Synthesis of Functional Chelating Diphosphines Containing the Bis[2-(diphenylphosphino)ethyl]amino Moiety and the Use of These Materials in the Preparation of Water-Soluble Diphosphine Complexes of Transition Metals

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Acylation of bis[2-(diphenylphosphino)ethyl]amine provides a flexible synthesis of functionalized chelating diphosphines. This reaction offers a route to diphosphine complexes of transition metals having a wide range of structures and physical properties and especially to water-soluble complexes. The aqueous solubility of the free ligands and of the complexes prepared from them depend on the ligand, on the metal, and on other materials (especially surfactants) present in the solution. We describe typical preparations of ligands and outline the properties of their complexes with certain transition metals.

Homogeneous catalysis and asymmetric synthesis increasingly require complex organic structures incorporating ligands capable of coordinating a transition-metal center. In earlier papers, we described a flexible synthesis of functionalized, water-soluble, chelating diphosphines and presented examples of applications of these materials. This paper provides experimental procedures for these syntheses and outlines factors affecting the properties of the resulting materials in aqueous solutions.

Results and Discussion

All syntheses are based on bis[2-(diphenylphosphino)ethyl]amine 1 (Scheme I). This compound, isolated as a crystalline, air-stable hydrochloride, can be acylated at

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Scheme I. Preparation of Bis[2-(diphenylphosphino)ethyl]amine and Derivatives

- 1 - 2 Ph₂PCH₂.NPh²
- 2. HCl → Cl⁻ H₂N (CH₂)₂CO₂K, THF
- 1 - Cl⁻ H₂N (CH₂)₂CO₂K, THF

The most useful synthetic strategy to emerge from this work used a diacylating reagent [trimellitic anhydride acid chloride (2) or tricarballylic anhydride acid chloride (3)] to couple 1 to another amine-containing group which conferred the physical properties required. Thus, for example, reaction of 1 with 2 proceeds cleanly at the more reactive acid chloride site and generates 3. The effect of this transformation is to convert 1 (in which functionalization is based on the difference between the nucleophilicity of the nitrogen and phosphorus centers) to 5 (in which functionalization can be based on the electrophilic reactivity of the nitrogen). Compound 5 (and the analogous 6) is not isolated but is allowed to react directly with other nucleophilic groups. These groups can be designed to confer the desired physical properties to the final complex.

An alternative strategy, direct acylation of 1 (e.g., 1 → 7) is also successful. Although this procedure appears simpler, in practice we have found it to be less useful than 1 → 5 or 1 → 6 → 9 as a method for generating functionalized (especially water soluble) diphosphines. The number of readily available reactive species of the type represented by 4 (that is, species which react selectively with nitrogen in the presence of phosphorus and which introduce highly polar groups) is small. By contrast, 2 is commercially available and inexpensive, and 5 reacts with a wide range of amines. In applications in which water solubility is not an important objective, however, direct acylation can provide a convenient and useful methodology (vide infra).

Table 1 lists the substances prepared, the coupling agents used in their preparation, and the yields in which they were obtained. The purification and characterization of these complexes proved difficult. Many have surfactant properties; their polar functionalities are hydrated or solvated to varying extents; they are noncrystalline. Characterization often was based primarily on IR and 31P and 1H NMR spectroscopies and on the physical properties (water solubility, ability to complex metals) of the compounds. Only compounds 10, 12, 13, 15, 17, 21, and 22 were isolated in a form sufficiently pure to give acceptable elemental analyses. Analytical data for others are included in the Experimental Section, as an aid in judging purity. Yields given in parentheses in Table 1 are for crude compounds and are upper limits.

The proton NMR spectra of a number of the water-soluble derivatives (17-20) in aqueous solution show broad, complex resonances, suggesting micelle formation, although the presence of aggregated structures was not rigorously established. The 31P NMR spectra of the free ligands are usually characterized by two lines centered at ~1.5 ppm. Control experiments demonstrated that the splitting occurs on acylation; we assume that it reflects slow rotation about

nitrogen without competing reaction at phosphorus. The ability to functionalize nitrogen selectively in the presence of the phosphine centers is the basis for a method for the incorporation of 1 into complex organic structures.

The reactivity of 1 toward acid chlorides, anhydrides, isocyanates, alkyl chlorocarbonates, and N-hydroxysuccinimide (NHS) active esters is that expected for a sterically hindered, secondary amine. These reactions go to completion at ambient temperatures (the time necessary for reaction depends both on the coupling group employed and on the nature of additional bases present in solution; see Experimental Section). Little or no competing reactivity is observed for the phosphine groups. Only in the cases of materials capable of reactions other than acylation do competing reactions become important: special care must be exercised in using these coupling agents. Acryloyl chloride can be used to acylate 1 under the conditions described below. All attempts to acylate 1 with maleic anhydride gave only air-sensitive, red gums: although some amide formation is apparent in the IR spectra of the reaction mixtures, we have been unable to isolate a useful derivative of 1 from these mixtures. Soft electrophiles (sulfonyl chlorides, cyanogen bromide, phosphoryl halides) also seem not to demonstrate the selectivity toward nitrogen required to achieve useful functionalization.

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Table 1. Functionalized Diphosphines from 1

<table>
<thead>
<tr>
<th>compd</th>
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<th>yield, %</th>
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<tr>
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<tr>
<td>10</td>
<td>RCONHS</td>
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a Yields given in parentheses are for crude compounds and are upper limits.

the amide bond. Examination of the $^{31}$P NMR data also showed that typical preparations of ligands contained <5% contamination by phosphine oxides. The physical properties of most of these compounds made purification difficult, and great care was required to prevent oxidation during manipulation or in syntheses. For similar reasons, all reagents were purified carefully prior to use. In most instances, impurities do not affect the performance of these materials as ligands for transition metals.

Solubility of Metal Complexes and Ligands. As might be expected, the nature of the metal coordinated to a particular ligand strongly influences the solubility of the final complex. For example, 11 ($n = 16$) forms a stable though sparingly soluble platinum(II) dichloride complex. When coordinated to a rhodium(I) nornbornadiene cation, 11-Rh(Nbd)$^+$, a much more soluble material is obtained. This same ligand in the red-brown complex 11-NiCl$_2$ decomposes to an insoluble white wax on contact with water. Similar results were also observed with nickel complexes having 7 as a ligand.$^6$ Of the several metals examined in this study, the cationic rhodium complexes were the most soluble in water.

The aqueous solubility of the free ligands seems to follow expected trends. The doubly charged species 17, 18, and 20 are much more soluble than singly charged materials such as 7, 16, and 19. The neutral polyethylene glycol system 11 shows increasing solubility with increasing molecular weight; at $n = 110$ the material appears to be completely soluble. In this same series similar changes were noted in the solubility of 11-PtCl$_2$ complexes.

Homogeneous Catalysis by Cationic Rhodium Complexes. The Rh(I) complexes of several of these ligands have been shown to act as effective homogeneous hydrogenation catalysts in aqueous solution for a range of water-soluble substrates.$^3$ The data presented below expand upon earlier observations.$^4$

In general, the most soluble complexes acted as the best catalysts. Catalysts that precipitated from solution (e.g., 16-Rh(I)) gave understandably low rates of hydrogenation with $\alpha$-acetamidoacrylic acid (turnover number = TN < 5 mol of olefin reduced/mol of rhodium complex/h). Solubility is, however, not the only requirement for high activity since 11-Rh(I) ($n = 110$) was a poor catalyst despite its reasonably high solubility in water. The complex 7-Rh(I) was sparingly soluble and had low activity. Since 7 is extremely soluble, we infer that coordination of the sulfonic acid group to rhodium results in this decrease in solubility and activity.$^8$ In our hands, rhodium complexes of 17 and 18 formed the catalysts having the highest activity. For several reasons, we believe that the best material for most applications in homogeneous hydrogenation is 17:Rh(I). First, unlike most of these ligands, 17 is highly crystalline and is easily purified. Second, the protonated form of the acid is soluble in a wide range of organic solvents, a feature attractive for catalyst preparation. Dissolution in water is easily accomplished by transferring the catalyst preparation in a water-miscible organic solvent such as acetone, under argon, into the reaction media. In this manner, the number of manipulations necessary to prepare the catalyst can be minimized. Third, the synthesis of 17 is simple and can be easily carried out on practical scales: routine preparations gave more than 10 g of purified material in nearly quantitative yield. Fourth, hydrogenation rates with 17-Rh(I) are the highest observed for any derivative of 1: for example, TN$_s > 275$ h$^{-1}$ ($P_{H_2} = 32$ psi; ~4000 turnovers of Rh(I), 100% reduction) were found with $\alpha$-acetamidoacrylic acid as a substrate.

An interesting effect is observed when hydrogenations using 16-Rh(I), a poor catalyst, are carried out in aqueous solutions containing 0.1% by weight sodium dodecyl sulfate. Under these conditions, useful rates (TN = 120 h$^{-1}$ for $\alpha$-acetamidoacrylic acid) were observed. This catalyst system was also found to be extremely stable, maintaining most of its catalytic activity even in the presence of low concentrations of substrate. At the completion of the reduction (total turnover number of Rh(I) >4000, 100% reduction) bright yellow and completely homogeneous solutions were obtained. Thus, it appears that 16-Rh(I) is incorporated into SDS micelles and that

$^6$ An exception was found for 11-NiCl$_2$ ($n = 110$). This material forms stable red solutions in water. The cause of this effect is not understood.

$^7$ Similar behavior was also observed with both NiBr$_2$ and NiI$_2$ complexes of a number of the ligands.

$^8$ Related effects have been observed with sulfonated triphenylphosphine complexes of Rh(I). See: Borowski, A. F.; Cole-Hamilton, D. J.; Wilkinson, G. Nouv. J. Chim. 1978, 2, 137-144.
THF and diethyl ether were distilled from sodium benzophenone diimide under argon. Methylen chloride and methanol (analytical grade) were used without further purification. Taurine, bis(2-chloroethyl)amine hydrochloride, tricarballylic acid, and trimellitic anhydride acid chloride were obtained from Aldrich. o-Sulfo-nitrobenzoic anhydride was obtained from Eastman. d-Glucosic acid d-lactone was obtained from Sigma. A generous sample of d-biotin was a gift of the Hoffman LaRoche Co. Polyethylene glycol monomethyl ethers (mol wt ~500, 750, 5000) were purchased from Polyscience. Gantrez AN-119, a copolymer of methyl vinyl ether and maleic anhydride, was purchased by GAF. Pyridine was distilled from calcium hydride under argon. Triethylamine was purified by treatment with benzoic anhydride followed by distillation. Ethylenediamine was distilled under argon. Reagent grade N,N-dimethylamine (Eastman) was used without purification.

**Diphenylphosphine was prepared by literature procedures.** Bis-[2-(diphenylphosphino)ethyl]amine (1). Diphenylphosphine (28.0 mL, 29.6 g, 160 mmol) was added by syringe to a suspension of potassium tert-butoxide (28 g, 250 mmol) in 500 mL of dry THF under argon. The resulting deep red solution was stirred for 5 min and bis(2-chloroethyl)amine hydrochloride (14.3 g, 80 mmol) added as a coarse powder. Caution: bis(2-chloroethyl)amine hydrochloride is carcinogenic and should be handled with care in a hood.

The mixture was refluxed for 16 h, poured into 800 mL of hexane, and washed in succession with 300-mL portions of 10% NaOH and saturated aqueous solutions. The hexane layer was separated, filtered, and stirred vigorously with 800 mL of 2 N aqueous HCl solution, giving a dense white precipitate of 1.HCl. Recrystallization from 300 mL of boiling acetonitrile under argon gave a 90% yield (34.4 g) of fine white needles: mp 174.5-175.5°C; 1H NMR (CDCl3) δ 8.3-3.3 (m, 8 H), 7.0-7.6 (m, 20 H), 9.9 (s, 2 H).


**Preparation of Compound 7.** In a 25-mL flask equipped with a stirring bar were placed 0.772 g (4.19 mmol) of o-sulfo-nitrobenzoic anhydride and 2.0 g (4.19 mmol) of 1-HCl. The system was capped with a serum stopper and flushed with argon. A solution of 3.5 mL of triethylamine in 30.0 mL of dry THF was added by syringe. The reaction was stirred for 24 h at ambient temperature, cooled to ~5°C, and filtered, and the separated organic phase was evaporated under reduced pressure. Drying in vacuum (0.05 torr) for 18 h gave 3.10 g (100%, calculated for the triethylammonium salt of a hygroscopic solid foam: IR (neat) 1650 (s), 1325 (s) cm⁻¹). This material was dissolved in 20 mL of MeOH, the solution was cooled to 0°C, and 2 mL of 2.0 M NaOH was added dropwise with vigorous stirring. The solvent was removed under reduced pressure to give a solid white foam. Drying for 1 week at 0.05 torr at ambient temperature gave 2.7 g (98%) of a white hygroscopic powder: IR (neat) 1630 (s), 1235 (s) cm⁻¹; 31P NMR (D2O): δ 21.1 ppm. Anal. Calcld for C34H24N15O9P2S: C, 64.90; H, 4.97; N, 2.16. Found: C, 63.28; H, 5.07; N, 2.00. Calcld for 7.H2O: C, 63.15; H, 5.14; N, 2.10.

**N-Biotinosuccinimide was prepared by literature procedures.** Bis-[2-(diphenylphosphino)ethyl]biotinamide (10). N-Biotinosuccinimide (67 mg, 0.20 mmol), 1-HCl (95 mg, 0.20 mmol), and triethylamine (80 mg, 0.80 mmol) were added to 3 mL of degassed DMF. The reaction mixture was stirred at ambient temperature for 60 h under argon, slowly diluted with 8 mL of degassed water, and cooled to 0°C. The resulting white precipitate was centrifuged off, the solution decanted, and the remaining white waxy solid washed with 30 mL of water. Drying at reduced pressure (0.05 torr) gave 110 mg (83%) of 10.

**Conclusion**

The catalytic activities of the rhodium complexes of 17 and 25 are dramatically influenced by the presence of α-chymotrypsin and bovine serum albumin in solution. Although the nature of the interaction of these substrates with these proteins has not been established, preliminary studies indicate that albumin may influence the substrate specificity of the rhodium catalyst. The conjugate of 10-Rh(I) with avidin is an asymmetric catalyst for the hydrogcnation of α-acetamidodiacyclic acid. The other rhodium-protein conjugates do not exhibit enantioselectivity in the hydrogenation of this substrate.

Complex 13-Rh(I) is a hydrogenation catalyst which is only sparingly soluble in aqueous solution. The hydrogenation of α-acetamidoacyclic acid with 13-Rh(I) (TN = 1000) yielded modest enantiomeric excesses of 16-18% for (S)-N-acetylanaline. The turnover number and optical yield are very sensitive to solvent and the presence of triethylamine.

These water-soluble phosphines complement materials such as sulfonated triphenylphosphine, whose application in homogeneous catalysis in aqueous solution has been the subject of several papers. While direct comparisons between these systems are difficult, the difference in activity and stability between them are qualitatively those expected for unidentate and bidentate phosphine complexes.
as a waxy solid: IR (Nujol) 1705, 1630 (s) cm⁻¹.
Anal. Caled for C₃₂H₃₀NO₂P₅: C, 68.34; H, 6.32; N, 2.24.
Found: C, 68.18; H, 6.60; N, 2.19.

Preparation of Compound 13. Into an argon-flushed, 100-mL round-bottomed flask equipped with a condenser and stirring bar was placed 0.50 g (1.1 mmol) of I-HCl. A solution of 0.22 mL of triethylamine in 20 mL of CH₂Cl₂ was added by cannula, and 0.130 g (1.00 mmol) of phenyl isocyanate in 5 mL of CH₂Cl₂ was added by syringe dropwise with stirring. The reaction was stirred for 24 h at ambient temperature, diluted with 30 mL of CH₂Cl₂, and washed with 0.2 M HCl (2 × 10 mL) and saturated aqueous Na₂SO₄ (1 × 10 mL), and the organic phase was separated and dried over Na₂SO₄, and the volatiles were removed under reduced pressure. Drying in vacuo (0.05 Torr) gave a quantitative yield of the anhydride amide of 0.21 g (95% yield) of product: IR (neat) 1705 (vs), 1625 (s) cm⁻¹. Attempts to purify this material further by low-temperature recrystallization were unsuccessful: IR (neat) 3500-2500 (br, s), 1715 (s), 1635 (s) cm⁻¹; 'H NMR (CDCl₃) δ 7.4 (s, 20 H), 3.8-2.1 (complex m, 12 H).

Preparation of Compound 14. A slurry of 0.476 g (1.00 mmol) of I-HCl in 10 mL of dry THF under argon at -5 °C was slowly warmed to 0 °C, and the reaction was stirred vigorously for 3 h, at which time a significant quantity of solid had precipitated. Analysis of an aliquot of the solution by 3¹P NMR spectroscopy indicated that little of the initially present remained in solution. The reaction was diluted with 5 mL of acetone and 0.5 mL of H₂O and acidified with 3 drops of concentrated HCl. The mixture was brought to reflux under argon for 30 min (sufficient to hydrolyze the remaining anhydride groups), and the resulting white solid was collected by filtration, washed with reduced pressure (0.05 Torr) to give 0.21 g (95% of product: IR (neat) 1705 (vs), 1625 (s) cm⁻¹).

*Note: The reference text is cut off at this point. The rest of the text is not visible.*
Preparation of Compound 18. In a 100-mL flask, under an argon stream, were placed 1.0 g (1.63 mmol) of 5, a stirring bar, and several glass beads. Into this mixture, with vigorous stirring, was poured a portion of 1.0 g (0.98 mmol) of sodium taurinate dissolved in 30 mL of degassed, absolute methanol. The sudy solution and white precipitate that formed were stirred for 20 h at ambient temperature. The methanol was removed under reduced pressure, and the white solids produced were extracted with portions (6 x 100 mL) of CHCl₃ under argon. The combined organic phases were filtered and the volatiles removed under reduced pressure (0.05 torr) for 3 days to give 3.3 g of a light yellow glass.

2 H), 3.4 (t, 2 H), 3.5-4.3 (m, 5 g H), 4.4 (d, -1 H); IR (neat) 3300 (vs, br), 1640 (s), 1550 (m) cm⁻¹.

Preparation of Compound 19. In an argon-flushed, 250-mL flask equipped with a stirring bar and addition funnel were placed 0.353 g (2.00 mmol) of tricarballylic anhydride acid chloride and 80 mL of dry CH₂Cl₂. The mixture was stirred until dissolution was complete. The addition funnel was charged with a solution of 0.96 g (2.00 mmol) of 1-HCl and 0.51 mL of 0.42 g (4.90 mmol) of N-N-dimethylaminomethyl in 20 mL of CH₂Cl₂, and this was added dropwise to the acid chloride solution at 0 °C with vigorous stirring. The reaction was warmed slowly to ambient temperature and stirred overnight. Examination of an aliquot by IR showed clean formation of the anhydride amide 6: 1850 (m), 1780 (vs), 1635 (s) cm⁻¹. The solution was filtered under argon, the volume reduced to ~20 mL, and the resulting solution then added with vigorous stirring to a solution of 3.82 g (16.0 mmol) of N-(2-aminoethyl)gluconamide in 20 mL of distilled water in a thin, continuous stream (ca. 8 min to complete addition). The frothy mixture was stirred for 6 h at ambient temperature, and the methylene chloride was evaporated carefully (foaming) under reduced pressure. The aqueous solution was cooled to 0 °C and slowly acidified to pH ~1.0 by dropwise addition of concentrated HCl. The white solid that precipitated was collected by filtration, washed quickly with 5 mL of saturated aqueous NaCl, 1 mL of H₂O, and portions (2 x 5 mL) of 21 (v/v) EtO₂CH₂/CH₂Cl₂; and dried under reduced pressure (0.05 torr) for 7 days at ambient temperature to give 1.2 g (74%) of off-white solid: IR (neat) 3300 (vs, br), 1710 (s), 1635 (s) cm⁻¹.

Preparation of Compound 20. Compound 6 was prepared by procedures similar to those described in the preparation of 19 (at half the scale described). The solution of 6 (~1.0 mmol) thus obtained was evaporated to dryness under reduced pressure and treated while being stirred vigorously with a solution of 0.75 g (5.1 mmol) of sodium taurinate in 30 mL of methanol. The reaction was stirred under argon for 24 h, the volatiles were removed under reduced pressure, and the solids were extracted with portions (8 x 100 mL) of CH₂Cl₂/MeOH (2.5:1 v/v) and CH₂Cl₂ (4 x 100 mL). The combined organic extracts were evaporated under reduced pressure to give an oily material which, when washed with 50 mL of ether, gave 0.64 g of a white, hygroscopic, semicrystalline solid: IR (neat) 3450 (s), 1630 (s), 1580 (s) cm⁻¹; 31P NMR -20.9 (s), -22.1 (s) ppm. The 1H NMR in D₂O spectra showed a series of broad resonances and significant levels of excess taurine. Anal. Calc'd for Ca₂H₁₉N₄O₇P₃: C, 61.53; H, 6.08; N, 3.34 (this material may be partially hydrated).
Preparation of Compound 22. The procedure and scale used were similar to that described for the preparation of 15. The product is initially obtained as a waxy gum and can be recrystallized from ethanol to give 70 mg (70%) of a white solid: mp 213-213.5 °C; 1H NMR (CDCl₃) δ 1.7-2.8 (br m, 8 H), 2.8-3.9 (br m, 8 H), 6.7-7.7 (m, 44 H); IR (Nujol) 1633 cm⁻¹.

Preparation of Compound 23. Polyethylene glycol monomethyl ether (average mol wt 550; 59 g, 0.11 mol) was dissolved in 100 mL of pyridine, and thionyl chloride (10 mL, 0.14) was added dropwise over a period of 10 min. After the exothermic reaction subsided, the solution was poured into 500 mL of ether, and the ether layer was decanted from the insoluble residue that was deposited. The residue was extracted with portions (3 x 500 mL) of ether, the combined organic phases were neutralized by washing with saturated aqueous NaHCO₃, and the volatiles were removed under reduced pressure to give a brown oil. The oil was dissolved in methylene chloride, decolorized with activated charcoal (Fischer Darco), filtered, passed through a 1 x 8 cm column of Woelm activity I neutral alumina, and evaporated under reduced pressure to give a clear oil (20.8 g, 31%). Part of this material (12 g, 21 mmol) was dissolved in 30 mL of THF and added dropwise to a stirred solution of potassium diphenylphosphine, prepared by reaction of 3.7 g (21 mmol) of diphenylphosphine with 0.65 g (21 mmol) of potassium hydride in 30 mL of THF at 0 °C. The reaction was stirred for 1 h and quenched by addition of 2 mL of water to the reaction mixture. The reaction was diluted with 500 mL of ether, filtered through 100 g of Woelm activity I neutral alumina, and crystallized at -22 °C to give a yellow oil at room temperature. This material was dried under reduced pressure (0.05 torr, 20 h) to give 11 g of product. The 31P NMR suggested that 11 (δ -22.8) comprised 85% of the phosphorus-containing species present.

Preparation of N,N-Bis[2-(diphenylphosphino)ethyl]-acrylamide (24). In a 25-mL flask was dissolved 1-HCl (465 mg, 0.264 mmol) and n-octadecylamine (71 mg, 0.264 mmol) were added dropwise over a period of 3 min, and the solution was stirred for several minutes before dropwise addition of the amine solution to the flask containing the anhydride. The yellow oily mixture was stirred for at least 2 h at room temperature under a static atmosphere of argon. The solvent was removed under reduced pressure by using a rotary evaporator (20 torr) and high vacuum (0.05 torr) to afford in quantitative yield (233 mg) a pale yellow glass. The glass was characterized by its NMR and IR spectra and was used in hydrogenation reactions without further purification: IR (neat, oil) 2980, 2900 (s), 1725 (m), 1640 (s, br), 1590 (m), 1470, 1440 (m) cm⁻¹; NMR (CDCl₃) δ 7.8-7.8 (m, 20 H), 2.0-3.9 (m, 10 H), 1.3 (m, 3.5 H).

Preparation of Metal Complexes. Nickel dichloride complexes of the phosphines described above were prepared by modification of literature procedures.19 Platinum dichloride complexes were prepared by standard procedures by reacting (COD)PtCl₂ under argon with a slight excess of the ligand in THF for 48 h; the products were isolated as THF-insoluble precipitates by filtration. Preparation of cationic rhodium complexes and subsequent catalyses performed with them were effected by procedures analogous to those already described.4

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Registry No. 1-HCl, 66534-97-2; 2, 1204-28-0; 3, 77461-97-3; 4, 81-08-5; 5, 71120-43-9; 6, 77461-98-4; 7-Na, 77461-99-5; 10, 66561-97-5; 11, 66561-67-2; 12, 66561-96-8; 13, 77519-44-9; 15, 66534-91-6; 16, 66534-94-9; 17, 77462-00-1; 18, 77462-01-2; 19, 77462-02-3; 20-Na, 77462-03-4; 20-Na, 77462-04-5; 21, 66534-92-7; 22, 66534-93-8; 23, 77461-22-4; 24, 77462-05-6; 25, 77462-06-7; diphenylphosphine, 829-85-6; bis(2-chloroethyl)amines HCl, 821-48-7; N-biotinosuccinimide, 35013-72-0; α-(chlorocarbonyl)-ω-methoxypoly(oxy-1,2-ethanediyl), 51023-28-0; phenyl isocyanate, 107-35-7; sodium taurinate, 7347-25-3; tricarballylic acid, 99-14-9; N-(2-aminoethyl)gluconamide, 74426-36-1; ethylenediamine, 107-15-3; o-tolualdehyde, 90-80-2; p-sulfamylbenzoyl chloride, 51594-97-9; terephthaloyl chloride, 100-20-9; α-(2-chloroethyl)ω-methoxypoly(oxy-1,2-ethanediyl), 52972-83-5; acryl chloride, 814-68-6; n-octadeclamide, 124-30-1.