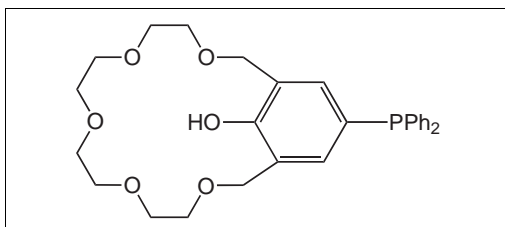


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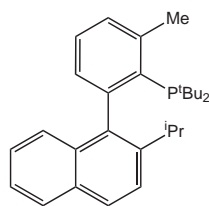


5-Diphenylphosphino-2-hydroxy-1,3-xylyl-18-crown-5 has been synthesized from 5-bromo-2-hydroxy-18-crown-5 by reacting it in sequence at low temperature with *n*-butyl lithium and methyl diphenylphosphonite. The phosphorous donor properties of this phenol phosphine (OH derivative) and the corresponding phenoxide (O⁻ derivative) have been studied in the presence and absence of alkali metal ions by determining the frequencies of the A₁ ν(CO) bands of Ni(CO)₃L complexes. For the OH and O⁻ derivatives, the latter generated by addition of CsOH to the former, the ν(CO) bands are observed at 2067.6 and 2063.4 cm⁻¹, respectively, providing the trend predicted by Hammett parameters for OH and O⁻ substituents. Addition of Na⁺ or K⁺ to the OH derivative has little effect on this stretching frequency, but the former ion shifts the O⁻ derivative band to 2067.7 cm⁻¹. A solid state structure has been obtained of the OH derivative, and two independent molecules were found in the unit cell. Both have a single water molecule hydrogen bonded to two across-ring oxygen atoms and the phenol hydrogen. The crown ether ring has the usual gauche and anti arrangements for the C-C and C-O bonds.

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Introduction.

Phosphine ligands and their complexes continue to generate considerable interest driven in large part by the proven applications of phosphine ligated complexes as catalytic or stoichiometric reagents for a variety of organic reactions. For example, phosphine ligated palladium complexes are known to be effective catalysts for a variety of coupling reactions [1-3]. Specific examples include bulky, electron rich phosphines including **1** which Buchwald and coworkers have reported to be, in conjunction with Pd(OAc)₂ or Pd₂(dba)₃, effective catalysts for coupling either aryl bromides with secondary alcohols or heteroaryl halides such as bromothiophenes with secondary amines [4-5]. As a result, there continues to be an

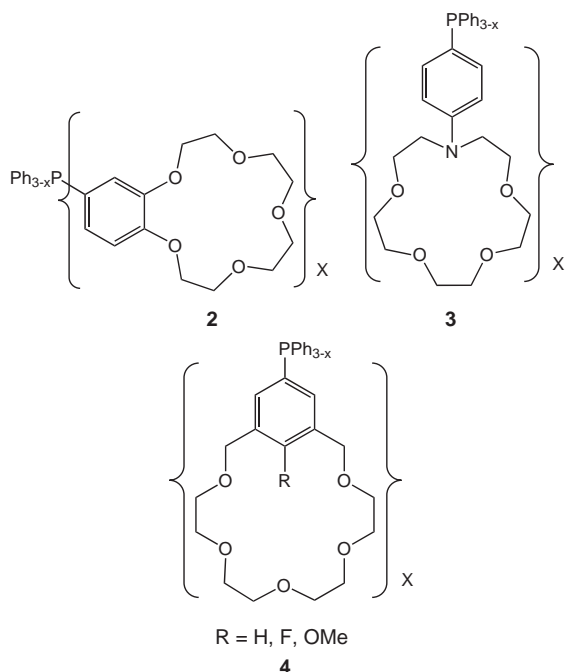


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interest in and a need for new types of phosphines with well-defined steric and electronic properties.

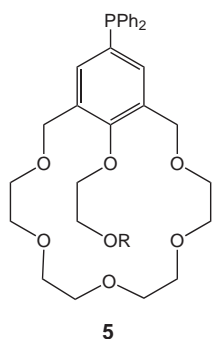
We have been interested in the properties of phosphines functionalized with crown ether or thioether groups. In regard to the former, our main focus has been on **2-4** with, as expected, **3** providing the best donors. For example, the Ni(CO)₃L complex of **3** with x = 3 provides an A₁ ν(CO) stretching value of 2060.8 cm⁻¹ [6], a value which is similar to that of 2060.3 cm⁻¹ reported for P(C₄H₉)₃ [7]. The OCH₃ groups in the series **4** ligands do not significantly increase the donor properties of the P(III) centers likely the result of the inability of the OMe carbon to be in the same plane as the phenyl ring carbons which is apparently necessary for the complete delocalization of the oxygen atom electron density [9-11].

As a result, the A₁ ν(CO) stretching bands for ligands **4**, x = 1 for example, with R = H and OCH₃ are 2069.1 and 2068.9, respectively [8]. In contrast, ligand **2** provides a value of 2068.3 cm⁻¹ [8] even though the 3-positioned oxygen substituent is an electron withdrawing group [12]. The OCH₃ groups do, however, appear to assist the crown ether in ion binding as indicated by the



stretching frequencies observed upon the addition of Na^+ ions to the $\text{Ni}(\text{CO})_3\text{L}$ complexes. Again for the $x = 1$ series of **4** with $\text{R} = \text{H}$ or OMe , the addition of Na^+ causes the $\nu(\text{CO})$ stretching bands to shift to 2069.5 and 2069.8 cm^{-1} , respectively [8].

To extend the information about the properties of these xylyl-based systems we have elected to prepare **4** with an OH group in the 2 position. This phenol derivative was selected because the Hammett parameters for OH and O^- are -0.37 and -0.81, respectively, compared to -0.27 and -0.63 for OCH_3 and NMe_2 , respectively [12], suggesting that the O^- derivative could provide a route to phosphines with better donor abilities than **3** while simultaneously providing an anion in position to assist with ion coordination. In addition, it seemed likely that the level of communication regarding ion coordination between the crown rings and P(III) centers would depend on whether or not the anion were an integral part of the system as could be the case for the O^- derivative. Further, the O^-



derivative could potentially be used to prepare lariat ethers such as **5** or novel bis crowns. Reported herein are the synthesis, molecular structure of the OH derivative and results from spectroscopic studies of the OH and O^- derivatives in the presence and absence of ions.

EXPERIMENTAL

Reagents and Materials.

Methyl diphenylphosphonite, lithium iodide, anhydrous pyridine, *n*-butyl lithium (2.5 molar in hexane) and cesium hydroxide were obtained from Aldrich Chemical Co., Inc. $\text{Ni}(\text{CO})_4$ was purchased from Strem Chemicals, Inc. Dichloromethane, Low Water, and tetrahydrofuran, Ultra Low Water, (THF) were obtained from J. T. Baker. The 5-bromo-1,3-bis(bromomethyl)-2-methoxybenzene(4-Bromo-2,6-di(bromomethyl)anisole) used as the precursor for 5-bromo-2-methoxy-1,3-xylyl-18-crown-5 was prepared as previously described [13]. The latter was also synthesized as described previously [8]. The alkali metal salts were dried under high vacuum at 60 °C for 24 h prior to use.

Methods and Instruments.

All reactions and purifications were carried out under argon. Chromatographic separations were carried out by using 40-63 μm silica gel cartridges in a Biotage® apparatus. IR and NMR spectra were recorded on Perkin Elmer Spectrum 1,000 and JEOL Eclipse 400 instruments, respectively. The ^1H and ^{31}P NMR spectra were recorded in deuterated chloroform and are referenced to TMS (internal) and 85% phosphoric acid (external), respectively. The IR instrument was calibrated with solutions of $\text{Ni}(\text{CO})_3\text{PPh}_3$ for which the $\text{A}_1 \nu(\text{CO})$ stretching band has been reported to be 2068.9 cm^{-1} [7]. The elemental analysis was carried out by Midwest Microlab Ltd., Indianapolis, IN. The X-ray analysis was carried out by the Molecular Structure Center, Indiana University, Bloomington, IN 47405.

IR studies.

The $\text{Ni}(\text{CO})_3\text{L}$ IR studies were carried out *in situ* as previously described using dry, deoxygenated dichloromethane. [7,14,15] The IR spectra in the presence of alkali metal ions were obtained on solutions of $\text{Ni}(\text{CO})_3\text{L}$ to which an excess of solid MSCN ($\text{M} = \text{Na}^+, \text{K}^+$) had been added; the salt- $\text{Ni}(\text{CO})_3\text{L}$ mixtures were shaken for ten min prior to obtaining the spectra. Spectra of $\text{Ni}(\text{CO})_3\text{PPh}_3$ were recorded between each sample.

Preparation of 5-Bromo-2-hydroxy-1,3-xylyl-18-crown-5.

5-Bromo-2-methoxy-1,3-xylyl-18-crown-5 (5.00 g, 1.23×10^{-2} mol) and LiI (3.30 g, 2.47×10^{-2} mol) dissolved in 100 mL of dry pyridine in a round bottomed flask equipped with a reflux condenser and magnetic stirrer. The solution was heated under gentle reflux for 10 h. The pyridine was removed *in vacuo*, and the residue was treated with 2 x 50 mL portions of H_2O which was subsequently removed *in vacuo*. The residue was then acidified with 3 M HCl(aq) to a pH of 1-2 and then extracted with 3 x 100 mL of CH_2Cl_2 . The combined organic fractions were then evaporated *in vacuo*. The resulting oil was dried under high vacuum. The residue was extracted with five *ca.* 50 mL portions of hot heptane

which were cooled to -5° providing 4.04 g (83.9 %) of colorless crystals which were used without further purification. $^1\text{H NMR}$ (CDCl_3): δ : 3.58-3.61 (m, 16 H), 4.64 (s, 4 H, CH_2), 7.29 (s, 2 H, arom) 8.05 (s, 1 H, OH).

Preparation of 5-Diphenylphosphino-2-hydroxy-1,3-xylyl-18-crown-5 (**5**).

5-Bromo-2-hydroxy-1,3-xylyl-18-crown-5 (4.00 g, 1.02×10^{-2} mol) was dissolved in 250 mL of dry THF contained in a thoroughly dried 500 mL round bottomed flask equipped with a magnetic stirrer and jacketed with an insulating foam container. The flask was cooled with an ethyl acetate/liquid nitrogen slush. *n*-Butyl lithium (8.20 mL, 2.05×10^{-2} mol) was added *via* syringe over a period of 10 min. After an additional 30 min. at this temperature, methyl diphenylphosphinite 2.1 mL (1.0×10^{-2} mol) in 3 mL of THF was added over 20 min. This solution was maintained at this temperature for another 30 min, and then it was allowed to gradually warm to room temperature over a period of *ca.* 12 h. About 1 ml of triethylamine was added to the mixture, and then most of the volatile materials were removed *in vacuo*. The resulting yellow oil was dissolved in 100 mL of CH_2Cl_2 and extracted with 50 mL of H_2O providing an emulsion which separated over the course of several days. After separating the layers, the water layer was extracted with an additional 100 mL of dichloromethane. The combined organic layer was then dried over anhydrous MgSO_4 , and the CH_2Cl_2 was subsequently removed *in vacuo* providing 3.78 g of colorless oil. A 1.25 g aliquot of the resulting oil was then chromatographed using a 3:1 mixture of dichloromethane and ethyl acetate as the mobile phase providing 0.68 g of product judged to be pure by TLC and NMR studies. Crystals of chromatographed 5-diphenylphosphino-2-hydroxy-1,3-xylyl-18-crown-5 were grown by slowly evaporating a solution of dichloromethane, ethyl acetate and 95% ethanol (*ca.* 2:1:1) at room temperature. $^1\text{H NMR}$ (CDCl_3): δ : 3.67-3.69 (m, 16 H), 4.58 (s, 4 H, CH_2), 7.09 (d, $J = 7.72$ Hz, 2 H, arom), 7.24-7.30 (m, 10 H, arom). $^{31}\text{P}\{\text{H}\}$ NMR (CDCl_3): δ : -5.84. IR (nujol mull) 3361, [16] 1124, 1096 cm^{-1} . Mp: 77-79 $^{\circ}\text{C}$.

Anal. Calcd. for $\text{C}_{28}\text{H}_{33}\text{O}_6\text{P} \cdot 2\text{H}_2\text{O}$: C, 63.15; H, 7.00. Found: C, 63.38; H, 6.76.

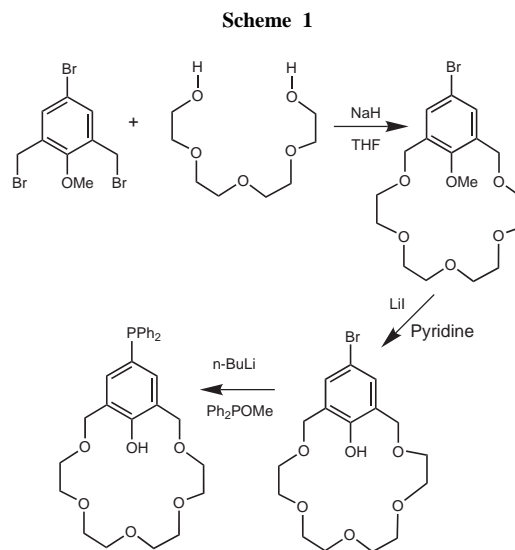
Single-Crystal X-ray Structure.

A crystal with dimensions 0.40 X 0.32 X 0.18 mm was affixed to a glass fiber using silicone grease and then cooled to 118 K for data collection. The data were collected on a Bruker SMART 600 sealed tube system using 3-second frames with an omega scan of 0.30 degrees.

The data were corrected for Lorentz and polarization effects and equivalent reflections averaged using the Bruker SAINT software as well as utility programs from the XTEL library. The structure was solved using SHELXTL and Fourier techniques. Statistical tests indicated a non-centric monoclinic space group, and subsequent solution and refinement confirmed the choice *Pc*. Two independent molecules were located in the asymmetric cell, and each has one water molecule hydrogen bonded in the crown. Hydrogen atoms were located in a difference Fourier phased on the non-hydrogen atoms and refined isotropically in the final cycles. As shown in the ORTEP diagram, the phosphorous atoms appear to be protonated.

Results and Discussion.

The target phenol, **4**, has been obtained in modest yield from the 5-bromo-2-hydroxy-1,3-xylyl-18-crown-5 precursor by way of low temperature Li/Br exchange followed by the addition of Ph_2POCH_3 as presented in Scheme 1. As shown, 5-bromo-2-hydroxy-1,3-xylyl-18-crown-5 was used as the starting material which required the addition of two equivalents of *n*-butyl lithium. This



Synthesis of 2-Hydroxy-5-bromo-1,3-xylyl-15-crown-5.

approach was utilized because the alternate method, which was also attempted, that involves cleaving the OCH_3 bond after formation of the C-P bond resulted in the formation of a phosphonium salt.

The crude product was chromatographed on silica gel which provided an oil that could be crystallized. The spectroscopic properties of the product are entirely consistent with the formulation. For example, the $^{31}\text{P}\{\text{H}\}$ chemical shift of δ -5.84 is similar to the shift of δ -5.02 observed for the corresponding P(III) OCH_3 derivative. [8]

The donor properties of the OH and O^- derivatives have been studied by using the nickel carbonyl method, [14,15] and the $\text{A}_1 \nu(\text{CO})$ bands observed are presented in Table 1. In the absence of ions, the phenol is a better donor than

Table 1
 $\text{A}_1 \nu(\text{CO})$ Stretching Frequencies for $\text{Ni}(\text{CO})_3\text{L}$ complexes

Ligand	Added Ions		
	none	Na^+	K^+
OH deriv.	2067.6	2067.7	2067.5
O^- deriv. ^a	2063.4	2066.5	2063.7
PPh_3	2068.9	2068.9	

^aCsOH(s) and MSCN(s) added in sequence

the related OMe derivative which, as indicated above, provides a value of 2068.7. This trend is consistent with that predicted by Hammett parameters, *vide supra*, which predict that an OH substituent should be a better donor than an OMe substituent. There are two additional factors, however, that may have an effect on the observed trend. First is the aforementioned effect that arises when OMe carbons are forced out of the plane of the phenyl ring carbons [9-11]. The second effect could arise from the nature of the phenol OH group which is likely hydrogen-bonded to oxygen 5 or 11. Hydrogen bonding of this type has been observed in 5-nitro-2-hydroxy-1,3-xylyl-18-crown-5 [17]. Hydrogen bonding would be expected to enhance the donor abilities of the phenol group.

As shown in Table 1, the addition of NaSCN or KSCN has little effect on the stretching vibrations of the OH derivative. This too is likely the result of an intramolecular hydrogen bond which must be broken before an ion can bind. However, these ions shift the corresponding OMe and H derivatives to higher frequencies by 0.9 and 0.4 cm^{-1} , respectively. In contrast, reacting the OH derivative with CsOH to produce the O⁻ derivative provides a shift to 2063.4 cm^{-1} . This could be a larger shift than would be predicted from the Hammett parameter which is -0.81 compared to -0.63 for an NMe₂ group. But, system **3** with $x = 1$ or 2 provide bands at 2066.3 and 2063.7 cm^{-1} , respectively [6] which support the idea that 2063.4 cm^{-1} is indeed a lower value than expected. Further addition of NaSCN to the phenoxide shifts the band in the direction expected by 3.1 cm^{-1} whereas this ion with **3**, $x = 2$, causes a shift of 2.4 cm^{-1} . As the situation with the OMe derivative, KSCN has a much smaller effect on the position of the bands which is consistent with the idea that there is a better match between crown-5 rings and sodium ions than potassium ions.

X-ray Structure[18].

Selected X-ray data, bond lengths and angles are presented in Table 2, and the ORTEP diagram is shown in Figure 1. Two independent molecules were located in the asymmetric cell both with waters of hydration and apparent hydrogen atoms bonded to the phosphorous atoms. The data for Tables 2 and 3 were selected from the structure labelled "a". The molecule labelled "b" is similar to "a", and that structure will not be discussed here.

As shown in Table 2, the C-C, C-O and C-P bond lengths are all in the ranges expected [19] and they are similar to those obtained for the oxide of 5-diphenylphosphino-1,3-xylyl-18-crown-5 [8] and for 5-nitro-2-hydroxy-1,3-xylyl-18-crown-5 [17]. For example, for these two molecules the mean Csp³-Csp³ bond lengths

were 1.489 Å. Further, the bond angles are also in the ranges expected. For example, the C-P-C angles are

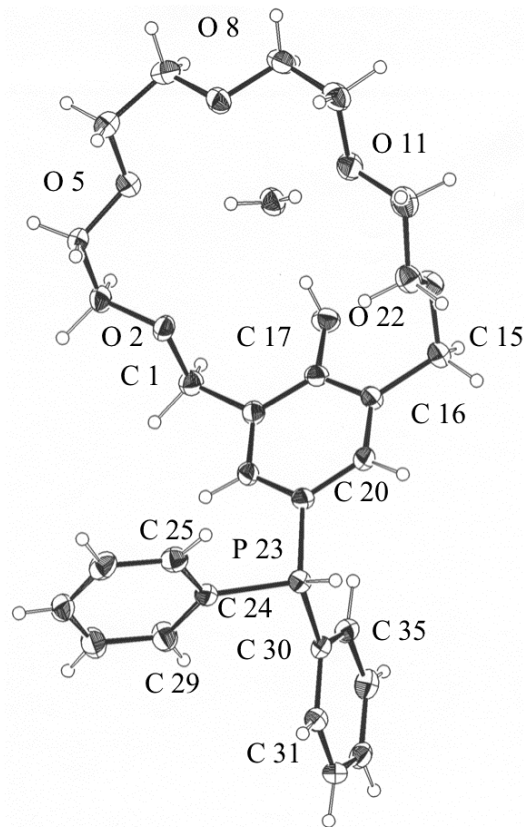


Figure 1. ORTEP Plot for 5-Diphenyl-phosphino-2-hydroxy-1-3-xylyl-15-crown 5.

similar to the average values of 102.2° and 101.2° reported for PPh₃ [20,21] and P(4-C₆H₄OCH₃)₃ [22,23], respectively. As evident in Figure 1, The O-C-C-O dihedral angles are approximately gauche, 63.85-70.91°, as expected. [23]

In regard to other distances and angles, O(2)-O(14) and O(5)-O(11) distances are 5.319 and 4.654 Å, respectively. That the latter is a relatively short distance is likely the result of the hydrogen bonded water spanning those two oxygen atoms. The comparable distances in the oxide of 5-diphenylphosphino-1,3-xylyl-18-crown-5 [8] and 5-azido-2-methoxy-1,3-xylyl-15-crown-5 [25] are 4.90 and 5.20 Å, respectively. As shown in Figure 1, the water is symmetrically located between the oxygen atoms with H-O distances of 2.030 and 2.038 Å from atoms 5 and 11 respectively. Also, the phenolic hydrogen is hydrogen bonded to the water oxygen with a bond length of 1.75 Å. These bond lengths are in the range expected for moderately strong hydrogen bonds which is ca. 1.5-2.2 Å for acids, phenols and hydrates. [26] With the phosphorus in a vertical position, the crown ether ring is folded over the

top of the phenyl ring, and the water oxygen is 1.29 Å below the mean plane defined by the five ring oxygen atoms. Additionally, the ring oxygen-to-hydrogen-to water

Table 2

Selected Bond Lengths (Å) and Angles (deg) for 5-Diphenylphosphino-2-hydroxy-1,3-xylyl-18-crown 5

Bond lengths, Å	
C(7)-O(8)	1.412, shortest
C(3)-C(4)	1.492, shortest
C(1)-C(18)	1.501(3), shortest
C(27)-C(28)	1.379(3), shortest
P(23)-C(20)	1.8238(19), shortest
C(17)-O(22)	1.361(2)
C(15)-O(14)	1.432(2), longest
C(12)-C(13)	1.505(3), longest
C(15)-C(16)	1.524(3), longest
C(20)-C(21)	1.404(3), longest
P(23)-C(30)	1.8260(19), longest
Bond angles, deg.	
C(30)-P(23)-C(24)	101.71(9), smallest
C(6)O(5)-C(4)	111.86(15), smallest
C(20)-P(23)-C(24)	101.91(9), largest
C(13)-O(14)-C(15)	113.23(15), largest

oxygen angles are $168 \pm 3^\circ$ which are also in the range expected which is $130 - 180^\circ$ [26]. Finally both the X-ray data, for example the C-P-C angles, and the expected spectroscopic behaviour of the $\text{Ni}(\text{CO})_3\text{L}$ complexes are indicative of the presence of P(III) rather than P(IV) centers.

Acknowledgement.

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