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**UNEXPECTED CYCLIZATION REACTION OF AN OVERCROWDED
2-PHOSPHINOPHENYLMETHANIMINE DERIVATIVE LEADING TO
THE FORMATION OF THE FIRST STABLE 2-PHOSPHA-2*H*-ISO-
INDOLE DERIVATIVE[#]**

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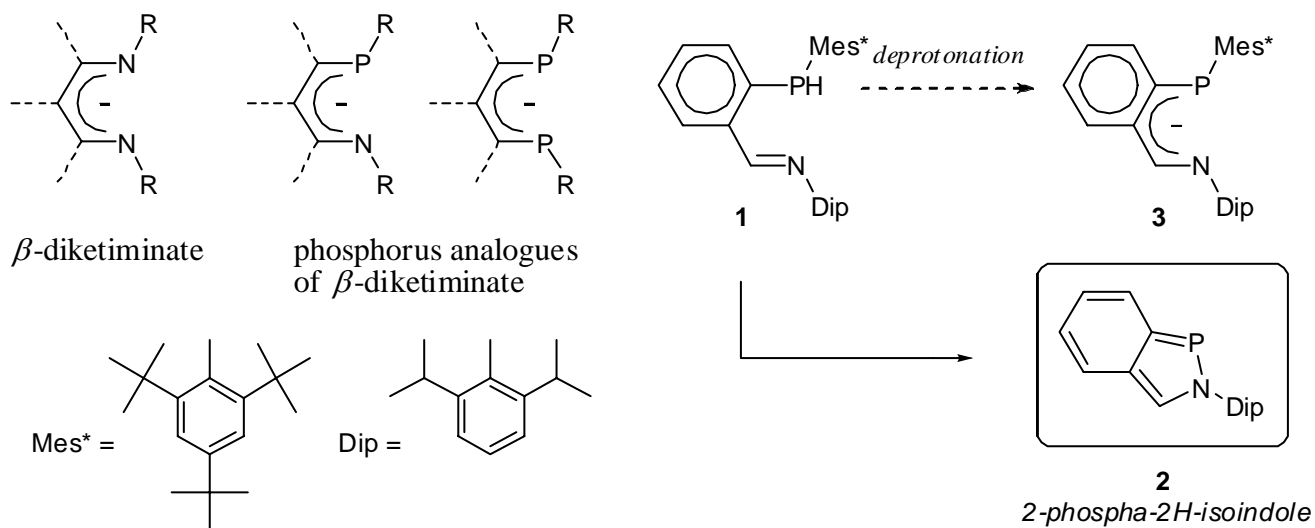
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Abstract – The reaction of overcrowded 2-phosphinophenylmethanimine derivative **1** bearing a 2,4,6-tri-*t*-butylphenyl (Mes*) group on the phosphorus atom and a 2,6-diisopropylphenyl (Dip) group on the nitrogen atom with potassium hydride afforded 2-phospha-2*H*-isoindole **2** along with Mes*H.

[#] Dedicated to Prof. Dr. Ryoji Noyori on the occasion of his 70th birthday.

Recently, β -diketiminato ligands bearing resonance structures with amido and imino moieties have attracted much attention from the viewpoint of unique monovalent bidentate ligands toward transition metals and main group elements.¹ On the other hand, the coordination chemistry of sp^2 -hybridized phosphorus compounds has drawn a great deal of recent attention due to their unique electronic properties of π -electron systems containing a phosphorus atom,² whose characteristic low-lying atomic orbital make it possible to work as a good π -acceptor toward the metal center.³ Although there have been much interest in the chemistry of phosphorus analogues of a β -diketiminato ligand, which should exhibit unique properties reflecting characteristic features of an sp^2 -hybridized phosphorus atom,^{4,5} it is difficult to isolate and handle such a low-coordinated phosphorus compound. It is well known that a double bond containing a heavier atom such as a P=C double bond is highly reactive to undergo facile oxidation, hydrolysis, and self-oligomerization.² Since the first isolation of stable phosphalkene (Bickelhaupt et al.)⁶ and diphosphene (Yoshifuji et al.)⁷ around 1980's, the idea of kinetic stabilization afforded by bulky substituents has been proven to be very effective for the construction of doubly bonded systems

containing (a) heavier atom(s).² During the course of our studies on the low-coordinated species of heavier group 15 elements by taking advantage of kinetic stabilization using bulky substituents,^{2,8} we have designed a novel phosphorus analogue of a benzo-fused β -diketiminato ligand, 2-phosphinophenylmethanimine **1**, a possible bidentate ligand toward transition metals and main group elements.⁴ In this paper, we describe the synthesis of 2-phosphinophenylmethanimine **1**, and the attempted deprotonation reaction of **1** using potassium hydride leading to the formation of unexpected heterocyclic compound, 2-phospha-2*H*-isoindole **2**, along with the elimination of Mes* unit. Since no synthetic work on a 2-phospha-2*H*-isoindole derivative has been reported so far, the reaction should be of great importance as a unique synthetic method for the construction of a phosphorus-containing heterocyclic compound, 2-phospha-2*H*-isoindole.



Scheme 1

2-Phosphinophenylmethanimine **1** was prepared according to Scheme 2.⁹ Although dichlorophosphines and phosphines having a P-H bond are generally difficult to handle in the air due to its high reactivity toward oxygen and moisture, Mes*PCl₂ and the related derivatives **5-7** bearing a P-X (X = Cl, H) bond are stable under ambient conditions owing to the bulky substituent, Mes* group. We have attempted the deprotonation reaction of **1** in the expectation of the formation of the corresponding phosphide **3** as a good precursor for the introduction of a transition metal or a main group element between P and N atoms. While **1** (54 mg, 0.10 mmol) was found to be inert toward potassium hydride (6.0 mg, 0.15 mmol, 1.5 eq.) in THF (10 mL) at room temperature as judged by the ¹H NMR spectrum, heating of the reaction mixture in C₆D₆ at 60 °C for 1 h afforded the unexpected products, 2-phospha-2*H*-isoindole **2**⁹ and Mes*H, quantitatively.¹⁰ Although **2** was found to be decomposed through the purification procedures using GLPC or column chromatography, a few single crystals of **2** suitable for X-ray crystallographic analysis were obtained by continual efforts on the recrystallization of the crude mixture. Thus, the

structural parameters of the first stable 2-phospha-2*H*-isoindole **2** were revealed by the X-ray crystallographic analysis (Figure 1).¹¹

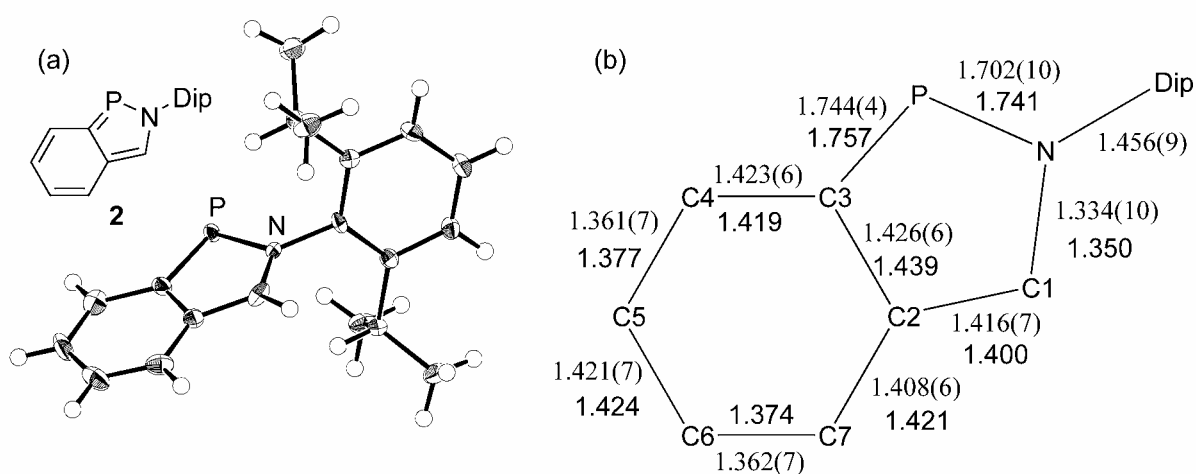
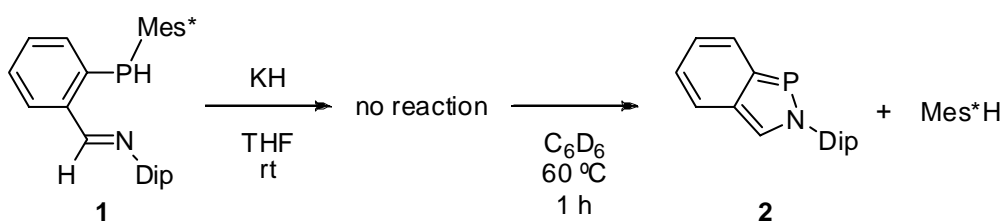
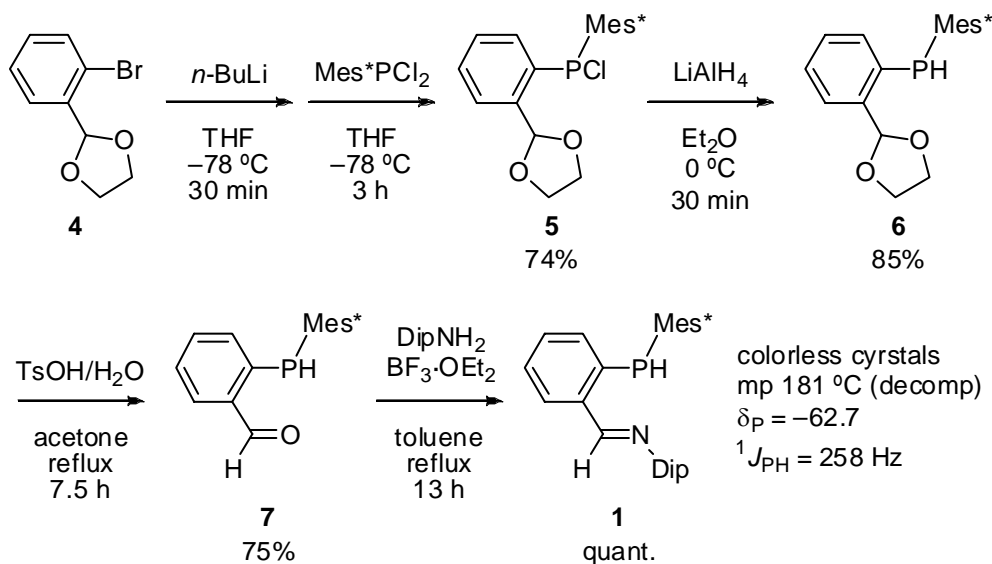
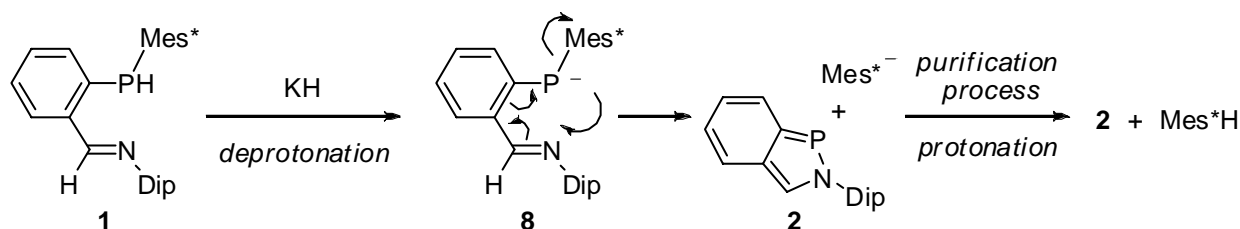


Figure 1. (a) Molecular structure of **2** (Major part of disordered molecules). Displacement ellipsoids were drawn at the 50% probability level (b) Observed (plane) and calculated (gothic) bond lengths of **2** (Å).

Although the 2-phospha-2*H*-isoindole skeleton was disordered in the X-ray crystallographic analysis, the observed structural parameters were supported by the theoretically optimized structure at

B3LYP/6-31+G(2d,p) level. The observed bond-alternation in the benzo-moiety suggests the electronic structure of **2** as a 2-phospha-2*H*-isoindole derivative. In addition, NBO calculations for the optimized structure of **2** showed σ - and π -bonds (double bonds) between C1=C2, C3=P, C4=C5, and C6=C7, while P-N, N-C1, C2-C7, C3-C4, and C5-C6 bonds were computed as single bonds, indicating somewhat localized π -electrons on the 2-phospha-2*H*-isoindole skeleton. In the ^{31}P NMR spectrum of **2** (in C_6D_6), a signal was observed in the relatively lower field at 182.8 ppm, which is characteristic of an sp^2 -hybridized phosphorus atom. Although isoindole derivatives are generally colorless compounds, 2-phospha-2*H*-isoindole **2** is colored as yellow. Indeed, **2** showed strong absorption around 363 nm probably corresponding to the π - π^* electron transitions in the UV/vis spectrum (in hexane),¹² indicating smaller HOMO-LUMO energy gap of **2** than those of isoindole derivatives, which should reflect the unique character of a π -electron conjugated system containing low-coordinated phosphorus atom.

The plausible formation mechanism of **2** by the thermal reaction of **1** with potassium hydride was shown in Scheme 4. Since the P-H proton should be the most acidic among those in **1**, the corresponding phosphide **8** should be a reasonable intermediate in this reaction. In the DFT calculations, the local minimum structure of model compound **9a**, which is a less hindered model compound for **8** bearing 2,6-dimethylphenyl (Dmp) groups on the phosphorus and nitrogen atoms instead of Mes* and Dip groups, was optimized as shown in Figure 2. Next, the structural optimizations for anion species **9b-d** were performed with the fixed P-N bond lengths as 2.00 (**9b**), 1.90 (**9c**), and 1.80 (**9d**) Å. As a result, it was found that the P-C(Dmp) bond was elongated as the P and N atoms get closer to each other, indicating the weakened P-C(Dmp) bond as the P-N bond was shortened. Thus, the generation of **2** and Mes*H in the reaction of **1** with potassium hydride at 60 °C is most likely interpreted in terms of the intermediacy of phosphide **8** giving **2** along with the elimination of Mes* anion species as shown in Scheme 4.



Scheme 4

In summary, a novel heterocyclic compound, 2-phospha-2*H*-isoindole **2**, was unexpectedly obtained by heating of overcrowded 2-phosphinophenylmethanimine **1** with potassium hydride at 60 °C in C_6D_6 together with Mes*H. Based on the theoretical calculations, the generation of **2** is most likely interpreted in terms of the intermediacy of the corresponding phosphide **8**. This unique reactivity of 2-phosphinophenylmethanimine **1** should be of importance in view of the construction of novel heterocyclic compounds containing a phosphorus atom.

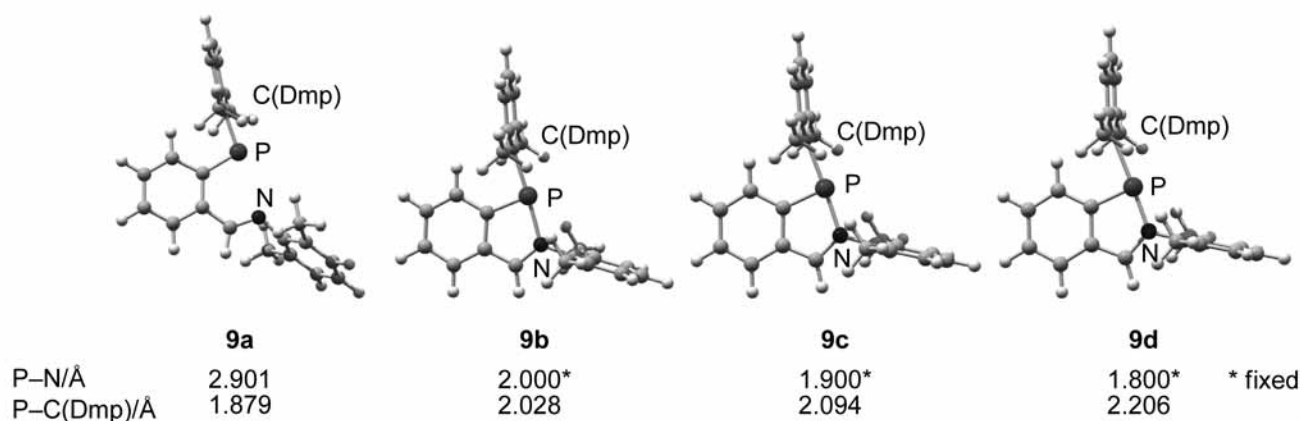


Figure 2. Theoretically optimized structures of phosphides **8a-d** (B3LYP/6-31+G(2d,p)).

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 9. Chemical data for **1**: yellow crystals, mp 118 °C (decomp.); ^1H NMR (300 MHz, C_6D_6 , 298 K) δ 1.27 (d, $^3J_{\text{HH}} = 7.2$ Hz, 6H), 1.29 (d, $^3J_{\text{HH}} = 7.2$ Hz, 6H), 1.37 (s, 9H), 1.46 (s, 9H), 1.70 (s, 9H), 3.37 (sept, $^3J_{\text{HH}} = 6.9$ Hz, 6H), 6.37 (d, $J_{\text{HH}} = 3.3$ Hz, 1H), 6.51 (d, $^1J_{\text{PH}} = 258.3$ Hz, 1H), 6.79 (pt, $J_{\text{HH}} = 7.5$ Hz, 1H), 6.88 (pt, $J_{\text{HH}} = 7.5$ Hz, 1H), 7.17-7.26 (m, 3H), 7.54 (dd, $J_{\text{HH}} = 2.6, 7.1$ Hz, 1H), 7.73 (s, 2H), 8.53 (d, $^4J_{\text{PH}} = 1.6$ Hz, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, C_6D_6 , 298 K) δ 23.8 (CH_3), 23.9 (CH_3), 28.6 (CH), 31.5 (CH_3), 33.5 (CH_3), 33.7 (CH_3), 33.9 (CH_3), 35.3 (C), 38.5 (C), 39.0 (C), 122.3 (CH), 123.2 (CH), 123.5 (CH), 124.7 (CH), 127.0 (CH), 130.3 (CH), 130.4 (C), 130.9 (C), 131.3 (CH), 133.3 (CH), 136.7 (C, d, $J_{\text{PC}} = 11.8$ Hz), 137.7 (C), 143.7 (C, d, $J_{\text{PC}} = 30.8$ Hz), 149.9 (C), 151.0 (C), 156.1 (C), 158.2 (C, d, $J_{\text{PC}} = 21.8$ Hz), 162.6 (CH, d, $J_{\text{PC}} = 5.5$ Hz); $^{31}\text{P}\{^1\text{H}\}$ NMR (120 MHz, C_6D_6 , 298 K) δ -62.7. High-resolution MS (ESI) m/z Calcd for $\text{C}_{37}\text{H}_{53}\text{NP}$ 542.3929. Found 542.3910 ($[\text{M}+\text{H}]^+$). Anal. Calcd for $\text{C}_{37}\text{H}_{52}\text{NP}$: C, 82.02; H, 9.67; N, 2.59%. Found: C, 82.04; H, 9.72; N, 2.76%. Chemical data for **2**: yellow crystals; ^1H NMR (300 MHz, C_6D_6 , 298 K) δ 0.98 (d, $^3J_{\text{HH}} = 6.9$ Hz, 6H), 1.11 (d, $^3J_{\text{HH}} = 6.9$ Hz, 6H), 2.38 (sept, $^3J_{\text{HH}} = 6.9$ Hz, 2H), 6.89-7.03 (m, 2H),

7.07 (d, $^3J_{\text{HH}} = 7.6$ Hz, 2H), 7.21 (dd, $^3J_{\text{HH}} = 7.6$ Hz, 1H), 7.58 (d, $^3J_{\text{PH}} = 3.9$ Hz, 1H), 7.70 (d, $J_{\text{HH}} = 8.1$ Hz, 1H), 7.98 (dd, $J_{\text{HH}} = 3.6, 8.4$ Hz, 1H); $^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, C_6D_6 , 298 K) δ 24.8 (CH_3), 25.4 (CH_3), 28.3 (CH), 122.7 (CH, d, $J_{\text{PC}} = 18.8$ Hz), 123.2 (CH, d, $J_{\text{PC}} = 3.8$ Hz), 123.6 (CH), 124.3 (CH, d, $J_{\text{PC}} = 1.9$ Hz), 129.4 (CH), 131.4 (C, d, $J_{\text{PC}} = 7.5$ Hz), 135.6 (CH, d, $J_{\text{PC}} = 8.3$ Hz), 138.7 (C, d, $J_{\text{PC}} = 10.5$ Hz), 145.0 (C, d, $J_{\text{PC}} = 2.3$ Hz), 150.3 (C), 158.3 (C, d, $J_{\text{PC}} = 41.3$ Hz); $^{31}\text{P}\{^1\text{H}\}$ NMR (120 MHz, C_6D_6 , 298 K) δ 182.8; High-resolution MS (ESI-TOF) m/z Calcd for $\text{C}_{19}\text{H}_{23}\text{NP}$: 296.1563. Found 296.1560 ($[\text{M}+\text{H}]^+$).

10. The resulting Mes*H was isolated in 95% yield. When **1** was heated in C_6D_6 for several hours in the absence of KH, no change was observed by the ^1H NMR spectra.
11. X-Ray crystallographic data for **2** ($\text{C}_{19}\text{H}_{22}\text{NP}$): $M = 295.35$, $T = 103(2)$ K, triclinic, $P\bar{1}$ (no.2), $a = 5.9609(2)$ Å, $b = 11.1103(3)$ Å, $c = 13.2811(3)$ Å, $\alpha = 72.1129(9)^\circ$, $\beta = 86.2549(11)^\circ$, $\gamma = 79.382(3)^\circ$, $V = 822.69(4)$ Å³, $Z = 2$, $D_{\text{calc}} = 1.192$ g cm⁻³, $\mu = 0.161$ mm⁻¹, $\lambda = 0.71070$ Å, $2\theta_{\text{max}} = 51.0$, 7063 measured reflections, 3004 independent reflections ($R_{\text{int}} = 0.0291$), 212 refined parameters, GOF = 1.225, $R_1 = 0.0868$ and $wR_2 = 0.2219$ [$I > 2\sigma(I)$], $R_1 = 0.0882$ and $wR_2 = 0.2225$ [for all data], largest diff. peak and hole 0.561 and -0.343 e.Å⁻³. The central P–N–C moiety was disordered (0.83 : 0.17). Crystallographic data (excluding structure factors) for the structure reported in this paper have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication no. CCDC 680783. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB21EZ, UK (fax: (+44)1223-336-033; E-mail: deposit@ccdc.cam.ac.uk.). The intensity data were collected on a Rigaku/MS Mercury CCD diffractometer. The structure was solved by direct methods (SHELXS-97) and refined by full-matrix least-squares procedures on F^2 for all reflections (SHELXL-97).
12. The hexane solution of the mixture of **2** and Mes*H was used in the measurement of UV-vis spectrum. Since Mes*H exhibits no absorption in the visible light region, the observed absorption should be assignable to those of **2**.