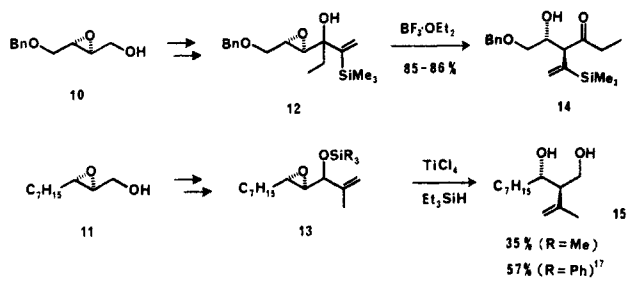
1,3-diol **15**[16,17] ($[\alpha]^{20}_D$ -16.8° (*c* 1.02, MeOH)), respectively, with rigorous stereoselectivities.



(15) Separate treatment of each diastereomer (erythro-trans and threo-trans isomers) of **12** with BF_3·OEt_2 gave rise to the same threo alcohol **14** in 85% and 86% yield, respectively.

(16) The diastereomeric isomer of **14** or **15** was not detected by TLC, ^1H NMR, capillary GLC, and/or HPLC analysis

(17) Rearrangement of the epoxy silyl ether **13** (R = Ph) yielded a mixture of **15** and its mono(triphenylsilyl) ether which was directly treated with Bu_4NF in THF at room temperature.

Chemistry of Platinum Hydrides: A Platinum(II) *cis*-Dihydride or a Platinum(0) η^2-Dihydrogen Complex?

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A complete understanding of the interconversion processes involving molecular hydrogen, η^2-dihydrogen species and hydride complexes is essential for the significant development of metal-catalyzed hydrogen chemistry. Recently, stable complexes containing η^2-dihydrogen ligands bonded to early transition metals such as chromium,[1-3] molybdenum,[4,5] tungsten,[4,5] and iron[6] have been reported although for the heavier transition metals comparable species of only ruthenium[6] and iridium[7] have been described. For the iron complex *trans*-$[Fe(\eta^2\text{-}H_2)(H)(dppe)_2]BF_4$, for which the X-ray crystal structure determination shows the coordination of the η^2-dihydrogen ligand to be similar to that in $[W(CO)_3(P\text{-}i\text{-}Pr_3)_2(\eta^2\text{-}H_2)]$, solution NMR spectroscopy suggests an exchange process between monohydride and η^2-dihydrogen ligands. We now report the preparation of a new series of complexes $[(Cy_2P(CH_2)_nPCy_2)PtH_2]$, n = 2, 3, or 4, (**1**, **2**, and **3**, respectively), in which the bulky chelating ligand forces the unusual *cis*-dihydride geometry and for which physical data (dynamic ^1H NMR) provides evidence for a correlated molecular rotation of the hydride ligands about the platinum center and chemical evidence displays easy displacement of dihydrogen. These species are therefore the first heavy-transition-metal dihydrides to provide evidence of dynamic processes involving a *cis*-dihydride ↔ η^2-dihydrogen exchange.

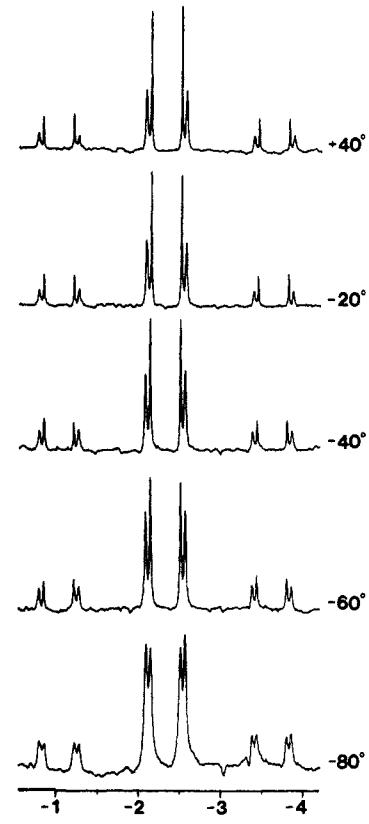

Figure 1. Variable-temperature (°C) ^1H NMR spectra of the hydride resonance of **3** in toluene-d_8 (spectral frequency = 400.13 MHz).

The title compounds may be prepared by subjecting either of the complexes $[(Cy_2P(CH_2)_nPCy_2)Pt^0]$[8a] (**4**) or $[(Cy_2P(CH_2)_nPCy_2)Pt(C_2H_4)]$ (**5**) to a pressure of hydrogen.[8b]

$$[(Cy_2P(CH_2)_nPCy_2)Pt^0] + H_2 \xrightarrow{\text{pressure}} [(Cy_2P(CH_2)_nPCy_2)PtH_2]$$

$$[(Cy_2P(CH_2)_nPCy_2)Pt(C_2H_4)] + H_2 \xrightarrow{\text{pressure}} [(Cy_2P(CH_2)_nPCy_2)PtH_2]$$

If the ethylene complexes **5** are treated with a *flow* of hydrogen gas, the *cis*-dihydride species are formed first with displacement of the coordinated ethylene but lose hydrogen and dimerize to form $[(Cy_2P(CH_2)_nPCy_2)Pt(\mu\text{-}H)]_2$ (**6**) (complete within 1 h for **1**). The same complexes (**6**) are also produced from solutions of the *cis*-dihydride species on standing. The analogous nickel(II) dimer $[(Cy_2P(CH_2)_3PCy_2)Ni(\mu\text{-}H)]_2$ has been prepared and structurally characterized.[10]

On dissolution of complexes **2** and **3** in benzene solution, a dynamic process is observed by NMR spectroscopy involving interchange of ligand position with retention of P–H spin correlation which is typified by the variable-temperature ^1H NMR spectra of the hydride region, Figure 1, for **3**. Such a process is strictly intramolecular. We have recently observed a similar line shape for the species *cis*-$[H(R_3Si)Pt(PCy_3)_2]$[11] (R = variously

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(8) (a) Hexane and benzene solutions of $[(Cy_2P(CH_2)_3PCy_2)Pt^0]$ are very pale orange/yellow and on cooling colorless crystals are obtained which react with, e.g., $HSiPh_3$, to form $[(Cy_2P(CH_2)_3PCy_2)Pt(SiPh_3)H]$. The monomeric nature of **4** is presumed by comparison with dimer $[(t\text{-}Bu_2P(CH_2)_3P\text{-}t\text{-}Bu_2)Pt^0]_2$,[9] which crystallizes as red hexagonal platelets, and from $^{31}P\{^1H\}$ NMR spectra in which no evidence for $^2J_{P\text{-}Pt}$ has been observed. (b) Complexes **4** and **5** are prepared by reduction of the corresponding platinum(II) dichlorides $[(Cy_2P(CH_2)_nPCy_2)PtCl_2]$ with 2 equiv of sodium naphthalide and addition of ethylene in the case of **5**.
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Table I. ^1H and ^{31}P NMR Spectroscopic Data[a]

compound	P_A	P_B	J_{P_A-Pt}	J_{P_B-Pt}	H	$J_{H-P_{cis}}$	$J_{H-P_{trans}}$	J_{H-Pt}
$[(Cy_2P(CH_2)_2PCy_2)PtH_2]$ (**1**)	78.2		1826		+0.65	16	177	1098
$[(Cy_2P(CH_2)_3PCy_2)PtH_2]$ (**2**)	22.7		1901		-1.18	24	174	1069
$[(Cy_2P(CH_2)_4PCy_2)PtH_2]$ (**3**)	36.9		2010		-2.06	24	171	1045
$[(Cy_2P(CH_2)_2PCy)Pt(\mu\text{-}H)]_2$ (**6**)	83.6		73,2782		-2.48	37		481
$[(Cy_2P(CH_2)_3PCy_2)Pt^0(DEA)$[b] (**7**)	17.9		3299					
$[(Cy_2P(CH_2)_3PCy_2)Pt^0(HC{\equiv}CPh)$[c] (**8**)	17.8	20.1	3138	3212	8.54	15	22	15
$[(Cy_2P(CH_2)_3PCy_2)Pt(HC{\equiv}CCO_2Me)]$[d] (**9**)	18.9	20.0	3156	3404	8.66	19	19	7

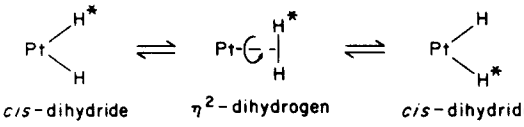
[a] P_A respresents the ^{31}P NMR resonance trans to an acetylenic hydrogen where relevant (i.e., **8** and **9**). [b] DEA = $EtO_2CC{\equiv}CCO_2Et$. [c] $J_{P_A-P_B}$ = 9 Hz. [d] $J_{P_A-P_B}$ not resolved.

substituted phenyl or benzyl), in which we believed (on the basis of other evidence) that the ligand position exchange process involves SiR_3 and H interchange rather than PCy_3 interchange. To distinguish between these two possibilities we have prepared a series of chelating diphosphine complexes including $[H(Ph_3Si)Pt(Cy_2P(CH_2)_7PCy_2)]$,[11,12] which exhibit variable temperature ^1H NMR hydride line shapes similar to those of the parent PCy_3 complexes. Assuming no fluxionality of the chelating diphosphine ligands,[15] this confirms the idea of SiR_3 and H ligand position exchange. The same process was also observed for *cis*-$[H(R_3Si)Pt(PPh_3)_2]$ (R = Ph, C_6H_4Cl)[13] and more recently for $(PEt_3)_2Pt(\mu\text{-}H)(\mu\text{-}CO)Mn(CO)_4$.[14] In the case of the dihydride complexes **2** and **3**, since *phosphine* ligand position exchange can presumably be precluded because of the chelating diphosphine ligands,[15] it is the hydride ligands that exchange positions. Alternatively, the hydride ligands may be regarded as an η^2-dihydrogen complex of platinum(0) in which the dihydrogen ligand is rotating about the Pt-H_2 bond, the H---H interaction presumably resulting from the steric constraints imposed by the bulky diphosphine ligand.[16]

Recently, a theoretical study[17] concluded that "oxidative addition" of H_2 to $Pt^0(PH_3)_2$ to form *cis*-$H_2Pt(PH_3)_2$ is not oxidative but rather an electronic promotion of platinum from the d^{10} ground state to the d^9s^1 state. Chemical confirmation that the hydride ligands are loosely bonded to platinum comes from the reaction of **2** with activated acetylenes. In this laboratory it has recently been shown[18] that activated acetylenes generally react with a close analogue of **2**, namely *trans*-$H_2Pt(PCy_3)_2$, by insertion into Pt-H bonds to form the corresponding σ-alkenyl products *trans*-$H(RHC{=}CR)Pt(PCy_3)_2$. In contrast, addition of stoichiometric amounts of the acetylenes $EtO_2CC{\equiv}CCO_2Et$, HC≡CPh, and $HC{\equiv}CCO_2Me$ to benzene solutions of **2** results in a rapid evolution of gas at room temperature with complete displacement of the hydride ligands to form the species $[(Cy_2P(CH_2)_3PCy_2)Pt^0(RC{\equiv}CR')]$, **7**, **8**, and **9**, respectively. For unsymmetrical acetylenes, two resonances in the $^{31}P\{^1H\}$ NMR spectra (with platinum satellites) indicate restricted rotation of the acetylene about the platinum center on the NMR time scale. The fact that the hydride ligands are so readily lost is consistent with their weak coordination to platinum.

Reversible H_2 coordination for the complex $[(t\text{-}BuPhP(CH_2)_2PPh\text{-}t\text{-}Bu)PtH_2]$[9] was demonstrated by a diminution of the hydride resonance in the ^1H NMR spectrum at 55 °C and a darkening of the solution to a red color, characteristic of the platinum(0) dimer $[(t\text{-}BuPhP(CH_2)_2PPh\text{-}t\text{-}Bu)Pt^0]_2$. In contrast, we observe no reduction in the ^1H NMR spectrum of the hydride signal intensity or darkening of a benzene solution of **3** on heating to 75 °C.

While the mechanistic details of the ligand position interchange process are still uncertain (e.g., a pseudotetrahedral or trigonal-planar intermediate), a sequence of events such as



can be envisaged and is consistent with the NMR data and the ease of displacement of both hydride ligands. We believe that the complexes described exist at an intermediate stage between dihydrides and η^2-dihydrogen complexes. We are currently studying the possibility of reversible *intermolecular* dihydrogen exchange in these compounds.

Registry No. 1, 102286-33-9; **2**, 102286-34-0; **3**, 102286-35-1; **4** (*n* = 2), 102286-36-2; **4** (*n* = 3), 102286-37-3; **4** (*n* = 4), 102286-38-4; **5** (*n* = 2), 102286-39-5; **5** (*n* = 3), 102286-40-8; **5** (*n* = 4), 102286-41-9; **6** (*n* = 2), 102286-42-0; **6** (*n* = 3), 102286-43-1; **6** (*n* = 4), 102286-44-2; **7**, 102286-45-3; **8**, 102286-46-4; **9**, 102286-47-5; $H(Ph_3Si)Pt(Cy_2P(CH_2)_7PCy_2)$, 102286-48-6; *trans*-$H_2Pt(PCy_3)_2$, 42764-83-0; H_2, 1333-74-0.

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Dynamics and Design of Enzymes and Inhibitors

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The mutual recognition and binding of ligands and receptors represents the first step in many biochemical processes. The ability to predict changes in affinity that would result from modifications in a ligand or receptor would therefore be helpful in the design of molecules with specific activities.[1-4] Here, we describe the first application to biological molecules of a new computer simulation approach to such problems. We compute the relative affinity of two benzamidine inhibitors for trypsin and of benzamidine for native and a mutant trypsin. The agreement with experimental data is encouraging.

To compute relative affinities, we use the thermodynamic cycle-perturbation approach.[5,6] This has already been used suc-

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