

**Figure 2.** Products resulting from mild base treatment of 7-ethylguanosine (9).

changeable signals at 6.7–8.2 ppm corresponding to *N*-formyl, thus suggesting imidazole ring opening. Because 7-substituted purine nucleosides are also known to undergo an important but unclarified imidazole ring fission,<sup>12,13</sup> a model system was first investigated. Namely, 7-ethylguanosine (9)<sup>14</sup> was treated with 2N NH<sub>4</sub>OH (room temperature, 2 lyophilized, lyophilized, and passed through Sephadex G-25. HPLC of the product gave an ill-resolved multiple peak pattern, the components of which also interconvert at room temperature. Since the UV resulting from subtraction of 2β,7-diamino-1α-hydroxymytosene from M-dG<sub>1</sub> was almost identical with that of base-treated 9, the latter was studied as a model for the M-dG<sub>1</sub> constituents.

Thus the NH<sub>4</sub>OH-treated 7-ethylguanosine (9) was acetylated and submitted to HPLC (IBM-ODS, MeCN/H<sub>2</sub>O 15/85) to give triacetates (90% yield) 11, 12, and 13 (Figure 2) in 1:2:2 ratio: CI-MS *m/z* 456 (identical for 11–13); UV (in CH<sub>3</sub>CN) for all three with peaks at 211, 238 (sh), and 272 nm are typical for ring-opened 7-alkylguanosines. the <sup>1</sup>H NMR of 11<sup>15</sup> and 12<sup>16</sup> show them to be the C-1' β- and α-anomers, respectively, of D-ribofuranose triacetate linked to N-9 of the imidazole-cleaved guanine moiety (Figure 2); similarly, 13<sup>16</sup> is the β-anomer of ribopyranose triacetate linked to N-9. The C-1' configurations of 11–13 were determined by NOE experiments. The furanoses and pyranoses result from addition of 4'- and 5'-OH in 10 to the imine bond (Figure 2).<sup>17</sup>

The unacetylated mixture from 9 was separated by HPLC, (IBM-ODS, MeCN/H<sub>2</sub>O 1.5/98.5) to yield pure 14, 15, and 16 upon collection at –78 °C; acetylation gave respective acetates 11, 12, and 13.

We thus conclude that MdG<sub>1</sub> also consists of interconverting ribosides 6–8 (Figure 1). Substitution of calf thymus DNA for d(GpC) (3) in the reaction with acid-activated MC was also found to yield M-guanines 4/5 and the MdG<sub>1</sub> mixture.<sup>18</sup>

Although many carcinogens alkylate guanosine residues at N-7, the imidazolium fission products had to date not been adequately characterized. Apurination or rearrangement of the riboside

(12) Haines, J. A.; Reese, C. B.; Lord Todd, *J. Chem. Soc.* **1962**, 5281.

(13) Lawley, P. D. In "Progress in Nucleic Acid Research and Molecular Biology"; Davidson, J. N., Cohn, W. E., Eds.; Academic Press: New York, 1966; Vol. 5, p 81.

(14) Cf. 7-methylguanosine: Jones, J. W.; Robins, R. K. *J. Am. Chem. Soc.* **1963**, *85*, 193.

(15) 11–16 are each present as a set of inseparable rotameric formyl isomers; thus, many protons give rise to more than one signal. <sup>1</sup>H NMR of 11 (Me<sub>2</sub>SO-*d*<sub>6</sub>) δ 10.78 (br s, exchangeable, N<sup>1</sup>-H); 8.11/7.71 (s, 8-CHO), 7.38/7.23 (d, exchangeable, N<sup>9</sup>-H), 6.77/6.65 (br s, exchangeable, 2-NH<sub>2</sub>), 5.93/5.82 (dd, 1'-H), 5.42/5.34 (dd, 2'-H), 5.25/5.20 (dd, 3'-H), 4.30–3.95 (m, 4'-H/5'-H), 3.52–3.12 (m, 7-CH<sub>2</sub>), 0.96/0.92 (t, 7-CH<sub>2</sub>CH<sub>3</sub>).

(16) Supplementary material.

(17) Cf.: Lönnberg, H.; Lehtikoinen, P. *J. Org. Chem.* **1984**, *49*, 4964.

(18) Tomas, M.; Lipman, R.; Verdine, G.; Nakanishi, K., manuscript in preparation.

moiety as shown in Figure 1 could lead to destruction of the secondary structure of DNA at the alkylation site. The nature of such ring-cleaved moieties resulting from interaction of MC with double-stranded DNA, as well as their relationship to excision–repair mechanisms, remains to be clarified.

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**Supplementary Material Available:** Difference UV of MdG<sub>1</sub> minus 2β,7-diamino-1α-hydroxymytosene, <sup>1</sup>H NMR of 11–16, <sup>1</sup>H NMR of MdG<sub>1</sub> mixture (downfield region), <sup>1</sup>H NMR of crude hydrolysis mixture from base treatment of 7-ethylguanosine, and <sup>1</sup>H NMR of M-guanine A (4) and M-guanine B (5) (11 pages). Ordering information is given on any current masthead page.

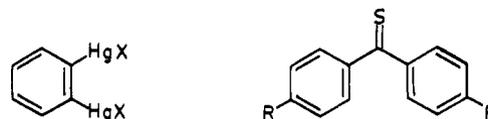
### Multidentate Lewis Acids. Reduction of Thioketones in the Presence of Organomercury Trifluoroacetates

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Recently we described the unusual coordination chemistry of three bidentate Lewis acids, the 1,2-phenylenedimercury dihalides 1–3.<sup>1</sup> Unlike simple monodentate organomercuric halides, bi-



- 1 (X = Cl)  
2 (X = Br)  
3 (X = I)  
4 (X = OOCF<sub>3</sub>)

- 5 (R = OCH<sub>3</sub>)  
6 (R = N(CH<sub>3</sub>)<sub>2</sub>)  
7 (R = H)

dentate acids 1 and 2 form isolable complexes with added halides. We have now discovered that related bidentate Lewis acids bind and activate thioketones, facilitating their reduction by formal donors of hydride.

Deep blue solutions of bis(4-methoxyphenyl)methanethione (5)<sup>2</sup> in CH<sub>3</sub>CN turned yellow-green when equimolar amounts of bis(trifluoroacetato)-1,2-phenylenedimercury (4)<sup>3,4</sup> were added. At the same time, singlets at δ –1595 (CD<sub>3</sub>CN)<sup>5a</sup> in the <sup>199</sup>Hg

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(2) Scheeren, J. W.; Ooms, P. H. J.; Nivard, R. J. F. *Synthesis* **1973**, 149–151.

(3) Prepared in 87% yield from chloride 1 by treatment with aqueous NaOH, followed by neutralization with CF<sub>3</sub>COOH.

(4) The structure assigned to this new compound is consistent with its elemental analysis and its IR, NMR, and mass spectra. These data are included in the supplementary material.

(5) (a) All δ (<sup>199</sup>Hg) are reported in parts per million relative to external neat dimethylmercury. Negative values indicate upfield shifts. (b) The direction of this shift is persuasive evidence of additional coordination to mercury. Kidd, R. G.; Goodfellow, R. J. In "NMR and the Periodic Table"; Harris, R. K., Mann, B. E., Eds.; Academic Press: London, 1978; pp 195–278. (c) Small upfield shifts in the <sup>13</sup>C NMR spectra of complexed thioketones are also reported by: Bret, J.-M.; Castan, P.; Commenges, G.; Laurent, J.-P.; Muller, D. *J. Chem. Soc., Chem. Commun.* **1983**, 1273–1275. Burman, S.; Sathyanarayana, D. N. *J. Inorg. Nucl. Chem.* **1981**, *43*, 1189–1192. Olah, G. A.; Nakajima, T.; Prakash, G. K. S. *Angew. Chem., Int. Ed. Engl.* **1980**, *19*, 811–812.



Research Council of Canada, and le Ministère de l'Éducation du Québec. We are indebted to Robert Mayer and Sylvie Bilodeau for recording our  $^{199}\text{Hg}$  and  $^{13}\text{C}$  NMR spectra, to Michael J. Evans and Christine Johnson for recording our mass spectra, and to Howard E. Katz for useful suggestions.

**Supplementary Material Available:** Spectroscopic and analytical data for compounds **4**, **8**, and **11-13** (1 page). Ordering information is given on any current masthead page.

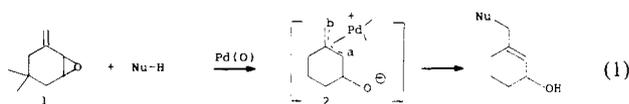
### Palladium-Mediated Vicinal Cleavage of Allyl Epoxides with Retention of Stereochemistry: A Cis Hydroxylation Equivalent

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The value of epoxides as synthetic intermediates in complex synthesis has increased dramatically as a result of the ability to control stereochemistry in both a relative and absolute sense.<sup>1</sup> Subsequent transformations rely on the ease of opening epoxides which, of necessity, proceeds with inversion and thus corresponds to a trans addition to the olefin. If epoxides could be opened with retention of configuration to give an equivalent of a cis addition, a practical broadening of the application of these intermediates in synthesis would result. In the case of vinyl epoxides, such as **1**, such a possibility could derive from a metal-promoted opening via **2** (eq 1). However, there is a strong bias in such systems



resulting from the presence of the oxygen substituent for a nucleophile to attack distal to that substituent (i.e., at  $\text{C}_b$  in **2**).<sup>2</sup> The net result is a clean 1,4-addition even in allyl systems of equal substitution or ones in which substitution might be thought to favor proximal attack (corresponding to  $\text{C}_a$  in **2**) even with carboxylic acids as the reacting partners. Considering oxygen nucleophiles, we are confronted with an additional problem, the product is also an excellent substrate for metal-catalyzed reactions.<sup>3</sup> In this paper we wish to report a practical solution to both of these problems involving carbon dioxide as a carboxylating agent in metal-catalyzed reactions.<sup>4,5</sup> The current great emphasis on diastereose-

**Table I.** Carbonate Synthesis from Vinyl Epoxides<sup>a</sup>

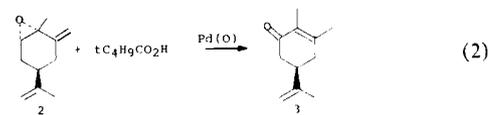
entry	vinyl epoxide	carbonate <sup>b</sup>	yield <sup>c</sup>
1			84%
2			85%
3			92%
4			95%
5			57%
6			82%
7			71%

<sup>a</sup> All reactions were performed according to the general procedure.

<sup>b</sup> All new compounds have been fully characterized spectrally and elemental composition established by high-resolution mass spectroscopy or combustion analysis. <sup>c</sup> Yields are for isolated pure products.

lective methods to form polyol systems makes such a development highly timely.

The notion to resolve the regioselectivity problem revolves around the question of anchoring a pro-nucleophile to the oxygen of **2** such that the nucleophile would be delivered in an intramolecular fashion to favor proximal attack. Such a capture of the oxygen must be faster than the known hydrogen migrations



in Pd-mediated reactions.<sup>6</sup> For example, in the case of **2**, using pivalic acid as a pro-nucleophile led only to rearrangement product **3** and no trapping.<sup>7</sup> We envisioned the possibility that a cumulative unsaturated species (carbon dioxide, carbon disulfide, isocyanate, etc.) might be a sufficiently reactive electrophile to capture the alkoxide in **2** and the resulting carboxylate or related

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(7) Carboxylic acids frequently act as nucleophiles in efficient and stereocontrolled 1,4-opening of vinyl epoxides in the presence of Pd(0) catalysts. Balkovec, J. M.; Angle, S. R., unpublished work in these laboratories.