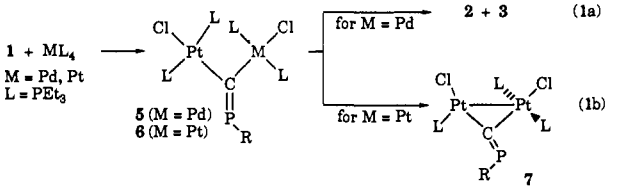
carbon-bonded to Pt(1) and η^2-bonded to Pt(2); the Pt atoms are not bonded to each other [Pt(1)—Pt(2) = 3.7868 (3) Å]. The atoms Pt(1), Cl(1), C(1), P(1), Pt(2), P(4), and P(5) are all nearly coplanar (within 0.061 Å), while P(2) and P(3) are 2.292 and 2.279 Å out of this plane. The C(1)—P(1) distance (1.666 (6) Å) is longer than those of triple bonds in phosphaalkynes RC≡P [1.52 (1) Å for R = 2,4,6-tri-*tert*-butylphenyl[10] and 1.536 (2) Å for R = *tert*-butyl][11] but is very similar to that (1.67 (2) Å) in the η^2(C,P)-coordinated phosphaalkyne in $(Ph_3P)_2Pt(\eta^2$-*t*-BuC≡P).[12] The C(1)—P(1) distance in **4** is also very similar to that of a C=P double bond, as found in Ph(H)C=PR (1.67 Å, where R = 2,4,6-tri-*tert*-butylphenyl).[13] Although there are no CN^- complexes analogous to **4** that would allow a comparison of Pt—CP vs Pt—CN bond lengths, the Pt(1)—C(1) distance (1.950 (6) Å) in **4** is shorter than the Pt—CN distances (1.992 (2) Å) in $K_2[Pt(CN)_4]$[14] and in $(Ph_3P)_2Pt(CN)(C{\equiv}CCN)$ (2.02 (3) Å).[15]

Since we have been unable to isolate and fully characterize **3**, its tentative assignment to the cyaphide structure in Scheme I is based on its ^{31}P NMR spectrum in the reaction mixture with **2**. Of the two ^{31}P signals, the one at 7.3 ppm is assigned to the PEt_3 ligands because the chemical shift is characteristic of a PEt_3 bound to Pt(II) and the ^{195}Pt–P coupling constant (2871 Hz) is typical of *trans*-$Pt^{II}(PEt_3)_2X_2$ complexes;[16] the small J_{PP} (9.16 Hz) is reasonable for coupling to the more distant phosphorus on the C≡P⁻ ligand. The signal at 68.0 ppm, which we assign to the cyaphide phosphorus, is split (J_{PP} = 9.16 Hz) into a triplet by the equivalent PEt_3 phosphorus atoms, and the ^{195}Pt satellites show a relatively small J_{Pt-P} (= 303 Hz) coupling constant. Supporting the structural assignment for **3** is its reaction with $Pt(PEt_3)_4$ which traps **3** (Scheme I) as the η^2(C, P)-complex **4**, which is obtained in high yield (80%).

The transfer of the chloro and 2,4,6-tri-*tert*-butylphenyl groups from **1** to the Pd in the first step (Scheme I) presumably occurs by initial oxidative addition (eq 1) of the C—Cl bond to the Pd(0) to give intermediate **5**; migration of the R group from the phosphorus to the Pd would give the observed products **2** and **3**.



The oxidative addition step is presumably very similar to that involved in the reaction (eq 1) of **1** with $Pt(PEt_3)_4$.[4] However, in this case, a PEt_3 ligand dissociates from intermediate **6**, which allows the formation of a Pt—Pt bond with a bridging arylisocyaphide (C≡PR)[17] ligand in **7**. These remarkable reactions of **1** with $Pd(PEt_3)_4$ and $Pt(PEt_3)_4$ have yielded the first examples of complexes containing C≡P⁻ and C≡PR ligands.

Acknowledgment. H.J. was supported in part by a government scholarship from the Republic of Korea. We thank the National Science Foundation (Grant CHE-9103948) for partial support of this research.

Supplementary Material Available: Description of the data collection and structure solution, completely labeled ORTEP drawing of **4**, and tables of crystal data, positional and thermal parameters, complete bond distances and angles, and least-squares planes for **4** (16 pages); listing of calculated and observed structure factors for **4** (25 pages). Ordering information is given on any current masthead page.

Syntheses and Absolute Configurations of Trehazolin and Its Aglycon

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Trehazolin (**1**) is a powerful trehalase inhibitor obtained from a culture broth of *Micromonospora* strain SANK 62390. Its structure was elucidated as a pseudodisaccharide shown in Figure 1 from degradation and ^1H NMR analysis.[1] A Suntory group presented the structure of trehalostain[2,3] as the C-2 epimer of **1**. However, trehalostatin has been postulated to be the same compound as trehazolin through comparison of their physical data. Therefore, it was necessary to determine the correct structure including absolute configuration. As a result, we were able to correlate the absolute configuration of natural trehazolin aglycon with that of D-glucose. We were also able to synthesize trehazolin itself.

The starting compound, (2*R*,3*S*,4*R*)-4-(benzoyloxy)-2,3-bis-[(methoxymethyl)oxy]-5-hexenal (**2**), was obtained from D-glucose[4] and was converted to the corresponding oxime (**3**) by treatment with hydroxylamine. Oxidation of **3** with aqueous sodium hypochlorite and spontaneous [2 + 3] cycloaddition[5] gave isoxazoline **4**. Cleavage of the N–O bond of **4** and coincident hydrolysis of the imine group with Raney nickel and boric acid in methanol–dioxane–H_2O (15:5:3) under an atmosphere of hydrogen[6] caused spontaneous elimination of the benzoyloxy group to give an α,β-unsaturated cyclopentenone (**5**). The primary alcohol of **5** was protected to give silyl ether **6**. The ketone of **6** was reduced to a 5:2 mixture of alcohols, **7** and its epimer, by treatment with sodium borohydride and cerium chloride.[7] The mixture was separable chromatographically on a silica gel column. Benzylation of the secondary alcohol of **7** with benzyl bromide and sodium hydride gave **8**, and deprotection of the silyl group of **8** with tetrabutylammonium fluoride[8] gave **9**.

Sharpless' epoxidation[9] of allylic alcohol **9** with diisopropyl L-tartrate, titanium(IV) isopropoxide, and *tert*-butyl hydroperoxide in dichloromethane gave **10** in 94% yield. Use of diisopropyl

(9) Crystallographic data for **4**: mol wt 941.23; space group $P2_1/n$; a = 11.686 (1) Å, b = 12.232 (2) Å, c = 25.964 (4) Å; V = 3635 (2) Å^3, d_{calcd} = 1.72 g/cm^3 for Z = 4 at −50 ± 1 °C, μ = 80.7 cm^{-1} (Mo Kα). Diffraction data were collected at −50 ± 1 °C with an Enraf-Nonius CAD4 automated diffractometer. A total of 13 067 reflections were collected. Of the 6369 unique data, 4824 were considered observed, having $F_o^2 > 3.0\sigma(F_o^2)$. R = 0.024 and R_w = 0.033. Details of data collection and refinement are given in the supplementary material.

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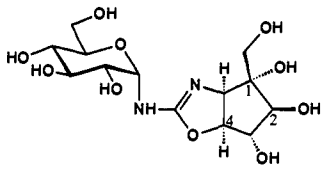
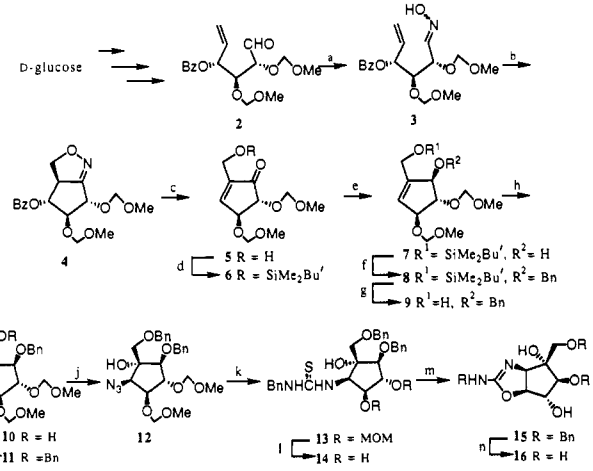


Trehazolin (1)

Figure 1.

Scheme I[a]

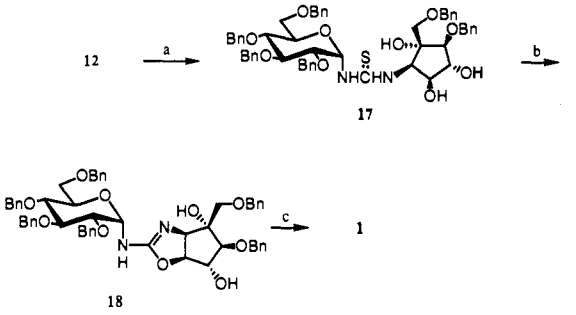


[a] (a) 10 equiv of NH_2OH·HCl, 10 equiv of Na_2CO_3, Et_2O–H_2O, 25 °C, 8 h, 74%. (b) Aqueous 5% NaOCl, catalytic Et_3N, CH_2Cl_2–H_2O, 0 °C, 40 min, 66%. (c) H_2, Raney Ni, $B(OH)_3$, 1,4-dioxane–MeOH–H_2O, 25 °C, 5 h, 72%. (d) 1.5 equiv of *tert*-$BuMe_2SiCl$, 1.5 equiv of imidazole, DMF, 25 °C, 16 h, 88%. (e) 1.5 equiv of $NaBH_4$, 1.5 equiv of $CeCl_3$·$7H_2O$, MeOH, 0 °C, 2 h, 53%. (f) 1.5 equiv of BnBr, 1.5 equiv of NaH, DMF, 0 °C, 1 h. (g) 1.5 equiv of *n*-Bu_4NF, THF, 0 °C, 1 h, 58% from **7**. (h) 1.4 equiv of $Ti(OPr^i)_4$, 1.5 equiv of diisopropyl L-tartrate, 2.0 equiv of *t*-BuOOH, CH_2Cl_2, −20 °C, 5 h, 94%. (i) 1.5 equiv of BnBr, 1.5 equiv of NaH, DMF, room temperature, 2 h, 98%. (j) 12 equiv of NaN_3, 12 equiv of NH_4Cl, DMF–ethylene glycol, 125 °C, 48 h, 78%. (k) 4.0 equiv of $LiAlH_4$, Et_2O, 0 °C, 4 h, then 1.5 equiv of BnNCS, THF, room temperature, 3 h, 83%. (l) 0.5 M aqueous HCl, 1,4-dioxane, 60 °C, 24 h, 74%. (m) 1.2 equiv of 2-chloro-3-ethylbenzoxazolium tetrafluoroborate, MeCN, 0 °C, 1 h, then quenched with 2.4 equiv of Et_3N, 0 °C, 3 h, 82%. (n) H_2, $Pd(OH)_2$–C, MeOH, 60 °C, 30 min, 71%.

D-tartrate instead of L-tartrate gave a diastereomer of the epoxide **10** in 77% yield. The configuration of these diastereomers followed Sharpless' epoxidation rule.[9]

After benzylation of **10** with benzyl bromide–NaH in DMF, treatment of the benzylated product **11** with sodium azide,[10] ammonium chloride, and ethylene glycol in dimethylformamide gave azide **12**. Reduction of the azide group of **12** with lithium aluminum hydride in ether and treatment of the resulting amine with benzyl isothiocyanate gave thiourea **13**. Deprotection of two methoxymethyl groups of **13** by 0.5 M aqueous hydrogen chloride in 1,4-dioxane afforded **14**. Treatment of **14** with 2-chloro-3-ethylbenzoxazolium tetrafluoroborate[11] gave aminooxazoline **15** through an intermediate carbodiimide. The benzyl groups of **15** were removed with hydrogen using palladium hydroxide on carbon (Pearlman's catalyst) in methanol to give **16** ($[\alpha]^{25}_D$ +14.4° (*c* 0.32, H_2O)), which was identical with natural trehazolin aglycon ($[\alpha]^{25}_D$ +13.5° (*c* 0.74, H_2O))[12] in all respects. The absolute configuration of natural trehazolin aglycon was thus determined as [1*R*-(1α,2β,3α,4β,5β)].

Scheme II[a]



[a] (a) 4.0 equiv of $LiAlH_4$, Et_2O, 0 °C, 4 h, 5% HCl–MeOH, 60 °C, 5 h, and then 1.0 equiv of 2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl isothiocyanate, 1.5 equiv of Et_3N, room temperature, 18 h, 69%. (b) 1.7 equiv of 2-chloro-3-ethylbenzoxazolium tetrafluoroborate, MeCN, 0 °C, 1 h, then quenched with 3.2 equiv of Et_3N, 0 °C, 1 h, 68%. (c) H_2, $Pd(OH)_2$–C, MeOH, 60 °C, 30 min, 44%.

Finally, we synthesized trehazolin as follows. Treatment of the amine obtained from **12** with 5% methanolic hydrogen chloride at 60 °C removed the two methoxymethyl groups, and then treatment of the resulting triol amine hydrochloride with 2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl isothiocyanate[13] and triethylamine gave an α-D-glucopyranosylthiourea derivative **17**.[14] Cyclization of **17** with 2-chloro-3-ethylbenzoxazolium tetrafluoroborate[11] and triethylamine in acetonitrile gave hexabenzyltrehazolin **18**, which was hydrogenolized to trehazolin (**1**) using Pearlman's catalyst. The synthetic trehazolin (**1**, $[\alpha]^{30}_D$ +112.7° (*c* 0.59, H_2O)) was identical with natural trehazolin ($[\alpha]^{25}_D$ +99.5° (*c* 0.44, H_2O))[1] in all respects, including inhibition activity toward both silkworm and porcine trehalases.[1]

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Biosynthesis of Dehydrorabelomycin and PD 116740: Prearomatic Deoxygenation as Evidence for Different Polyketide Synthases in the Formation of Benz[*a*]anthraquinones

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During the past decade the structural diversity of known naturally occurring benz[*a*]anthraquinones has expanded, causing them to become a major class of polyketide metabolites.[1] The biosynthesis of three members has been reported: two are derived from the predictable folding of a decaketide precursor,[2-5] while a third may be derived by rearrangement of a linear intermediate.[8] Many benzanthraquinones possess a hydroxyl at C-6 (derived from C-1 of acetate, e.g., dehydrorabelomycin (**1**)[6,9]), while a nearly

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