(colorless oil), showing ^{1}H NMR peaks at δ 3.34 (s, 3 H, OCH_3), 3.13 (dd, J = 7.6, 1.9 Hz, 1 H at C-11), and 2.82 (td, J = 5.1, 1.9 Hz, 1 H at C-12).

A simple synthesis of 14,15-EPETE (**6**) as the methyl ester from (15*S*)-HPETE[11a,18] was effected as follows.[9] The methyl ester of (15*S*)-HPETE (formed from the acid by using CH_2N_2 in ether at 0 °C) in 1:1 methylene chloride–ether at −110 to −105 °C was treated with 5 equiv of 1,2,2,6,6-pentamethylpiperidine[9] and 2 equiv of trifluoromethanesulfonic anhydride for 45 min, quenched (at −105 °C) with pentane–triethylamine, and isolated extractively (with the cold aqueous phase at ca. pH 9). The crude product consisted of the desired methyl ester of **6** and the 15-ketone, arising from simple dehydration of 15-HPETE in a ratio of 2:1. Because the chromatographic separation of this mixture was not easy, it was treated with sodium borohydride in dimethoxyethane at 0 °C to reduce the ketone and then chromatographed on silica gel by using 7:3 pentane–ether containing triethylamine[9,19] to afford the pure methyl ester of **6** (40%)[14] [UV_{max} (in CH_3OH as for **4**) 268, 279, 288 nm (ϵ at 279 nm 40 000); $[\alpha]^{23}_D$ −5.0° (*c* 0.3, cyclohexane containing 0.2% triethylamine)]; ^{1}H NMR data were in accord with **6** although not very characteristic.

The *S*-glutathione conjugates of **4** and **6** (**5** and **7**, RS = *S*-glutathionyl) were prepared as described previously for the conversion of leukotriene A (**2**) to leukotriene C (**3**, RS = *S*-glutathionyl).[3] The methyl ester of **4** or **6** was treated in a minimum of methanol containing **4** equiv of triethylamine with 2 equiv of *N*-(trifluoroacetyl)glutathione dimethyl ester at 23 °C for 4 h, and the resulting product [UV_{max} (in CH_3OH) 268, 277 (ϵ 40 000), 288 nm] was purified by reversed-phase (RP) chromatography [RP-high-performance liquid chromatography (high-performance LC)] with a Waters Associates μ-Bondapak C_{18} column with 65:35:0.1 CH_3OH–H_2O–HOAc buffered to pH 5.6 by the addition of 2.0 M NH_4OH. From racemic **4** methyl ester, as expected, two separable diasteromeric peptide conjugates were obtained in equal amounts whereas **6** (optically active) gave only a single conjugate. Each tripeptide conjugate was deprotected by exposure to 25 equiv of 1.0 M lithium hydroxide in 5:1 dimethoxyethane–water at 0 °C for 30 min and 23 °C for 12 h, and purification was effected by RP-high-performance LC as described above. Retention volumes (R_v) of the two diastereomers of **5** (RS = glutathionyl) were almost identical (4.8), and that of **7** (RS = glutathionyl) was 5.5[20] (leukotriene C = 6.4).

The *S*-cysteinylglycyl conjugates were obtained from the methyl esters of **4** and **6** in a similar way[5] by using *N*-(trifluorocysteinyl)glycine methyl ester[5] for forming the dipeptide conjugate and purifying the final deprotected products by RP-high-performance LC; R_v values were 6.2 and 6.8 for the two diasteromers **5** (RS = *S*-cysteinylglycyl) and 7.7 for **7** (RS = *S*-cysteinylglycyl) (leukotriene C = 6.4).

Arachidonic acid has in the past several years emerged as one of nature's most versatile substrates for the synthesis of important natural products, recalling such celebrated molecules as squalene, δ-aminolevulinic acid, and shikimic acid. It seems not unreasonable that this efficiency might extend to pathways via EPETEs to peptide conjugates such as **5** and **7**. With the successful synthesis of these substances by efficient and simple routes, the stage is now set for the study of their biological properties and a search to determine their presence or absence in living systems. These investigations will be reported in due course.[21]

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(19) For the synthesis of the peptide S-conjugates **7**, this purification of **6** methyl ester was unnecessary.

(20) Each of the S-conjugates **5** and **7** showed UV_{max} (CH_3OH) at 270, 280 (ϵ 40 000), and 290 nm.

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Tantalum–Neopentylidene Hydride and Tantalum–Neopentylidyne Hydride Complexes[1]

Sir:

α-Hydride elimination is the name given to the postulated intramolecular formation of an alkylidene–hydride complex from an alkyl complex. So far, however, there is no unambiguous example of such a reaction.[2] Since we have prepared various "d^0"[3] tantalum–neopentylidene complexes,[4] we thought we might be able to prepare analogous neopentylidene hydride complexes by reducing Ta(V)–neopentyl complexes by two electrons, a process which formally involves an "α-elimination" reaction. Another version of "α elimination" might be the conversion of a d^2 neopentylidene complex to a neopentylidyne hydride complex. We report here several examples of such reactions along with one reduction which yields a "d^2" neopentylidene complex which is stable toward formation of an alkylidyne–hydride complex.

The reduction of $Ta(CH_2CMe_3)Cl_4$ with 2 equiv of 0.4% sodium amalgam in ether/tetrahydrofuran in the presence of 5 equiv of PMe_3 under N_2 or Ar gives **1a** as beige crystals (eq 1) in moderate

$$Ta(CR_2CMe_3)Cl_4 + 2Na/Hg + 5PMe_3 \xrightarrow{\text{ether/THF}} Ta(CRCMe_3)(R)Cl_2(PMe_3)_3 \quad (1)$$

1a, R = H
1b, R = D

yield.[5] An analogous reduction of $Ta(CD_2CMe_3)Cl_4$ gave **1b**. The infrared spectrum of **1a** shows two medium strength peaks at 2440 and 1730 cm^{-1} which shift to 1805 and 1270 cm^{-1} in **1b**. The former we assign to the ν_{CH_α} stretch of a distorted neopentylidene ligand (one with a large $Ta-C_\alpha-C_\beta$ angle[4,6]). The latter, broader peak we assign to ν_{TaH}.

NMR studies (^{1}H, ^{31}P,[7] and ^{13}C[8]) suggest this formulation is correct. The ^{1}H NMR spectrum (270 MHz, −20 °C) of **1a** shows an eight line resonance due to Ta–H at δ 10.00 (J_{HP_A} = 17.7 Hz, J_{HP_B} = 101.9 Hz, J_{HP_C} = 91.0 Hz) which is further split due to coupling to the neopentylidene α-hydrogen atom (J_{HH_α} = 1.5 Hz). The signal for the neopentylidene α-hydrogen atom (a broadened doublet) is found at δ 0.24. Both are absent in **1b**. The ^{13}C NMR spectrum contains a signal for the neopentylidene α-carbon atom at δ 216 with J_{CH_α} = 72 Hz and J_{CP} = 6.4 Hz. The low value for J_{CH_α} also suggests that this neopentylidene ligand is highly

(1) Multiple Metal–Carbon Bonds. 18. Part 17 in press.

(2) (a) The best evidence for a process of this sort is Green's isolation of $[W(\eta^5\text{-}C_5H_5)_2(CD_2PPhMe_2)(D)]^+$ from the reaction of $[W(\eta^5\text{-}C_5H_5)_2(\eta^2\text{-}C_2H_4)(CD_3)]^+$ with $PPhMe_2$.[2b] He proposes that "$[W(\eta^5\text{-}C_5H_5)_2(CD_3)]^+$" is in equilibrium with $[W(\eta^5\text{-}C_5H_5)_2(CD_2)(D)]^+$: (b) Cooper, N. J.; Green, M. L. H. *J. Chem. Soc., Dalton Trans.* **1979**, 1121–1127, and references therein.

(3) By "d^0" we mean Nb- or Ta-alkylidene complexes containing three anionic ligands such as chlorides, alkyl groups, etc.[4] If one draws an analogy between an alkylidene and an oxo ligand (O^{2-}), then the metal is d^0. In order to be consistent, we must call alkylidyne ligands trianions.

(4) Schrock, R. R. *Acc. Chem. Res.* **1979**, *12*, 98–104.

(5) Anal. Calcd for $TaC_{14}H_{38}Cl_2P_3$: C, 30.51; H, 6.95. Found: C, 30.37; H, 7.01.

(6) (a) There is good evidence that a neopentylidene ligand is often severely distorted in some "d^0" alkylidene complexes toward a "neopentylidyne" ligand with a pseudo-bridging H_α between C_α and the metal.[4,6b] This distortion seems severe when "softer" ligands are present (η^5-C_5R_5, Br, PR_3) and comparatively mild when "harder" ligands are present (OR,[6c] O[6d]). (b) Schultz, A. J.; Williams, J. M.; Schrock, R. R.; Rupprecht, G. A.; Fellmann, J. D. *J. Am. Chem. Soc.* **1979**, *101*, 1593–1595. (c) Schrock, R.; Rocklage, S.; Wengrovius, J.; Rupprecht, G.; Fellmann, J. *J. Mol. Catal.* **1980**, *8*, 73–83. (d) Wengrovius, J. H.; Schrock, R. R.; Churchill, M. R.; Missert, J. R.; Youngs, W. J. *J. Am. Chem. Soc.* **1980**, *102*, 4515–4516.

(7) ^{31}P{^{1}H} NMR (ppm from H_3PO_4, toluene-d_8, 109.29 MHz, −30 °C) showed a 12-line ABC spectrum with peaks at −26.2 (A), −17.5 (B), and −4.1 (C) with $J_{P_AP_C}$ = 115.0 Hz, $J_{P_BP_C}$ = 51.1 Hz, and $J_{P_AP_B}$ = 29.3 Hz. Selectively decoupling the PMe_3 protons yields a 24-line pattern with J_{P_AH} = 17.3 Hz, J_{P_BH} = 101.0 Hz and J_{P_CH} = 90.6 Hz.

(8) ^{13}C NMR (ppm from Me_4Si, toluene-d_8, 67.89 MHz, −15 °C, gated ^{1}H decoupled): 216.0 (d of octet, $J_{CP} \approx$ 6.4 Hz, J_{CH} = 72 Hz, $CHCMe_3$), 46.23 (s, $CHCMe_3$), 34.13 (q, J_{CH} = 124 Hz, $CHCMe_3$), 22.82 (qd, J_{CP} = 24.82 Hz, $J_{CH} \approx$ 131 Hz, PMe_3(A)), 18.76 (qd, J_{CP} = 26.85 Hz, $J_{CH} \approx$ 131 Hz, PMe_3(B)), 16.26 (qd, J_{CP} = 20.69 Hz, $J_{CH} \approx$ 131 Hz, PMe_3(C)).

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distorted toward a neopentylidyne ligand.[4,6]

Reduction of a mixture of $Ta(CH_2CMe_3)Cl_4$ and $Ta(CD_2CMe_3)Cl_4$ in the presence of PMe_3 gave a significant amount of $Ta(CDCMe_3)(H)(PMe_3)_3Cl_2$ (by 250-MHz ^1H NMR). Since we showed that a mixture of $Ta(CHCMe_3)(H)(PMe_3)_3Cl_2$ and $Ta(CDCMe_3)(D)(PMe_3)_3Cl_2$ yielded no $Ta(CDCMe_3)(H)(PMe_3)_3Cl_2$, this "$\alpha$-elimination" reaction may not be a relatively simple intramolecular version.

The reduction of $Ta(\eta^5\text{-}C_5Me_5)(CH_2CMe_3)Cl_3$ in the presence of PMe_3 gave another neopentylidene hydride complex, **2** (eq 2), as the only NMR observable product. It is extremely soluble

$$Ta(\eta^5\text{-}C_5Me_5)(CH_2CMe_3)Cl_3 + 2Na/Hg + 2PMe_3 \rightarrow \underset{\mathbf{2}}{Ta(\eta^5\text{-}C_5Me_5)(CHCMe_3)(H)(PMe_3)Cl} \quad (2)$$

in pentane but can be isolated in 30% yield from concentrated solutions at −30 °C. The IR and NMR data for **2** are in complete accord with its formulation.[9] The neopentylidene ligand is, again, one of the distorted variety with $J_{CH_\alpha} = 72$ Hz and $\nu_{CH_\alpha} = 2525$ cm^{-1}, and $\nu_{TaH} = 1730$ cm^{-1}.

Since the neopentlyidene ligands in **1** and **2** are distorted, we were interested in knowing whether the hydride would behave as a leaving group and abstract H_α. Heating **1a** with excess PMe_3 led only to intractable oils, but **2** gave **3**[10] (eq 3) in good yield.

$$\underset{\mathbf{2}}{Ta(\eta^5\text{-}C_5Me_5)(CHCMe_3)(H)(PMe_3)Cl} \xrightarrow[60\ ^\circ C]{PMe_3} \underset{\mathbf{3}}{Ta(\eta^5\text{-}C_5Me_5)(CCMe_3)(PMe_3)_2Cl} \quad (3)$$

The preparation of an alkylidyne–hydride complex from an alkylidene complex was similarly successful. $Ta(\eta^5\text{-}C_5Me_5)(CHCMe_3)Br_2$[11] in the presence of 2 equiv of PMe_3 gives $Ta(\eta^5\text{-}C_5Me_5)(CCMe_3)(PMe_3)_2(H)$ (**4**) in 80% yield on reduction with 2 equiv of sodium amalgam. A more convenient synthesis (but one which is probably more complex mechanistically) employs $Ta(\eta^5\text{-}C_5Me_5)(CH_2CMe_3)_2Cl_2$ (eq 4). (**2** was first prepared by

$$Ta(\eta^5\text{-}C_5Me_5)(CH_2CMe_3)_2Cl_2 + 2PMe_3 + 2Na/Hg \rightarrow \underset{\mathbf{4}}{Ta(\eta^5\text{-}C_5Me_5)(CCMe_3)(PMe_3)_2(H)} \quad (4)$$

treating **3** with LiC_2H_5;[12] it is believed to be a trans tetragonal pyramidal molecule analogous to **3** and $Ta(\eta^5\text{-}C_5Me_5)(CPh)(PMe_3)_2Cl$.[13]) A related compound (**5**) can be prepared employing dmpe instead of PMe_3 (eq 5). Its ^1H, ^{13}C, and ^{31}P NMR

$$Ta(\eta^5\text{-}C_5Me_5)(CH_2CMe_3)_2Cl_2 + Me_2PCH_2CH_2PMe_2 + 2Na/Hg \rightarrow \underset{\mathbf{5}}{Ta(\eta^5\text{-}C_5Me_5)(CCMe_3)(dmpe)(H)} \quad (5)$$

spectra suggest that both ends of the dmpe ligand are coordinated to Ta and that they are equivalent.[14] We believe the geometry to be pseudo-tetrahedral with the hydride ligand capping the PPC_α face.

In light of the above findings, it is interesting to note that reduction of $Ta(CHCMe_3)(PMe_3)_2Cl_3$ in the presence of PMe_3 under argon does *not* give an alkylidyne–hydride complex, but **6** (eq 6), the only "d^2" alkylidene complex which does not contain

$$Ta(CHCMe_3)(PMe_3)_2Cl_3 \xrightarrow[3PMe_3]{2Na/Hg} \underset{\mathbf{6}}{Ta(CHCMe_3)(PMe_3)_4Cl} \quad (6)$$

an olefin ligand.[15] NMR data suggest that **6** contains one of the most distorted alkylidene ligands so far. We found the α-proton signal at δ −7.4, the α-carbon signal at 209 ppm with $J_{CH_\alpha} = 69$ Hz, and the CH_α stretch at 2200 cm^{-1}.[16] The α-proton signal is a quintet ($^3J_{HP} = 5.9$ Hz) at 25 °C, and we have not yet been able to obtain a low-temperature-limiting NMR spectrum characteristic of a less symmetric molecule. There, we believe some low-energy intramolecular process is equilibrating all PMe_3 ligands.

These results demonstrate how potentially complex the chemistry of alkyl and alkylidene complexes of early transition metals in "intermediate" oxidation states can be, and that under the right circumstances we can expect to observe or isolate alkylidene–hydride or alkylidyne–hydride complexes of other early transition metals such as Mo, W, or Re.[17] However, it is not yet clear that they can be formed by an *intramolecular* α-elimination reaction.

Acknowledgment. We thank the National Science Foundation for support (CHE79-05307).

(9) IR (cm^{-1}, Nujol): 2525 (ν_{CH_α}), 1730 (ν_{MH}). ^1H NMR (ppm from Me_4Si, toluene-d_8, 250 MHz, −30 °C): 7.53 (d, 1, $J_{HP} = 73.6$ Hz, $J_{HH_\alpha} = 1.8$ Hz, Ta–H), 2.44 (d, 1, $J_{HH_\alpha} = 1.83$ Hz, $CHCMe_3$), 2.09 (s, 15, C_5Me_5), 1.18 (d, 9, $J_{HP} = 7.3$ Hz, PMe_3), 1.11 (s, 9, $CHCMe_3$). ^{13}C NMR (ppm, toluene-d_8, 67.89 MHz, −30 °C, gated ^1H decoupled): 232.4 (dd, $J_{CP} = 6.5$ Hz, $J_{CH} = 72$ Hz, $CHCMe_3$), 112.1 (s, C_5Me_5), 47.4 (s, $CHCMe_3$), 33.4 (q, $J_{CH} \approx 122$ Hz, $CHCMe_3$), 18.41 (qd, $J_{CP} = 25.6$ Hz, $J_{CH} \approx 125$ Hz, PMe_3), 13.0 (q, $J_{CH} = 130$ Hz, C_5Me_5). ^{31}P NMR (ppm from H_3PO_4, C_6D_6, 36.4 MHz, 30 °C): −14.9 ($J_{PH} = 71$ Hz).

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(13) Churchill, M. R.; Youngs, W. J. *Inorg. Chem.* **1979**, *18*, 171–176.

(14) In the $^{13}C\{^1H\}$ NMR spectrum, $CCMe_3$ is found at 306.4 ppm (t, $J_{CP} = 8.9$ Hz). The hydride signal was not found in the ^1H NMR spectrum, but coupling to it could be observed in the ^1H-coupled ^{31}P NMR spectrum [28.5 ppm (d, $J_{PH} = 62$ Hz)].

(15) (a) Examples are $Ta(\eta^5\text{-}C_5Me_5)(CHCMe_3)(C_2H_4)(PMe_3)$[15b] and $Ta(CHCMe_3)(C_2H_4)(PMe_3)_2Et$.[15c] (b) Schultz, A. J.; Brown, R. K.; Williams, J. M.; Schrock, R. R. *J. Am. Chem. Soc.*, in press. (c) Fellmann, J. D., unpublished results.

(16) ^1H NMR (ppm, 250 MHz, toluene-d_8): −7.4 (quintet, 1, $^3J_{HP} = 5.9$ Hz, $CHCMe_3$), 1.10 (s, 9, $CHCMe_3$), 1.5 (t, 36, $J_{HP} = 2.4$ Hz, PMe_3). ^{13}C NMR (ppm, 22.93 MHz, toluene-d_8): 25.29 (quartet of quintets, $J_{CH} = 127$ Hz, $J_{CP} = 3.9$ Hz, PMe_3), 34.65 (q, $J_{CH} = 127$ Hz, $CHCMe_3$), 47.57 (s, $CHCMe_3$), 208.8 (dt, $J_{CP} = 7.8$ Hz, $J_{CH} = 69$ Hz, $CHCMe_3$).

(17) Alkylidyne hydride complexes of Mo and W are already known. M. Green reported *trans*-$Mo(\eta^5\text{-}C_5H_5)[P(OMe)_3]_2(H)(CCH_2CMe_3)$.[18a] We have found that the $W(dmpe)_2(C_5H_{10})$ complex mentioned previously[18b] is *trans*-$W(dmpe)_2(CCMe_3)(H)$.[18c]

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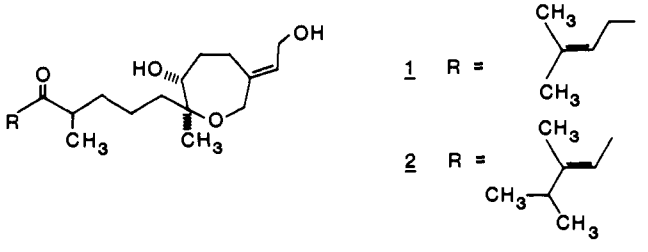
Total Synthesis of (±)-Zoapatanol

Sir:

Zoapatanol and montanol, two novel and biologically active oxepane diterpenoids, were isolated from the leaves of the zoapatle plant (*Montanoa tomentosa*) and assigned structures **1** and **2**, respectively.[1] This communication describes a novel process for



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