does not. However, since a cis arrangement has also been found in benzoquinone deviates, e.g., duroquinone,[21] this argument is to be taken with caution. In both isomers the carboxyl group adopts the somewhat unusual anti conformation which is stabilized by the intramolecular hydrogen bond.

While the room-temperature X-ray data are best explained by a disordered model, they provide no information as to whether the disorder is static or dynamic. However, taken in conjunction with the low-temperature results, they suggest that a proton-transfer process may take place in the solid state. As pointed out[11] in the similar case of naphthazarin, the problem of whether crystal sites are occupied exclusively by molecules with structures **1a** and **1b** is open to question, as is the mechanism of proton exchange. Further studies, especially by low-temperature solid-state NMR techniques, should provide answers to these problems.

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Registry No. 1a, 518-75-2; **1b**, 92720-00-8.

Supplementary Material Available: Table with details of data collection and refinement, final positional and thermal parameters at 290 and 147 K, and lists of observed and calculated structure factors at the two temperatures (22 pages). Ordering information is given on any current masthead page.

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1,2-Migration of Hydrogen during the Biosynthesis of Tropic Acid from Phenylalanine

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(*S*)-Tropic acid (**4**) is the acid moiety of the ester alkaloids hyoscyamine (**1**) and scopolamine (**2**) which are found in *Datura* and related species of the Solanaceae. It is formed from phenylalanine (**3**) by an intramolecular 1,2-migration of the carboxyl group from C-2 to C-3.[2] No definitive work has appeared on the mechanism of this rearrangement.[3] This communication describes work on the fate of the hydrogens present at the C-3 position of phenylalanine.[4]

Since it was anticipated that the loss of hydrogen from the prochiral C-3 position of phenylalanine would be stereospecific, preliminary feedings (by the wick method) to *Datura innoxia* and *Datura stramonium* plants were carried out with a mixture of equal amounts of the four possible stereoisomers of [1-^{14}C,3-^{3}H]phenylalanine.[5] It was expected that the resultant alkaloids would retain 50% of the ^{3}H relative to ^{14}C. The results of the feeding to *D. innoxia* are recorded in Table I. The alkaloids were isolated and separated as previously described.[3,6] Both scopolamine (>95% optically pure) and hyoscyamine (58% optically pure)[7] retained significantly more than 50% of the ^{3}H. The tropic acid, mp 118 °C, obtained by hydrolysis of the scopolamine with barium hydroxide[8] had $[\alpha]^{25}_{D}$ −13.9° (ca. 18% optically pure).[9] The reduction in the ^{3}H/^{14}C ratio in this tropic acid corresponds to this degree of loss of tritium from the chiral center. The tropic acid was dehydrated to atropic acid (**6**), which was oxidized to afford formaldehyde (assayed as its dimedine derivative) and benzoylformic acid (assayed as its oxime) (**5**) as previously described.[8] Activities of these degradation products clearly indicate that tritium was located on the methylene group of the tropic acid. Similar results were obtained with the alkaloids isolated from *D. stramonium* plants, except that the degree of incorporation of radioactivity was somewhat lower.

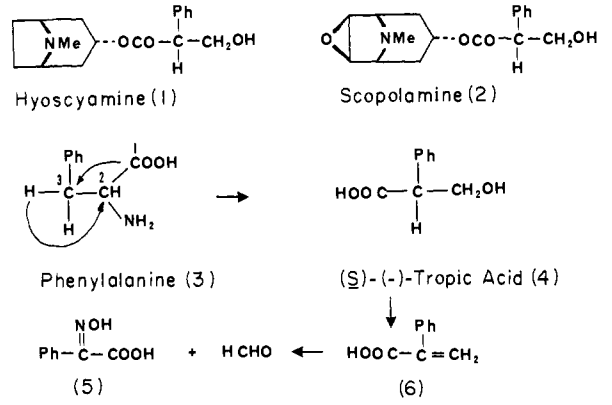
It is thus apparent that when the carboxyl group of phenylalanine migrates, there is also a migration of one of the hydrogens at C-3 to the carbon that ultimately becomes the hydroxymethyl group of tropic acid. In the scheme, this migration is represented as occurring with retention of configuration, and investigations with (3*S*)- and (3*R*)-[3-^{3}H]phenylalanine are in progress to settle this point. Although the formation of tropic acid from phenyl-

Table I. Activities of the Alkaloids, and Their Degradation Products, Derived from [1-^{14}C,3-^{3}H]Phenylalanine (0.5 mM) Fed to 3-Month Old *Datura innoxia* Plants for 10 Days

compound	activity,[a] dpm/mM ^{14}C	^{3}H	^{3}H/^{14}C
[1-^{14}C,3-^{3}H]phenylalanine	4.23×10^{7}	5.26×10^{8}	12.4
scopolamine HCl (^{14}C inc,[b] 0.18%)	7.6×10^{4}	9.0×10^{5}	11.8
tropic acid	7.1×10^{4}	5.2×10^{5}	7.3
oscine picrate[c]	$<0.1 \times 10^{4}$	$<0.1 \times 10^{4}$	
atropic acid (**6**)	7.0×10^{4}	4.3×10^{5}	6.1
formaldehyde–dimedone	$<0.1 \times 10^{4}$	4.2×10^{5}	
benzoylformic acid oxime (**5**)	6.8×10^{4}	$<0.1 \times 10^{5}$	
hyoscyamine HCl (^{14}C inc,[b] 0.20%)	8.4×10^{4}	7.9×10^{5}	9.4
tropic acid	8.3×10^{4}	5.1×10^{5}	6.2
tropine picrate[c]	$<0.1 \times 10^{4}$	$<0.1 \times 10^{4}$	

[a] Determined in duplicate with consistent results (within 5%). [b] inc = total radioactivity in the isolated alkaloid/total activity in the administered phenylalanine. [c] The tropane base isolated from the basic hydrolysis of the alkaloids.

Scheme I. Biosynthesis of Tropic Acid (Structures 3 and 4 are Fischer Projections



(1) Contribution 193 from this laboratory. Part 34 in the series "Chemistry of the Tropane Alkaloids". For Part 33, see: Leete, E. *J. Am. Chem. Soc.* **1983**, *105*, 6727.

(2) Leete, E.; Kowanko, N.; Newmark, R. A. *J. Am. Chem. Soc.* **1975**, *97*, 6826.

(3) Leete, E. *Phytochemistry* **1983**, *22*, 933 and references cited therein.

(4) Previous work related to this problem is ambiguous. When [1-^{14}C,2-^{3}H]phenylalanine was fed to a sterile culture of *Datura metel* roots the resultant tropic acid had lost 93% of the ^{3}H relative to ^{14}C: (a) Liebisch, H. W.; Bhavsar, G. C.; Schaller, H. J. *Biochem. Physiol. Alkaloide, Int. Symp., 4th, 1969* **1972**, 233. (b) Schutte, H. R.; Liebisch, H. W. *Z. Pflanzenphysiol.* **1967**, *57*, 440. (c) Liebisch, H. W. *Symp. Pap.—IUPAC Int. Symp. Chem. Nat. Prod., 7th* **1970**, 557. These authors also reported that tropic acid derived from [2-^{14}C,2,3-^{3}H$_3$]phenylalanine retained 39% of the ^{3}H relative to ^{14}C. However, the stereochemical location of ^{3}H at C-3 of the phenylalanine was not determined, and no comments were made on the loss of ^{3}H from the chiral center of tropic acid during basic hydrolysis of the labeled tropane alkaloids.

(5) The isomers 2*R*,3*R*, 2*R*,3*S*, 2*S*,3*R*, and 2*S*,3*S* were prepared from [1-^{14}C]glycine and [*formyl*-^{3}H]benzaldehyde as previously described: Wightman, R. H.; Staunton, J.; Battersby, A. R.; Hanson, K. R. *J. Chem. Soc., Perkin Trans. 1* **1972**, 2355.

(6) Leete, E. *Phytochemistry* **1972**, *11*, 1713.

(7) Esters of tropic acid are readily racemized in basic solution (Frankland, P. F. *J. Chem. Soc., Trans.* **1913**, *103*, 713); however, scopolamine, for unknown reasons, is much less susceptible to racemization than hyoscyamine.

(8) Louden, M. L.; Leete, E. *J. Am. Chem. Soc.* **1962**, *84*, 4507.

(9) Watson and Youngson (Watson, M. B.; Youngson, M. B. *J. Chem. Soc., Perkin Trans 1*, **1972**, 1597) record $[\alpha]_D$ +74.4° for (*R*)-(+)-tropic acid, which has mp 129 °C.

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alanine must also involve a step whereby the amino function is converted to a hydroxyl group, the overall transcarboxylation is very similar to the conversion of methylmalonyl coenzyme A to succinyl coenzyme A.[10] This reaction also involves a simultaneous 1,2-migration of a carboxyl group (as a coenzyme A ester) and hydrogen.

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Registry No. 1, 101-31-5; **2**, 51-34-3; **3**, 63-91-2; **4**, 16202-15-6.

(10) Cf. for leading ref: Grate, J. H.; Grate, J. W.; Schrauzer, G. N. *J. Am. Chem. Soc.* **1982**, *104*, 1588. Retey, J. In "New Comprehensive Biochemistry. Volume 3. Stereochemistry"; Tamm, Ch., Ed.; Elsevier Biochem. Press, 1982; p 261-265.

Rapid Intramolecular Rearrangement of a Hydridocyclopropylrhodium Complex to a Rhodacyclobutane. Independent Synthesis of the Metallacycle by Addition of Hydride to the Central Carbon Atom of a Cationic Rhodium π-Allyl Complex

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Hydridoalkylmetal complexes (general structure R-M-H) are very sensitive; most undergo decomposition at temperatures substantially below ambient. This ease of decomposition is generally due to rapid reductive elimination of hydrocarbon R-H.[1] We wish to report that hydridocyclopropylrhodium complex **2** (the product of rhodium-based C-H activation of cyclopropane[2]) is unique: like its congeners it decomposes rapidly at temperatures above 0 °C, but it does *not* only regenerate hydrocarbon. Rather, it undergoes a competitive, unprecedented rearrangement to the corresponding C-C insertion product, rhodacyclobutane **3**. In addition, we report (a) that **3** may be prepared independently by treatment of the corresponding π-allyl complex **5** with hydride reagents, to our knowledge only the second system in which nucleophiles add to the center, rather than the end carbon, of a coordinated allyl ligand,[3] (b) the results of an X-ray diffraction study of metallacycle **3**, and (c) preliminary mechanistic results which indicate that the rearrangement of hydride **2** to metallacycle **3** is intramolecular.

Our synthetic results are summarized in Scheme I. As reported earlier,[2] ultraviolet irradiation of $Cp^*(L)RhH_2$ (**1a**) in liquid cyclopropane at −60 °C results in selective formation of hydrido cyclopropyl complex **2**. This material can also be prepared thermally by warming the hydrido *n*-propyl complex[2,4] **1b** to −10 °C in liquid cyclopropane (sealed tube). Upon further warming of **2** in cyclopropane, apparent rearrangement occurs, leading to C-C insertion product **3** in quantitative yield as estimated by ^1H NMR. This material can be obtained in 70% isolated yield as yellow crystals by slow crystallization from pentane at −40 °C. The complex has been fully characterized by spectral and analytical techniques and by X-ray diffraction.[5,6] An ORTEP diagram of the structure is illustrated in Figure 1; it shows clearly that the metallacyclobutane ring is essentially planar and symmetrical about the Rh-C_{12} axis.

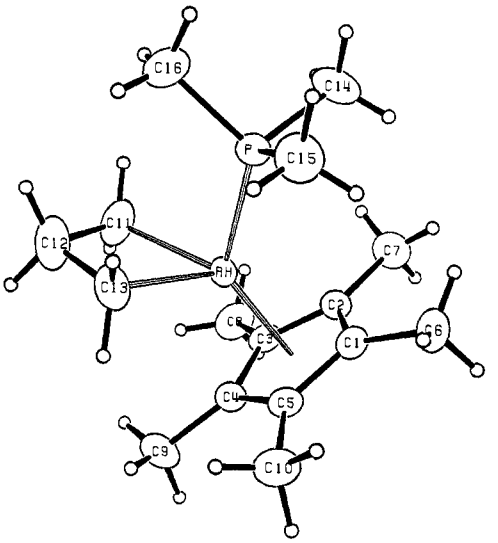
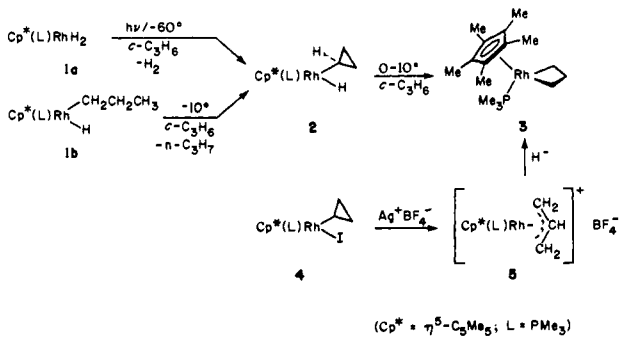
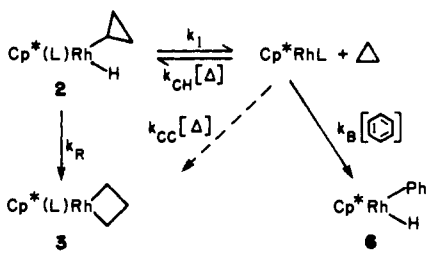


Figure 1. ORTEP diagram illustrating the structure of $(\eta^5\text{-}C_5Me_5)(PMe_3)Rh(CH_2)_3$ (**3**). Selected bond distances (Å): $Rh\text{-}C_{11} = Rh\text{-}C_{13} = 2.085$, $C_{11}\text{-}C_{12} = 1.512$, $C_{12}\text{-}C_{13} = 1.527$. Selected bond angles: $C_{11}C_{12}C_{13} = 99.55°$, $C_{12}C_{13}Rh = 96.24°$, $RhC_{11}C_{12} = 96.59°$, $C_{11}RhC_{13} = 67.61°$.

Scheme I



Scheme II



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(4) (a) Jones, W. D.; Feher, F. J. *Organometallics* **1983**, *2*, 562; (b) *J. Am. Chem. Soc.* **1984**, *106*, 1650.

(5) Selected data for X-ray structure of **3**: space group $P2_1/n$; $a = 10.2713$ (14) Å, $b = 12.9644$ (15) Å, $c = 12.8022$ (21) Å; $\beta = 94.249$ (12)°; $V = 1700.1$ (7) Å^3; $D_c = 1.392$ g cm^{-3}; μ_{calcd} (Mo Kα) = 10.66 cm^{-1}. A total of 2330 reflections were collected; 2206 unique reflections were used to solve the structure by standard least-squares and Fourier techniques. Peaks for all hydrogen atoms were found by using difference Fourier techniques following refinement of the Rh and P atoms with anisotropic thermal parameters. Final residuals for which $F^2 > 3\sigma(F^2)$ were $R = 1.67\%$, $R_w = 2.77\%$, and GOF = 2.001. Full details of the structure determination are provided as supplementary information.

(6) Supplementary information provided with this paper also includes (a) low-temperature (−40 °C) ^1H, ^{13}C, and ^{31}P NMR data for **2** and (b) spectral, analytical, and melting point data for complexes **3**, **4**, and **5**.

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