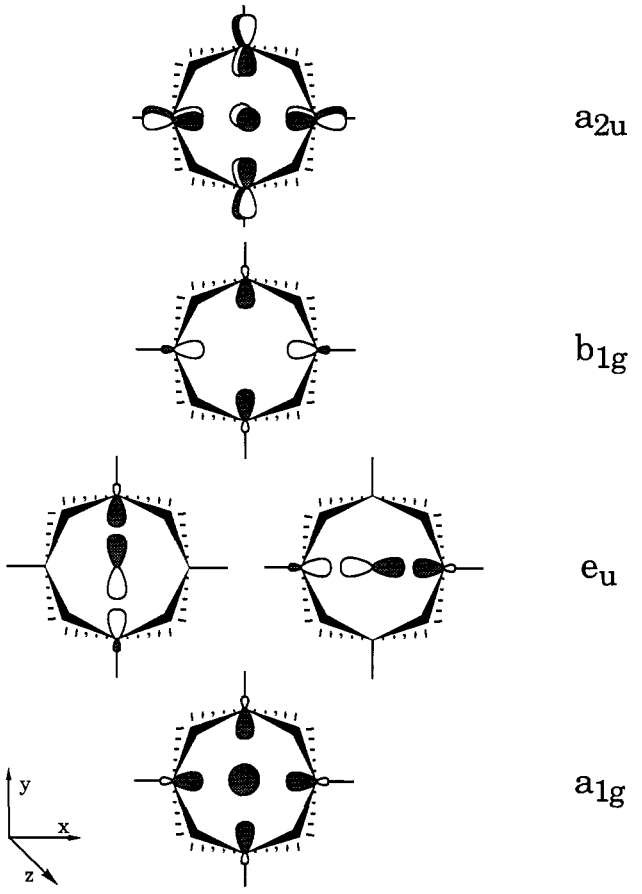

Figure 2. Depiction of the five orbitals referred to in the text. This figure and the text discussion employ D_{4h} notation for convenience in axis labeling and to emphasize that the O p_x and p_y orbitals are playing essentially equivalent roles. The calculations were actually performed on the D_{2h} model complex (see text), but the lowering of symmetry is minimal and the orbitals are almost of D_{4h} symmetry.

which is assigned to the thermal population of low-lying empty orbitals. There also seems no apparent reason why other ions with appropriate orbitals could not be embedded in the V_4 cage provided that enough space is available.[21]

Finally, what of our original thought that a lower edt^{2-}:V ratio might yield a metal-metal bonded mixed Cl^-/edt^{2-} dinuclear species. Inspection of Figure 1 makes it tempting to speculate that such a species may indeed have formed as an intermediate (viz. $[V_2(\mu\text{-edt})(\mu\text{-Cl})_2Cl_4]^{2-}$ or similar) that then "dimerized" to **2** with incorporation of adventitious O. To evaluate this possibility, the V:edt^{2-} = 2:1 and 1:1 reactions are currently under further investigation.

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Supplementary Material Available: Tables of fractional coordinates and isotropic and anisotropic thermal parameters (3 pages). Ordering information is given on any current masthead page.

(20) An Evans method determination in CD_3CN gave a value of ca. 2.0 μ_B/V.

(21) Note that an example of a square-planar OH^- has recently been reported: McKee, V.; Tandon, S. S. *J. Chem. Soc., Chem. Commun.* **1988**, 385.

UV Endonuclease V from Bacteriophage T_4 Catalyzes DNA Strand Cleavage at Aldehydic Abasic Sites by a Syn β-Elimination Reaction

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We recently reported unequivocal evidence that UV endonuclease V from bacteriophage T_4 (UV endo V) cleaves the phosphodiester bond on the 3'-side of an aldehydic abasic site in a DNA heteroduplex via a novel β-elimination mechanism.[1,2] We now report determination of the stereochemical course of the elimination reaction. Stereospecifically tritiated abasic sites in polymers prepared from samples of poly(dA-dU) were used to probe the stereospecificity of hydrogen abstraction; UV endo V abstracts the *pro-S* 2-hydrogen. ^1H NMR spectroscopy of the product obtained from unlabeled polymer revealed that the α,β-unsaturated aldehyde has the trans geometry. Thus, the stereochemistry of the β-elimination reaction is syn, and this indicates that the reaction proceeds from an acyclic species derived from the mixture of cyclic hemiacetals which predominates in solution.[3]

The choice of substrate for these studies was based on the availability of samples of dUTP stereospecifically labeled with ^3H in either the *pro-S* or *pro-R* 2'-hydrogen.[4] In the presence of a template, the Klenow fragment of DNA polymerase from *Escherichia coli* synthesizes poly(dA-dU) from dATP and dUTP.[5] Three samples of poly(dA-dU) were prepared: no label in dU, ^3H in the *pro-S* 2'-hydrogen of dU, and ^3H in the *pro-R* 2'-hydrogen of dU. The uracil present in these polymers was quantitatively removed by the action of uracil-DNA glycosylase from *E. coli*.[6] These "damaged" and presumably single-stranded polymers are substrates for UV endo V and can be completely degraded to a single product.

The polymer containing ^3H in the *pro-R* 2-hydrogen of the abasic site (specific radioactivity, 44 000 cpm/μmol) was converted by UV endo V[7] into a tritiated nucleotide ester product (specific

(1) Manoharan, M.; Mazumder, A.; Ransom, S. C.; Gerlt, J. A.; Bolton, P. H. *J. Am. Chem. Soc.* **1988**, *110*, 2690-2691.

(2) Two other laboratories have concluded that UV endo V, the UV endonuclease from *Micrococcus luteus*, and endonuclease III from *Escherichia coli* (Bailly, V.; Verly, W. G. *Biochem. J.* **1987**, *242*, 565-572. Kim, J.; Linn, S. *Nucleic Acids Res.* **1988**, *16*, 1135-1141. Bailly, V.; Sente, B.; Verly, W. G. *Biochem. J.* **1989**, *259*, 751-759) catalyze β-elimination reactions. These conclusions were based upon the chromatographic properties of the sugar-phosphate product as well as the labilization of ^3H from abasic sites labeled in the both the 1-position (40%) and the *pro-R* 2-position (60%). The structure of the sugar-phosphate product was not actually determined. The stereospecificity of ^3H abstraction by UV endo V that was implicitly determined by Bailly et al. is inconsistent with the results we are now reporting.

(3) Wilde, J. A.; Bolton, P. H.; Mazumder, A.; Manoharan, M.; Gerlt, J. A. *J. Am. Chem. Soc.* **1989**, *111*, 1894-1896.

(4) The synthesis of [2'(*R*)-^3H]dUTP was accomplished by the reduction of UTP in ^3H_2O catalyzed by ribonucleoside triphosphate reductase from *Lactobacillus leichmannii*. The synthesis of [2'(*S*)-^3H]dUTP is described in the supplementary material.

(5) Setlow, P.; Brutlag, D.; Kornberg, A. *J. Biol. Chem.* **1972**, *247*, 224-231.

(6) The conditions for the uracil-DNA glycosylase reaction and the analytical methods used to follow the progress of the reaction are available in the supplementary material.

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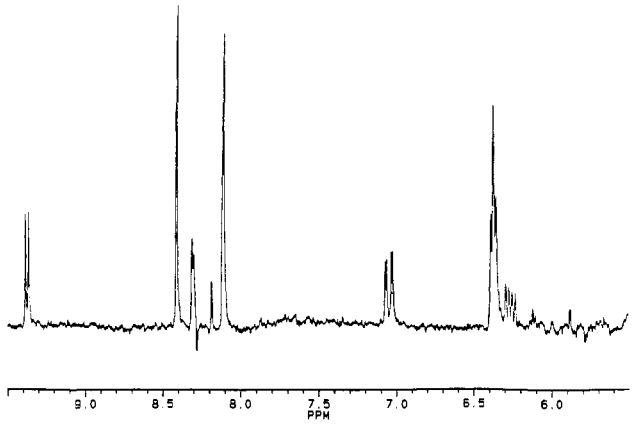
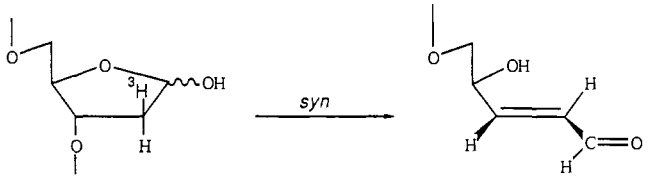


Figure 1. ^{1}H NMR spectrum (400 MHz) of the product of the UV endo V catalyzed degradation of polymer containing alternating deoxyadenosine and abasic site residues. The assignments of the α,β-unsaturated aldehyde are made in the text; the resonances at 8.41, 8.11, and 6.37 ppm are associated with the H_8, H_2, and $H_{1'}$ protons, respectively, of the deoxyadenosine portion of the product.

Scheme I



radioactivity, 44 800 cpm/μmol at 91% reaction). No ^{3}H was found in the solvent after bulb-to-bulb lyophilization. The polymer containing ^{3}H in the *pro-S* 2-hydrogen of the abasic site (specific radioactivity, 239 000 cpm/μmol) was converted by UV endo V into a nucleotide ester product which contained no radioactivity. However, at 22% reaction, the specific radioactivity of the unreacted abasic site was 266 000 cpm/μmol, and at 61% reaction, the specific radioactivity of the unreacted abasic site was 329 000 cpm/μmol. These increases in specific radioactivity correspond to tritium selection effects of 8 and 10, respectively.[8] UV endo V catalyzes the stereospecific abstraction of the *pro-S* 2-hydrogen of the abasic site to affect the β-elimination reaction (Scheme I). The significant isotope effect demonstrates that proton abstraction is rate determining.

Unlabeled poly(dA-dU) was treated with uracil-DNA glycosylase, and following removal of the uracil by gel filtration, this damaged polymer was fully degraded by UV endo V.[9] The 400-MHz ^{1}H NMR spectrum of the product is reproduced in Figure 1. The aldehydic H_1 of the enzymatic product (9.37 ppm) is coupled to the vinylic H_2 (6.24 ppm, $J_{1,2}$ = 8 Hz). H_2 is coupled to the vinylic H_3 (7.04 ppm, $J_{2,3}$ = 16 Hz), which is also coupled to H_4 ($J_{3,4}$ = 4 Hz). Since the chemical shifts and coupling constants for H_1, H_2, and H_3 of the enzymatic product are essentially identical with those of the analogous protons of (4*R*)-4,5-dihydroxy-*trans*-2-pentenal,[10] the trans geometry can be assigned to the enzymatic product. In support of this assignment, photoisomerization of both the enzymatic product and (4*R*)-4,5-dihydroxy-*trans*-2-pentenal yields anomeric mixtures of cyclic unsaturated hemiacetals.[11] On the basis of these properties, the UV endo V product is the 3'-ester of deoxyadenosine 3',5'-bisphosphate with the 5-hydroxyl group of (4*R*)-4,5-dihydroxy-*trans*-2-pentenal. The abstraction of the *pro-S* 2-hydrogen and the geometry of the product define the stereochemical course of the elimination reaction as syn (Scheme I). The identical stereochemical course is also followed with a double-stranded substrate [generated from poly(dA-dT,dU), where the dT:dU ratio is 8:1] (data not shown). Although all of the analogous enzyme catalyzed elimination reactions β to the carbonyls of ketones and thiolesters proceed with the same stereochemical course,[12] the relatively low pK_a of the phosphate monoester leaving group presumably would not require protonation by the conjugate acid of the base abstracting the 2-hydrogen.[13]

This stereochemical course requires that the β-elimination reaction proceed from an open-chain form of the abasic site whose predominant form in solution is a mixture of cyclic hemiacetals. Whether the acyclic substrate is the aldehyde itself or an activated derivative such as an imine remains to be elucidated.

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Supplementary Material Available: Synthesis of [2'-^{3}H]UTP used to prepare [2'(*S*)-^{3}H]dUTP, reaction conditions for various enzymatic reactions, ^{1}H NMR spectra comparing the UV endo V product with (4*R*)-4,5-dihydroxy-*trans*-2-pentenal, ^{1}H NMR spectra comparing the photoisomerized UV endo V product with photoisomerized (4*R*)-4,5-dihydroxy-*trans*-2-pentenal, and the ^{13}C NMR spectrum of photoisomerized (4*R*)-4,5-dihydroxy-*trans*-2-pentenal (10 pages). Ordering information is given on any current masthead page.

(7) The conditions for this UV endo V reaction are available in the supplementary material.
(8) Melander, M. *Isotope Effects on Reaction Rates*; Ronald Press: New York, 1960.
(9) The conditions for this UV endo V reaction are available in the supplementary material.
(10) Esterbauer, H.; Sanders, E. B.; Schubert, J. *Carbohydr. Res.* **1975**, *44*, 126-132.
(11) The photoisomerization was conducted in 5-mm NMR tubes by using flint-filtered light. The ^{1}H NMR spectra of the photoisomerized enzymatic product and unsaturated 2-deoxyribose are virtually identical. The ^{13}C NMR spectrum of the isomerized unsaturated 2-deoxyribose reveals the presence of two hemiacetal carbons as well as two resonances for each of the remaining carbon atoms. These spectra are available in the supplementary material.
(12) (a) Schwab, J. M.; Klassen, J. B.; Habib, A. *J. Chem. Soc., Chem. Commun.* **1986**, 357. (b) Widlanski, T.; Bender, S. L.; Knowles, J. R. *J. Am. Chem. Soc.* **1987**, *109*, 1873-1875.
(13) Alternatively, the 3'-phosphodiester could act as the general base which catalyzes its own elimination: Widlanski, T.; Bender, S. L.; Knowles, J. R. *J. Am. Chem. Soc.* **1989**, *111*, 2299-2300.

Iron-Hydroperoxide-Induced Phenylselenization of Hydrocarbons (Fenton Chemistry)

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The Gif systems (iron catalyst, reduced dioxygen, py/HOAc) for the selective transformation of methylenic carbons to ketones,[1-3] when done in the presence of 1,2-diphenylselenide (PhSeSePh), yields PhSe derivatives of the hydrocarbon substrates at the expense of the ketonization process. A recent study[4] has characterized the use of iron(II) bis(picolinate) [Fe(PA)$_2$] as a catalyst to activate HOOH for the efficient, selective ketonization of methylenic carbons. Because the latter system closely parallels the substrate transformations of the Gif system,[2,3] we became curious as to the effect of PhSeSePh. Here we wish to report that the combination of Fe(PA)$_2$, HOOH, PhSeSePh, and a hydrocarbon substrate (e.g., c-C_6H_{12}) [2:2:1:100 mole ratio] in py/HOAc reacts stoichiometrically to give 2 equiv of the PhSe derivatives of the substrate [e.g., 2(c-C_6H_{11})-SePh].

(1) Barton, D. H. R.; Boivin, J.; LeCoupanec, P. *J. Chem. Soc., Chem. Commun.* **1987**, 1379.
(2) Barton, D. H. R.; Gastiger, M. J.; Motherwell, W. B. *J. Chem. Soc., Chem. Commun.* **1983**, 41.
(3) Barton, D. H. R.; Boivin, J.; Motherwell, W. B.; Ozbalik, N.; Schwarzentruber, K. M.; Jankowski, K. *Nouv. J. Chim.* **1986**, *10*, 387.
(4) Sheu, C.; Richert, S. A.; Cofrē, P.; Ross, B., Jr.; Sobkowiak, A.; Sawyer, D. T., submitted to *J. Am. Chem. Soc.*, **1989**.

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