acetate, 87762-10-5; 8, 87762-11-6; *N*-(3-hydroxypropyl)-4-[(4-methoxybenzoyl)-2,3-dichlorophenoxy]acetamide, 87762-12-7; *N*-(4-hydroxybutyl)-4-[(4-methoxybenzoyl)-2,3-dichlorophenoxy]acetamide, 87762-13-8; *N*-(5-hydroxylpentyl)-4-[(4-methoxybenzoyl)-2,3-dichlorophenoxy]acetamide, 87762-14-9; *N*-(2-hydroxyethyl)-2-(4-nitrophenoxy)acetamide, 52547-52-1; 2-(2,3-dichlorophenoxy)-*N*-(2-hydroxyethyl)acetamide, 87762-15-0; 2-(4-chlorophenoxy)-*N*-(2-hydroxyethyl)acetamide, 7462-17-1; 2-(2-bromophenoxy)-*N*-(2-hydroxyethyl)acetamide, 87762-16-1; *N*-(2-hydroxyethyl)-2-phenoxyacetamide, 6326-87-0; *N*-(2-hydroxyethyl)-2-(4-methylphenoxy)acetamide, 66889-71-2; *N*-(2-hydroxyethyl)-2-(4-methoxyphenoxy)acetamide, 51816-48-9; 3-[[4-(4-methoxybenzoyl)-2,3-dichlorophenyl]amino]propanol, 87762-17-2; 4-[[4-(methoxybenzoyl)-2,3-dichlorophenyl]amino]butanol, 87762-18-3; 2-[(4-nitrophenyl)amino]ethanol, 1965-54-4; 2-[(2,3-dichlorophenyl)amino]ethanol, 87762-19-4; 2-[(4-chlorophenyl)amino]ethanol, 2933-81-5; 2-[(2-bromophenyl)amino]ethanol, 87762-20-7; 2-(phenylamino)ethanol, 122-98-5; 2-[(4-methylphenyl)amino]ethanol, 2933-74-6; 2-[(4-methoxyphenyl)amino]ethanol, 2933-77-9; (4-nitrophenoxy)acetic acid, 1798-11-4; (2,3-dichlorophenoxy)acetic acid, 2976-74-1; (4-chlorophenoxy)acetic acid, 122-88-3; (2-bromophenoxy)acetic acid, 1879-56-7; phenoxyacetic acid, 122-59-8; (4-methylphenoxy)acetic acid, 940-64-7; (4-methoxyphenoxy)acetic acid, 1877-75-4; ethanolamine, 141-43-5; *n*-butylamine, 109-73-9; sodium hydride, 7646-69-7; toluene, 108-88-3; dichloromethane, 75-09-2; tetrahydrofuran, 109-99-9; dimethylformamide, 68-12-2; 18-crown-6, 17455-13-9; potassium hydride, 7693-26-7.

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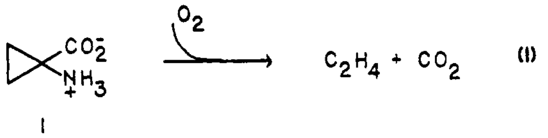
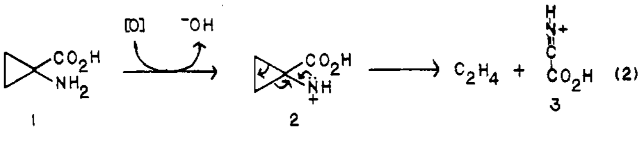
Ethylene Biosynthesis. 1. A Model for Two Reactive Intermediates

Summary: Two reactive intermediates, 1-carboxycyclopropylnitrene and 1-carboxycyclopropylnitrenium, have been demonstrated as competent intermediates for the biosynthetic conversion of 1-aminocyclopropanecarboxylic acid to ethylene.

Sir: The 1979 report of Adams and Yang[1] that 1-aminocyclopropanecarboxylic acid (ACC, 1) is the immediate biosynthetic precursor to the plant hormone ethylene solved a long-standing problem in plant physiology[2] (eq 1). It has generated many new questions about the chemistry involved, however, few of which have thus far been answered. Research in this area is hampered by the fact that the enzyme responsible for ethylene biosynthesis (EFE, ethylene-forming enzyme) is associated with the cell membrane and does not survive breakage of the cell wall.[3] It is well established through in vivo studies that the EFE requires oxygen and is inhibited by free-radical scavengers,[1,3] metal chelators,[4] reducing agents,[3] and white light.[5]

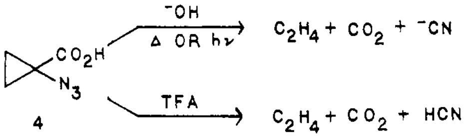


Several proposals have been made for the chemistry behind ethylene biosynthesis. Yang[1] proposed the nucleophilic opening of the cyclopropane ring at the fully substituted carbon by hydrogen peroxide. Lurssen[6] postulated the NADH-mediated reduction of a CoA-ester-ACC-pyridoxal Schiff base followed by a fragmentation; this hypothesis remains unsupported by evidence for any of these cofactors in the EFE. Baldwin[7] proposed covalent bonding between ACC and the EFE, oxidative decarboxylation to a cyclopropanone imine, and extrusion of ethylene. This yields an isonitrile, which is hydrolyzed to formate. Finally, Yang made another proposal[8] involving oxidation of ACC by hydrogen peroxide to yield a nitrenium ion (2). He then proposed fragmentation of this ion to ethylene and cyanoformate conjugate acid 3 (eq 2).



In order to evaluate the merits of the last mechanistic proposal, we have examined the nitrenium ion proposed by Yang as well as nitrene intermediates for ethylene biosynthesis. The latter were investigated because we were uncertain of the state of protonation of 2 at pH 6, the pH maximum for ethylene biosynthesis.

The decomposition of 1-azidocyclopropanecarboxylic acid[9] (4, AzCC) was conducted thermally, photochemically, and under acid catalysis. The thermal (125 °C, aqueous KOH) and photochemical (9:1 $EtOH/H_2O$, 450-W Hanovia lamp, Vycor filter, sensitized and unsensitized) reactions in a 10-mM basic solution, representing the nitrene intermediate, yield ethylene, carbon dioxide, and cyanide ion. The chemical yield of each component under a given set of conditions is the same, 25% in the former and 75% in the latter. This was determined by gas chromatography[10]



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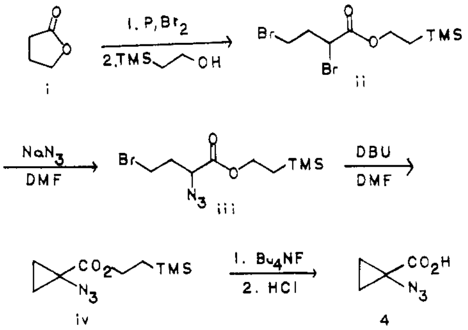
(9) Prepared in 47% overall yield by a modification of the procedure found in: DuBois, G. E.; Crosby, G. A.; McGarraugh, G. V.; Ng, S. Y.-W.; Stephenson, R. A.; Wang, P. C.; Wingard, R. E. *J. Org. Chem.* **1982**, *47*, 1319.



(10) Ethylene and CO_2 were identified and quantified by using an 80% Porapak N/20% Porapak Q 6 ft × 1/8 in. column, operated at 35 °C and using a thermal conductivity detector.

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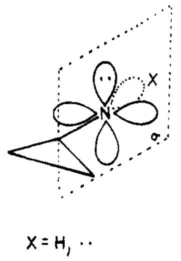

Figure 1.

and by cyanide ion selective electrode.[11] Kinetic analysis of the high-yielding photochemical reaction reveals that cyanide, ethylene, and CO_2 are formed at identical rates. First-order kinetics are observed for the direct photochemical reaction, with a rate constant of 2.2×10^{-4} s^{-1}. In the presence of benzophenone, the yield is decreased with increasing concentration of triplet sensitizer, while the rate remains approximately constant. The identification of ACC in the reaction mixture suggests hydrogen abstraction as the competitive triplet reaction. Triplet quenchers (methyl pentadiene) have little effect.

The decomposition of 4 was also conducted in a 0.1-mM ethanol solution, and kinetics were determined by gas chromatography alone (flame ionization). The same rate is found in both *neutral* and basic solutions, suggesting that the reactive intermediate in the former case is the nitrene and not the alternative zwitterionic nitrenium carboxylate. This suggests that the pK_a of the nitrenium ion is less than ca. 5, the pK_a of cyclopropane carboxylic acid.

The acid-catalyzed decomposition of 4 was conducted under both singlet (TFA, AcOH) and triplet (TFA, $CHBr_3$) conditions. The yields are 16% and 15%, respectively, as determined by gas chromatography of the headspace and by trapping in basic solution of the hydrogen cyanide so produced. The rates are considerably faster than in the photochemical reaction ($\sim 1.5 \times 10^{-2}$ s^{-1}). It did not prove possible to identify any nonvolatile products of these nitrenium ion reactions.

The evidence presented above has demonstrated the competence of both singlet nitrene and nitrenium intermediates in ethylene biosynthesis. The facile conversion of these intermediates to ethylene and CO_2 is best explained by a concerted, chelatropic reaction to yield ethylene and cyanoformate, followed by rapid decarboxylation to give cyanide. Support for this proposals comes from the photochemical decomposition of ester iv, which yields 2-(trimethylsilyl)ethyl cyanoformate. Interestingly, an MO correlation diagram demonstrates that an orbital symmetry-allowed chelatropic reaction is possible both for singlet nitrene and nitrenium intermediates, but only when the empty nitrogen p orbital is in the "bisected" conformation (Figure 1). This situation contrasts sharply with that for the Baldwin mechanism; a retro [2 + 2] reaction to give alkene and isonitrile is symmetry disallowed.

A key aspect of nitrene and nitrenium ion proposals for ethylene biosynthesis is how the much-touted metal ion,[12] possibly manganese,[13] is involved. N-Hydroxylation through metal-oxene or -peroxide complexes appears an attractive access to the nitrenium ion, while direct M=N bond formation followed by homolysis might yield the nitrene. The former has precedent in ferrous hemes such as cytochrome P-450,[14] while the intermediacy of manganese nitrenes is inferred from a recent report.[15] Further studies as to the competence of these intermediates for ethylene biosynthesis await more detailed information regarding the natural system.

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Registry No. 1, 22059-21-8; 4, 82998-00-3; ii, 87831-15-0; iii, 87831-16-1; iv, 87831-17-2; ethylene, 74-85-1.

Supplementary Material Available: Experimental details of compounds ii–iv and 4 (4 pages). Ordering information is given on any current masthead page.

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[11] Cyanide ion was quantified by using an Orion Research cyanide ion selective electrode calibrated at cyanide concentrations from 10^{-5} to 10^{-3} M.

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Highly Selective Synthesis of α-Alkylidenetetrahydrofurans and γ-Alkylidenebutyrolactones via Intramolecular Opening of Epoxysilanes[1]

Summary: Treatment of α-(3-hydroxypropyl)-α-(trimethylsilyl) epoxides with KH in THF cleanly provides α-alkylidenetetrahydrofurans in high yields with ≥95% retention of stereochemistry, while epoxidation of γ-(trimethylsilyl)-γ,δ-unsaturated carboxylic acids with MCPBA produces γ-(1-hydroxyalkyl)-γ-(trimethylsilyl)butyrolactones that can be converted into γ-alkylidenebutyrolactones in high yields via acetylation–fluoride treatment with ≥99% inversion of stereochemistry.

Sir: Stereodefined exocyclic alkenes of the types **1** and **2** (Chart I) represent a wide variety of natural products such as prostacyclin[2] (**3**) and freelingyne[3] (**4**). Their high sensitivity toward acids makes it desirable to synthesize them in a highly selective manner, preferably without having to perform isomeric separation. Although haloetherification has been successfully applied to the synthesis of prostacyclin and its *E* isomer,[2b-d] chromatographic separation of diastereomeric halo ether intermediates appears to be necessary. Stereoselective cyclic addition reactions of an acetylenic alcohol[4] or carboxylic acid[5] can produce in a stereoselective manner one stereoisomer but not the other.

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