

Design and Synthesis of a New Macrobicyclic Tris(phosphazide)

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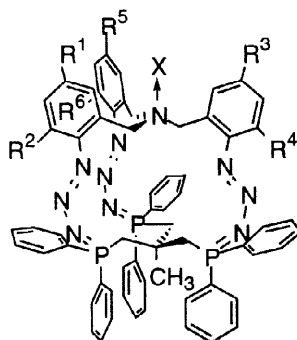
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Abstract

Design, synthesis and full characterization, including X-ray determination, of the first macrobicyclic tris(phosphazide) with two *Z* and one *E* PN₃ units is described. © 1998 Elsevier Science Ltd. All rights reserved.

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The imination reaction of trivalent phosphorus compounds with organic azides is known as the Staudinger reaction [1–4], a two-step process involving the initial nucleophilic attack of a P(III) centre, usually a tertiary phosphane (R¹)₃P to the terminal nitrogen atom of an azide R²N₃ followed by dinitrogen extrusion from the intermediate phosphazide R²N₃P(R¹)₃ giving the λ⁵-phosphazene R²N=P(R¹)₃ (also known as phosphine imine or iminophosphorane). Only in a few instances have the primary imination products, phosphazides, been isolated [3–5]. We recently described the preparation of the first examples of macrobicyclic tris(phosphazides) **1** by coupling of two tripodal subunits, tris(*o*-azidobenzyl)amines and 1,1,1-tris[(diphenyl phosphino)methyl]ethane (triphos), *via* triple P–N bond formation through the Staudinger reaction [6,7]. Such new type of C₃-symmetric cage compounds were shown to possess three intracyclic PN₃ units of *Z* configuration, propeller-like topology, and a new conformation of the tripodal phosphane fragment [6].



1 X = lone pair, O

Herein we report the results obtained when other tripodal

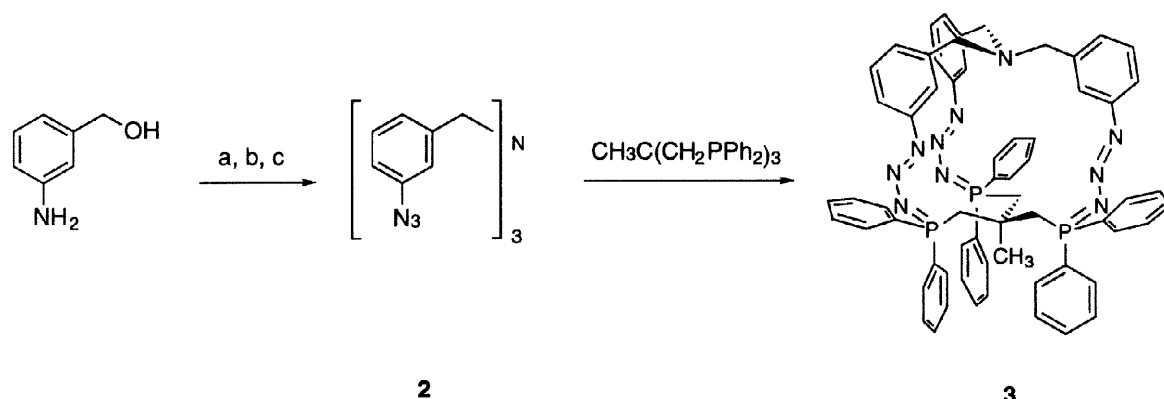
tris(azides) were reacted with triphos, which have led to the rational design and successful preparation of a new, fully characterized macrobicyclic tris(phosphazide) of unusual structure.

Initial attempts to couple efficiently other tripodal tris(azides), such as $\text{CH}_3\text{C}(\text{CH}_2\text{N}_3)_3$ [8], $\text{N}(\text{CH}_2\text{CH}_2\text{N}_3)_3$ [9], and *N,N*-bis(*o*-azidobenzyl)(*o*-azidophenethyl)amine [10], with triphos were unsuccessful. These reactions, under a variety of reaction conditions, always led to uncharacterized oligomeric products. After these discouraging results, a more careful design of the tris(azide) reaction partner was undertaken.

On the basis of the topological similarities existing between the tris(*o*-azido) and tris(*m*-azido) benzylamine structural fragments, both showing feasible conformations that yield the same relative positioning of their three azido groups, we reasoned that tris(*m*-azidobenzyl)amine could be a suitable candidate molecule to couple efficiently with triphos. In that case, the resulting macrobicyclic would have the pivotal N lone pair oriented inside of the macrocyclic cavity.



Tris(*m*-azidobenzyl)amine **2** was prepared by standard chemistry starting from commercially available *m*-aminobenzyl alcohol, by using the synthetic protocol that we previously applied for the preparation of tris(*o*-azidobenzyl)amines [7, 10] (Scheme 1).



Reagents and conditions: (a) NaNO_2 , $\text{H}_2\text{SO}_4\text{-H}_2\text{O}$, $0\text{-}5^\circ\text{C}$, 1 h, then NaN_3 , r.t., 12 h (82%); (b) SOCl_2 , CH_2Cl_2 , r.t., 2 h (86%); (c) NH_3 , sealed tube, r.t., 48 h (28%)

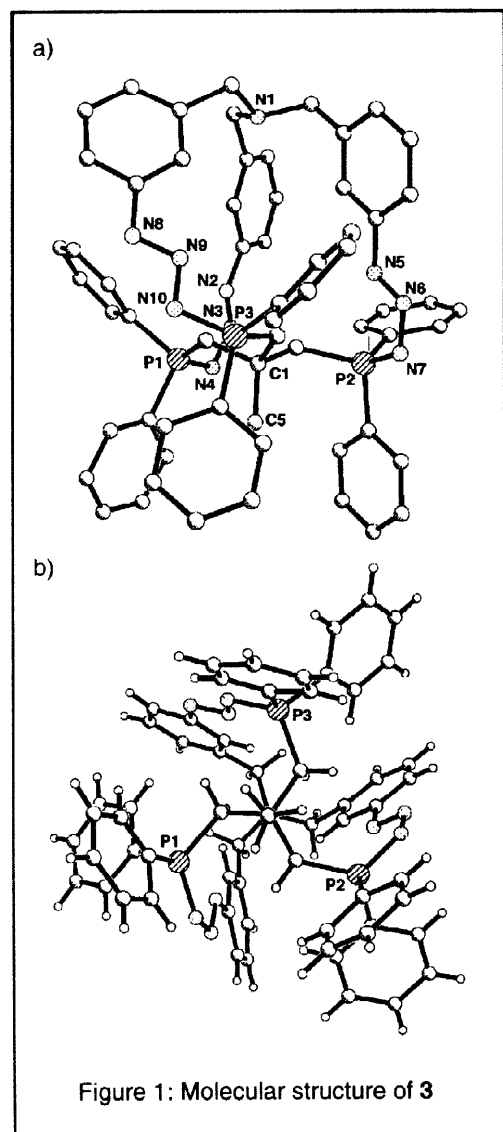
Scheme 1

From the reaction of equimolar amounts of tris(azide) **2** with triphos in diethyl ether at room temperature, the new macrobicyclic tris(phosphazide) **3** was isolated in 79 % yield in the form of yellow microcrystals which precipitated from the reaction mixture after 2 h (Scheme 1).

Analytical and spectral data¹ of **3** were consistent with its presumed C_3 -symmetric tris(phosphazide) structure, and essentially similar to those of **1**. The more significant

difference between **1** and **3** was the phosphorus resonance in the $^{31}\text{P}\{^1\text{H}\}$ NMR spectrum of **3** in CDCl_3 at 298 K, as a very broad signal around δ 4, contrary to the sharp singlet near δ -1 shown by compounds **1** under similar recording conditions. Other signals in the ^1H and ^{13}C NMR spectra of **3** were also broad. These observations may be indicative of the fluxionality of **3**, not present in compounds **1**, as a consequence of the lengthening by one carbon atom in each arm of the bicyclic skeleton of **3** in relation to **1**, which rendered less rigid the new macrobicyclic.

Crystals of **3** suitable for X-ray structure analysis were grown by slow diffusion of diethyl ether into a dichloromethane solution of the crude reaction product. The molecular structure of **3** [Figure 1(a)] shows, as expected, the C5 atom located outside of the bicyclic cavity, whereas the nitrogen lone pair at N1 is oriented inside. Its propeller-like shape is clearly apparent when the molecule is viewed along the C5-C1-N1 vector [Figure 1(b)]. Rather surprisingly, two of the zwitterionic PN_3 fragments ($\text{P}^+-\text{N}=\text{N}-\text{N}^-$), those containing P1 and P2, present a *Z* configuration with respect to the central $\text{N}=\text{N}$ bond, in contrast with the *E* configuration of that containing P3. This molecule is thus the first reported polyphosphazide with PN_3 units of different configuration.



The observed magnetic equivalence of the three arms of the macrobicyclic **3** in the solution NMR experiments can only be understood if, in these conditions, the fluxionality of **3** involves

¹ Compound **3**: m.p. > 350°C. $\text{C}_{62}\text{H}_{57}\text{N}_{10}\text{P}_3$ (m.w. 1035.1) Calculated: C, 71.94; H, 5.55; N, 13.53. Found: C, 71.77; H, 5.68; N, 13.36. FT-IR (Nujol) 1440, 1122, 1075, 695 cm^{-1} . ^1H NMR (300 MHz, CDCl_3 , 298 K) δ 8.10-7.90 (m, 9H), 7.59 (d, 3H, $J = 7.8$ Hz), 7.50-7.25 (m, 18H), 7.18 (t, 3H, $J = 7.5$ Hz), 7.10-6.80 (m, 9H), 3.86 (m, 6H), 3.63 (br d, 6H, $J = 14.3$ Hz), -0.26 (s, 3H). ^{13}C NMR (75 MHz, CDCl_3 , 298 K) δ 150.39, 141.55, 132.92 (d, $J = 7.5$ Hz), 132.26 (d, $J = 1.0$ Hz), 132.16 (d, $J = 105.8$ Hz), 131.48 (d, $J = 2.0$ Hz), 131.09 (d, $J = 9.1$ Hz), 129.85 (d, $J = 83.6$ Hz), 128.73 (d, $J = 11.6$ Hz), 128.71 (d, $J = 10.1$ Hz), 128.65, 125.78, 119.00 (br, two carbons), 57.35, 40.68 (q, $J = 3.5$ Hz), 40.05 (m), 26.58. $^{31}\text{P}\{^1\text{H}\}$ NMR (121 MHz, CDCl_3 , 298 K) δ 3.76 (br). FAB⁺-MS 1036 (M^++1).

E/Z equilibration of the phosphazide fragments to yield a C_3 -symmetric mean conformation. This assumption is also in accord with the results of low temperature NMR experiments. Thus, on cooling to 243 K the broad singlet in the $^{31}\text{P}\{^1\text{H}\}$ NMR spectrum of **3** in CDCl_3 solution resolved into two well-separated multiplets of complex fine structure, centered at δ 2 and 23, which probably are associated with two types of phosphorus atoms: those included into PN_3 units of *Z* and *E* configuration respectively.

Contrary to compounds **1** ($X = \text{lone pair}$), which were unstable in CDCl_3 solution at room temperature decomposing totally in less than 24 h [7], the new tris(phosphazide) **3** was notably more stable, remaining unchanged at RT for weeks, thus paralleling the stability of *N*-oxides **1** ($X = \text{O}$). The stability of **3** can be a consequence of the larger skeleton of the macrobicycle **3** in relation to **1**, resulting in a higher degree of conformational freedom.

Whereas compounds **1** ($X = \text{O}$) were easily obtained by coupling of tris(*o*-azidobenzyl)amine *N*-oxides and triphos, conversion of tris(*m*-azidobenzyl)amine **2** to its corresponding *N*-oxide and further reaction with triphos did not yield the expected tris(phosphazide), instead of giving rise to oligomeric products. This result must be associated to the topological differences at the bridgehead nitrogen atom between macrobicycles **1** and **3**, lone pair (or oxygen) oriented outside of the cavity in **1**, inside in **3**.

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