 22.5, J_{HH} 7.5); *m/z* 281 and 279 (M^+, 25%), 177 and 175 ($M^+ - PhCH{=}CH_2$, 15) and 105 ($PhCHMe^+$, 100); ν_{max}(Nujol)/cm^{-1} 3170 (NH) and 1210 (P=O) (Found: C, 60.0; H, 5.3; N, 4.7. $C_{14}H_{15}ClNOP$ requires C, 60.1; H, 5.4; N, 5.0%).

A similar preparation, but with most of the benzene being removed from the filtrate prior to the addition of ether, gave the phosphonamidic chloride (83%) as a mixture of diastereoisomers (ratio 30:70), $\delta_P(CDCl_3)$ 43.3 and 42.7 (major).

N-*Alkyl*-N′-*phenyl*-P-(1-*phenylethyl*)*phosphonic Diamides*.—The compounds below were produced in the reactions of the methanesulfonate **10** with $MeNH_2$ and Bu^tNH_2.

N-*Methyl*-N′-*phenyl*-P-(1-*phenylethyl*)*phosphonic diamide* **11**. (a) A pure sample of one diastereoisomer (product B) of the phosphonic diamide **11** was obtained by crystallisation of the product from the reaction of the methanesulfonate **10** (sample B) with $MeNH_2$ (neat or 1.0 mol dm^{-3} solution in CH_2Cl_2): m.p. 132–133 °C (softens at 120–122 °C) (from CH_2Cl_2–light petroleum); $\delta_P(CH_2Cl_2)$ 25.7; $\delta_H(CDCl_3$; 300 MHz) 7.45–6.85 (10 H, m), 4.66 (1 H, d, J_{PH} 10, N*H*Ph; exchanges with D_2O), 3.25 (1 H, dq, J_{PH} 17.5, J_{HH} 7.5. C*H*MePh), 2.70 (1 H, dq, J_{PH} ~ 12, J_{HH} ~ 6, N*H*Me; exchanges with D_2O), 2.59 (3 H, dd, J_{PH} 11.5, J_{HH} 5.5, NH*Me*; simplifies to d when treated with D_2O) and 1.62 (3 H, dd, J_{PH} 17.5, J_{HH} 7.5, CH*Me*Ph); *m/z* 274 (M^+, 35%), 169 ($M^+ -$ CHMePh, 100), 105 ($PhMeCH^+$, 35) and 93 ($PhNH_2^+$, 40%); ν_{max}(Nujol)/cm^{-1} 3220, 3190 (NH) and 1170 (P=O) [Found: C, 65.2; H, 6.5; N, 10.0 (approx.; very small sample). $C_{15}H_{19}N_2OP$ requires C, 65.7; H, 7.0; N, 10.2%]. A sample recrystallised from toluene was used for single crystal X-ray analysis.[1]

(b) A sample of the phosphonic diamide **11** having a predominance of the other diastereoisomer (product A) (ratio *ca.* 5:1) was obtained by distillation of the product from the reaction of the methanesulfonate **10** (sample A) with $MeNH_2$ (neat or 1.0 mol dm^{-3} solution in CH_2Cl_2): b.p. 150 °C (oven temp.) at 0.03 mmHg; $\delta_P(CH_2Cl_2)$ 26.2 (major component); $\delta_H(CDCl_3$; 300 MHz) 7.45–6.85 (10 H, m), 5.70 (1 H, d, J_{PH} 6.5, N*H*Ph; exchanges with D_2O), 3.29 (1 H, dq, J_{PH} 16.5, J_{HH} 7.5, C*H*MePh), 2.51 (3 H, dd, J_{PH} 11.5, J_{HH} 6, NH*Me*; simplifies to d with D_2O), 2.28 (1 H, dq, J_{PH} ~ 12, J_{HH} ~ 5.5, N*H*Me; exchanges with D_2O) and 1.56 (3 H, dd, J_{PH} 17.5, J_{HH} 7.5, CH*Me*Ph) (smaller signals for diastereoisomer B also present); *m/z* 274 (M^+, 40%), 169 (100), 105 (60) and 93 (50) (Found: M^+, 274.1235. $C_{15}H_{19}N_2OP$ requires *M*, 274.1235).

(c) An authentic sample of the phosphonic diamide **11** was obtained as a mixture of diastereoisomers (^1H and ^{31}P NMR; ratio A:B ~ 2:1) by treatment of *N*-phenyl-*P*-(1-phenylethyl)-phosphonamidic chloride **14** with $MeNH_2$; m.p. 126–130 °C (from benzene–light petroleum). The two diastereoisomers could not be separated GLC but were just separable by TLC (silica; EtOAc).

N-tert-*Butyl*-N′-*phenyl*-P-(1-*phenylethyl*)*phosphonic diamide* **12**. (a) The reaction of methanesulfonate **10** (sample B) with neat Bu^tNH_2 gave the phosphonic diamide **12** having diastereoisomer B as the dominant component (90%); crystallisation from CH_2Cl_2–light petroleum gave a sample containing comparable amounts of diastereoisomers B and A, m.p. 120–124 °C; for B (major before crystallisation), $\delta_P(CDCl_3)$ 22.5; $\delta_H(CDCl_3$; 300 MHz) 7.40–6.85 (10 H, m), 4.71 (1 H, d, J_{PH} 8, N*H*Ph), 3.245 (1 H, dq, J_{PH} ~ 18, J_{HH} ~ 7.5, C*H*MePh), 2.46 (1 H, d, J_{PH} 14, N*H*Bu^t), 1.62 (3 H, dd, J_{PH} 17.5, J_{HH} 7.5, CH*Me*Ph) and 1.305 (9 H, s); for A, $\delta_P(CDCl_3)$ 22.75; $\delta_H(CDCl_3$; 300 MHz) 7.40–6.85 (10 H, m), 5.11 (1 H, d, J_{PH} 6, N*H*Ph), 3.23 (1 H, dq, J_{PH} ~ 17, J_{HH} ~ 7.5, C*H*MePh), 2.12 (1 H, d, J_{PH} 13, N*H*Bu^t), 1.53 (3 H, dd, J_{PH} 17.5, J_{HH} 7.5, CH*Me*Ph) and 1.19 (9 H, s); *m/z* 316 (M^+, 25%), 301 ($M^+ -$ Me, 5), 260 ($M^+ - C_4H_8$, 10), 211 ($M^+ -$ CHMePh, 45), 155 ($M^+ - C_4H_8 -$ CHMePh, 100), 105 ($PhMeCH^+$, 45) and 93 ($PhNH_2^+$, 50); ν_{max}(Nujol)/cm^{-1} 3390, 3210 (NH) and 1190 (P=O); R_t 8.3 (A) and 9.5 min (OV 1701, 230 °C).

(b) Samples of the phosphonic diamide **12** in which diastereoisomer B was less dominant were obtained from other reactions of the methanesulfonate **10** with Bu^tNH_2.

(c) An authentic sample of the phosphonic diamide **12** was obtained as a mixture of diastereoisomers (A:B ~ 3:2) by treatment of *N*-phenyl-*P*-(1-phenylethyl)phosphonamidic chloride **14** with Bu^tNH_2: m.p. 122–123.5 °C (from ether–light petroleum) (Found: C, 68.1; H, 8.1; N, 8.85. $C_{18}H_{25}N_2OP$ requires C, 68.3; H, 8.0; N, 8.85%).

N-*Alkyl*-N′-(1-*phenylethyl*)-P-*phenylphosphonic Diamides*.—Samples of these compounds were required to confirm that they were not formed in the rearrangements of methanesulfonate **10**. They were prepared as detailed below.

N-*Methyl*-N′-(1-*phenylethyl*)-P-*phenylphosphonic diamide* **15** (R = Me). (±)-1-Phenylethylamine (2 mol equiv.) in benzene

(1 cm^3 per mmol) was added to a stirred (powerful magnet) solution of phenylphosphonic dichloride (1 mol equiv.) in benzene (2 cm^3 per mmol) over 20 min (N_2 atmosphere). After 2.5 h the mixture was diluted with ether and insoluble material (RNH_3Cl) was filtered off under nitrogen. The filtrate [δ_P 32.9 and 31.3; PhP(O)(NHCHMePh)Cl (diastereoisomers)] was treated with $MeNH_2$ (4–5 mol equiv.); much solid ($MeNH_3Cl$) precipitated. Volatile material was evaporated and the residue was partitioned between CH_2Cl_2 and water. The organic portion was dried and concentrated to give the *phosphonic diamide* **15** (R = Me), $\delta_P(CH_2Cl_2)$ 20.2 (major) and 19.8, diastereoisomer ratio 55:45. Crystallisation from chloroform–light petroleum gave an almost pure sample (97%) of the major diastereoisomer, m.p. 133–136 °C; $\delta_H(CDCl_3$; 300 MHz) 7.82–7.71 (2 H, m), 7.52–7.36 (3 H, m), 7.34–7.17 (5 H, m), 4.34 (1 H, ddq, J_{PH} ~ 9, J_{HH} ~ 9 and 7, NHC*H*MePh; simplifies to dq with D_2O), 2.865 (1 H, br dd, J_{PH} ~ J_{HH} ~ 9, N*H*CHMePh; exchanges with D_2O), 2.52 (3 H, dd, J_{PH} 12, J_{HH} 6, NH*Me*; simplifies to d with D_2O), 2.38 (1 H, br m, N*H*Me; exchanges with D_2O) and 1.44 (3 H, d, J_{HH} 7, CH*Me*Ph) [small signals for the minor diastereoisomer at 2.635 (dd, J_{PH} 12, J_{HH} 6, NH*Me*) and 1.48 (d, J_{HH} 7, CH*Me*Ph)]; *m/z* 274 (M^+, 12%), 259 (M^+ – Me, 25) 154 (M^+ – NHCHMePh, 35) and 120 (100); ν_{max}(Nujol)/cm^{-1} 3290, 3240 (NH) and 1180 (P=O) (Found: C, 65.3; H, 7.0; N, 10.25. $C_{15}H_{19}N_2OP$ requires C, 65.7; H, 7.0; N, 10.2%).

N-tert-*Butyl*-N′-(1-*phenylethyl*)-P-*phenylphosphonic diamide* **15** (R = Bu^t). (±)-1-Phenylethylamine (363 mg, 3.0 mmol) was added to a stirred solution of PhP(O)(NHBu^t)Cl (231 mg, 1.0 mmol)[16] in CH_2Cl_3 (3 cm^3). After 30 min the mixture was diluted with CH_2Cl_2 and washed, first with dilute aqueous NaOH, then with dilute hydrochloric acid (just sufficient to remove the excess amine), and finally with water. The organic portion was dried and concentrated to give the *phosphonic diamide* **15** (R = Bu^t), b.p. 128 °C (oven temp.) at 0.02 mmHg; $\delta_P(CDCl_3)$ 17.3 and 16.5 (diastereoisomers; ratio *ca.* 1:1); $\delta_H(CDCl_3$; 300 MHz) 7.87–7.68 (2 H, m), 7.49–7.13 (8 H, m), 4.62 and 4.29 (total 1 H; both ddq, J_{PH}, J_{HH}, J_{HH} all ~7–9, NHC*H*MePh), 2.81 and 2.71 br (total 1 H; both dd, J_{PH} ~ 9, J_{HH} ~ 7.5, N*H*CHMePh), 2.42 and 2.24 (total 1 H; both d, J_{PH} 7 or 8.5, N*H*Bu^t), 1.47 and 1.41 (total 3 H; both d, J_{HH} 7, CH*Me*Ph), and 1.23 and 1.13 (total 9 H; both s); *m/z* 316 (M^+, 20%), 301 (M^+ – Me, 85), 197 (M^+ – Me – H_2C=CHPh, 45), 140 (60), 120 (100) and 105 (PhCHMe$^+$, 70); $\nu_{max}(CH_2Cl_2)$/cm^{-1} 3400 (NH), 1225, 1200 and 1120 (Found: M^+, 316.1704. $C_{18}H_{25}N_2OP$ requires *M*, 316.1705).

Stereochemical Studies.—In general, the methanesulfonate **10** (sample A or sample B) (27 mg, 0.08 mmol) was added to a large excess of the amine (≥20 mol equiv.), neat or as a solution in CH_2Cl_2 (1.0 or 0.1 mol dm^{-3}) at room temperature (Bu^tNH_2), or below ($MeNH_2$; 0 °C). In the case of neat $MeNH_2$ the amine was added to the methanesulfonate at −5 to −10 °C. After preliminary examination of the reaction mixture by ^{31}P NMR spectroscopy, volatile material was evaporated and the residue was partitioned between CH_2Cl_2 and water (to remove RNH_3^+ OMs). The organic layer was dried and the diastereoisomer ratio of the phosphonic diamide rearrangement product **11** or **12** was determined by ^{31}P NMR spectroscopy and confirmed by ^1H NMR spectroscopy (Table 1). In some cases the rearrangement product was purified by distillation and/or crystallisation and further characterised.

Side reactions were appreciable (10–20%) or extensive (25–50%) for the reaction using 1.0 or 0.1 mol dm^{-3} amine. Evidence was obtained for 3 types of by-product: phosphinic hydrazide **20** [with R = Bu^t, isolated (acid extraction) from reaction of **10** (sample B) with 0.1 mol dm^{-3} Bu^tNH_2 as one diastereoisomer, δ_P 35.3; identified by comparison (^1H NMR, MS) with authentic sample (phosphinic chloride **7** + Bu^t$NHNH_2$), δ_P 36.9 and 35.3 (diastereoisomers)]; phosphinic amide **22** [δ_P ~ 33 (2 peaks; diastereoisomers) as for authentic sample (phosphinic chloride **7** + NH_3)]; phosphonamidic anhydride **21** [δ_P 24.5–23.5 (several peaks; diastereoisomers); hydrolysed to PhMeCHP(O)(NHPh)OH, identified by comparison with authentic acid (phosphonamidic chloride **14** + H_2O) and by conversion (CH_2N_2) into its methyl ester].

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