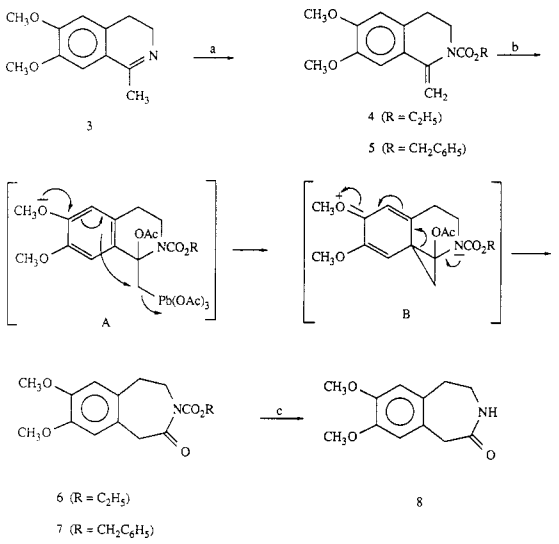
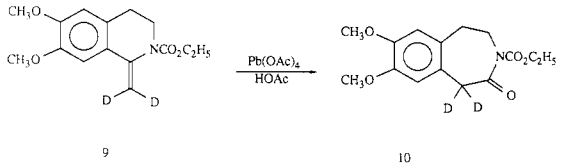
Scheme II[a]



[a] Reagents: (a) diethyl pyrocarbonate (for **4**); ref 7 for **5**; (b) lead tetraacetate/acetic acid; (c) Pd/H_2 (for **7**).

Scheme III



intermediate B that can then ring open to the observed benzazepinone. This mechanism predicts migration of the aromatic ring from C-1 of the isoquinoline ring to the exocyclic methylene group in **4**, which after LTA oxidation becomes the methylene group in **6**. This was proved by deuterium labeling (Scheme III). Oxidation of the enamide **9**, deuteriated on the exocyclic methylene group, yielded the benzazepine **10**, where the deuterium is now found on the methylene group between the aromatic ring and azepinone carbonyl group.[17] Equivalent results were also obtained when the exocyclic methylene group in **4** was ^{13}C-labeled. The olefinic methylene signal in **4** (δ 102.2) shifted to δ 45.1, the signal for the methylene group in **6**. This type of rearrangement has precedence in the LTA oxidative rearrangement of certain styrenes;[8,18] however the LTA oxidation of acetophenone enol ethers does not induce a rearrangement.[19]

A representative selection of the isoquinoline enamides studied is collected in Table I. A variety of electron-releasing substituents in various positions on the aromatic ring can be accommodated; even the unsubstituted enamide **19** forms the corresponding benzazepinone **20** in reasonable yield. The nature of the carbonyl substituent, alkoxycarbonyl, acyl, or aroyl, does not have an effect (cf ref. 11), and the ethylidene enamide **21** forms the corresponding methyl-substituted benzazepinone **22**. In summary, LTA oxidation of 1-methylene- and 1-ethylideneisoquinoline enamides in acetic acid forms benzazepinones rapidly and in high yield by a novel rearrangement, making these compounds easily accessible from readily available precursors.

Acknowledgment. The author would like to thank Prof. Paul Margaretha, Universität Hamburg, for suggesting the ^{13}C experiment, as well as Dr. E. Ezell of BOC for conducting the X-ray analysis of **26**.

Supplementary Material Available: Representative procedures for the oxidative ring expansion of enamides **5** and **25** and the formation of benzazepine **8**, together with spectral data for all compounds and X-ray data for compound **26**, containing positional and thermal parameters (35 pages). Ordering information is given on any current masthead page.

George R. Lenz*,†
Health Care R & D
BOC Group Technical Center
100 Mountain Avenue
Murray Hill, New Jersey 07974, and
Department of Medicinal Chemistry
G.D. Searle & Co.
4901 Searle Parkway
Skokie, Illinois 60077
Received June 16, 1988
† Address correspondence to Health Care R & D.

(17) Prepared by deuterium exchange of the methyl protons in **3** using D_2O. Deuteriated **9** possessed 90% D_2, 9% D_1. Benzazepinone **10** retained 56% D_2, 31% D_1 by MS and NMR spectroscopy.

(18) (a) Criegee, R.; Dimroth, P.; Noll, K.; Simon, R.; Weis, C. *Chem. Ber.* **1957**, *90*, 1070–81. (b) Yukowa, Y.; Hayashi, N. *Bull. Chem. Soc. Jpn.* **1986**, *39*, 2255–6. (c) Norman, R. O. C.; Thomas, C. B. *J. Chem. Soc. B* **1967**, 771–9. (d) Norman, R. O. C.; Thomas, C. B. *J. Chem. Soc. B* **1968**, 994–1005.

(19) (a) Rubottom, G. M.; Gruber, J. M.; Kincaid, K. *Synth. Commun.* **1976**, *6*, 59–62. (b) Rubottom, G. M.; Gruber, J. M.; Mong, G. M. *J. Org. Chem.* **1976**, *41*, 1673–4. (c) Moriarty, R. M.; Penmasta, R.; Prakash, I. *Tetrahedron Lett.* **1987**, *28*, 873–6.

(20) Brossi, A.; Dolan, L. A.; Teitel, S. *Org. Synth.* **1977**, *56*, 3–7.

(21) Lenz, G. R. *J. Org. Chem.* **1974**, *39*, 2839–45.

A Divergent de Novo Synthesis of Carbohydrates Based on an Accelerated Inverse Electron Demand Diels–Alder Reaction of 1-Oxa-1,3-butadienes

Summary: A divergent, de novo synthesis of selectively protected carbohydrates based on the accelerated and productive $LUMO_{diene}$-controlled [4 + 2] cycloaddition reaction of β,γ-unsaturated α-keto esters [e.g., methyl *trans*-4-methoxy-2-oxo-3-butenoate (**1**)] with electron-rich dienophiles (e.g., **2a,b**) is detailed.

Sir: The 4π participation of simple α,β-unsaturated aldehydes and ketones, electron-deficient heterodienes bearing a terminal oxygen atom, in $LUMO_{diene}$-controlled Diels–Alder reactions typically suffers from low conversions, competitive polymerization, and harsh reaction conditions.[1-3] A limited number of 1-oxa-1,3-butadiene structural variations and modified reaction conditions have been successfully introduced that have permitted the productive 4π participation of α,β-unsaturated carbonyl compounds in [4 + 2] cycloaddition reactions[3-6] and in-

(1) Desimoni, G.; Tacconi, G. *Chem. Rev.* **1975**, *75*, 651.

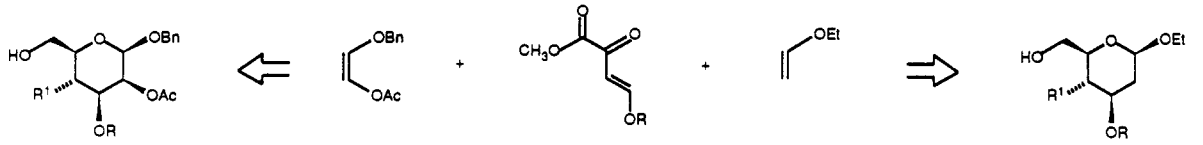
(2) Boger, D. L.; Weinreb, S. M. *Hetero Diels–Alder Methodology in Organic Synthesis*; Academic: New York, 1987.

(3) For recent examples of intramolecular [4 + 2] cycloaddition reactions, see: Snider, B. B.; Duncia, J. V. *J. Org. Chem.* **1980**, *45*, 3461. Snider, B. B.; Roush, D. M.; Killinger, T. A. *J. Am. Chem. Soc.* **1979**, *101*, 6023. Snider, B. B.; Roush, D. M. *J. Org. Chem.* **1979**, *44*, 4229. Cookson, R. C.; Tuddenham, R. M. *J. Chem. Soc., Perkin Trans. 1* **1978**, 678. Martin, S. F.; Benage, B.; Williamson, S. A.; Brown, S. P. *Tetrahedron* **1986**, *42*, 2903. Martin, S. F.; Benage, B. *Tetrahedron Lett.* **1984**, *25*, 4863. Tietze, L. F.; Beifuss, U. *Tetrahedron Lett.* **1986**, *27*, 1767. See also ref 2 and 4.

(4) 1-Oxa-1,3-butadienes bearing a C-3 electron-withdrawing substituent: Tietze, L. F. In *Selectivity-A Goal for Synthetic Efficiency*; Trost, B. M., Bartmann, W., Eds.; Verlag-Chemie: Weinheim, 1984; pp 299–315. See also ref 2.

0022-3263/88/1953-5793$01.50/0

Scheme I



2b **1** **2a**

3c R^1 = H 4-deoxy-mannopyranose
3d R^1 = OH mannopyranose

3a R^1 = H 2,4-deoxy-mannopyranose
3b R^1 = OH 2-deoxy-mannopyranose

Table I. Diels–Alder Reactions of Methyl *trans*-4-Methoxy-2-oxo-3-butenoate (1)

entry	diene	dienophile	reaction conditions: equiv of 2, solvent, temp (°C) (time, h)	product (endo:exo)	% yield[a]
1	1	**2a**[b]	2.5, neat, 13 kbar, 24 (65)	**4** (5.7:1.0)	82
2			2.5, CH_2Cl_2, 6.2 kbar, 24 (108)	**4** (5.7:1.0)	75
3			5.0, toluene, 110 (29)	**4** (1.8:1.0)	48
4			5.0, toluene, 25 (36)	**4** (–:–)	0
5			2.5, CH_2Cl_2, –78 (5 min) $EtAlCl_2$ (0.1 equiv)	**4** (0.8:1.0)	75
6			2.5, CH_2Cl_2, –78 (5 min) $TiCl_4$ (0.1 equiv)	**4** (1.0:3.0)	61
7	1	**2b**[b]	4.2, CH_2Cl_2, 13 kbar, 24 (80)	**7** (>45:1)[c]	49
8			1.5, toluene, 110 (37)	**7** (–:–)	0
9			1.0, CH_2Cl_2, 0 (30 min) $(p\text{-}BrC_6H_4)_3N^{\bullet+}SbCl_5$ (0.2 equiv)	**7** (2:1:1[d]:–)	59
10	1	**2c**[b]	1.5, CH_2Cl_2, 13 kbar, 24 (74)	(–:–)	0
11	1	**2d**[b]	2.5, CH_2Cl_2, 13 kbar, 24 (101)	**10** (6.5:1.0)	69

[a] Isolated yield of purified product isolated by chromatography (SiO_2). Entries 1–3, 5, and 6 taken from ref 7. [b] **2a** = ethyl vinyl ether, **2b** = (*Z*)-1-acetoxy-2-(benzyloxy)ethylene, **2c** = (*Z*)-1-(benzoyloxy)-2-(benzyloxy)ethylene, **2d** = benzyl vinyl ether. [c] The endo cycloadduct **7** was the only diastereomer detected. [d] C-1 epimer of **7** endo.

clude our recent demonstration of the accelerated, productive 4π participation of β,γ-unsaturated α-keto esters in endo-selective $LUMO_{diene}$-controlled Diels–Alder reactions.[7,8] Herein, we detail the extension of these observations to the divergent, de novo synthesis of carbohydrates[9] applicable to ongoing efforts on the total synthesis of bleomycin A_2, Scheme I. Central to the development of this approach was the recognition that the selection of the desired 1-oxa-1,3-butadiene (selection of R) and selection of one of two accessible dienophiles (**2a**, 2-deoxy- and 2,4-dideoxypyranoside; **2b**, pyranoside and 4-deoxypyranoside) as appropriately matched diene–dienophile partners for participation in a $LUMO_{diene}$-controlled [4 + 2] cycloaddition reaction would permit the divergent preparation of carbohydrates bearing a full range of selectively protected oxygen substituents.

The comparative results of a study of the thermal, pressure-promoted, Lewis acid catalyzed, and radical-cation-catalyzed [4 + 2] cycloaddition reactions of methyl *trans*-4-methoxy-2-oxo-3-butenoate (**1**)[10] with ethyl vinyl ether (**2a**)[7] and (*Z*)-1-acetoxy-2-(benzyloxy)ethylene (**2b**)[11] are summarized in Table I.[12]

Heterodiene **1**, as previously detailed,[7] exhibited excellent thermal reactivity with ethyl vinyl ether (80–110 °C), cleanly providing the [4 + 2] cycloadduct.[13] The

(5) For recent examples of Lewis acid catalyzed [4 + 2] cycloaddition reactions, see: Denmark, S. E.; Sternberg, J. A. *J. Am. Chem. Soc.* **1986**, *108*, 8277. Yamamoto, Y.; Suzuki, H.; Mora-Oka, Y. *Chem. Lett.* **1986**, 73. Danishefsky, S.; Bednanski, M. *Tetrahedron Lett.* **1984**, *25*, 721. Hall, S. S.; Weber, G. F.; Dussan, A. J. *J. Org. Chem.* **1978**, *43*, 667.

(6) Pressure-promoted [4 + 2] cycloaddition reactions: Sera, A.; Uchida, T.; Matsumoto, K. *Synthesis* **1985**, 1 and 999.

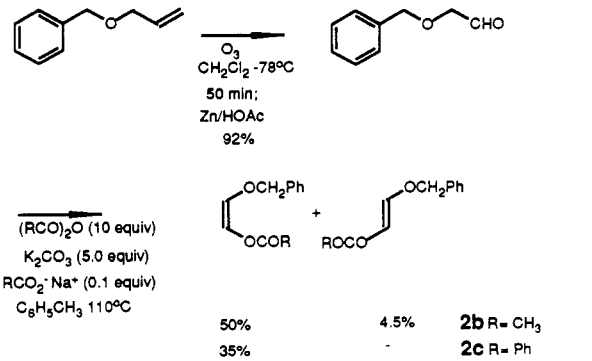
(7) Boger, D. L.; Robarge, K. D. *J. Org. Chem.* **1988**, *53*, 3373.

(8) The enhanced reactivity of β,γ-unsaturated α-keto esters was based on the predictable stabilization of the 1-oxa-1,3-butadiene LUMO achieved through the noncomplementary addition of a C-2 electron-withdrawing substituent. In contrast to the complementary C-3 addition of an electron-withdrawing substituent to the 1-oxa-1,3-butadiene system,[4] the noncomplementary C-2 addition of an electron-withdrawing substituent would not be expected to additionally stabilize a developing zwitterionic or biradical transition state for a [4 + 2] cycloaddition reaction. In a refined comparison with full structure optimization (MOPAC, AM1 Hamiltonian, Version 1.00) including a final, single geometry SCF calculation with CI (CI = 2), the *E* (LUMO) for methyl *trans*-4-methoxy-2-oxo-3-butenoate (**1**) proved substantially lower (0.706 eV) than that of *trans*-3-methoxypropenal.

(9) For reviews of Diels–Alder approaches to carbohydrates employing a heterodiene, see: Schmidt, R. R. *Pure Appl. Chem.* **1987**, *59*, 415. McGarvey, G. J.; Kimura, M.; Oh, T.; Williams, J. M. *J. Carbohydr. Chem.* **1984**, *3*, 125. Danishefsky, S. *Acc. Chem. Res.* **1981**, *14*, 400. Apparao, S.; Maier, M. E.; Schmidt, R. R. *Synthesis* **1987**, *10*, 900. Tietze, L. F.; Voss, E. *Tetrahedron Lett.* **1986**, *27*, 6181. Santelli, M.; Douniazad, E. A.; Jellal, A. *J. Org. Chem.* **1986**, *51*, 1199. El-Abed, D.; Jellal, A.; Santelli, M. *Tetrahedron Lett.* **1984**, *25*, 4503. Ismail, Z. M.; Hoffmann, H. M. R. *Angew. Chem., Int. Ed. Engl.* **1982**, *21*, 859.

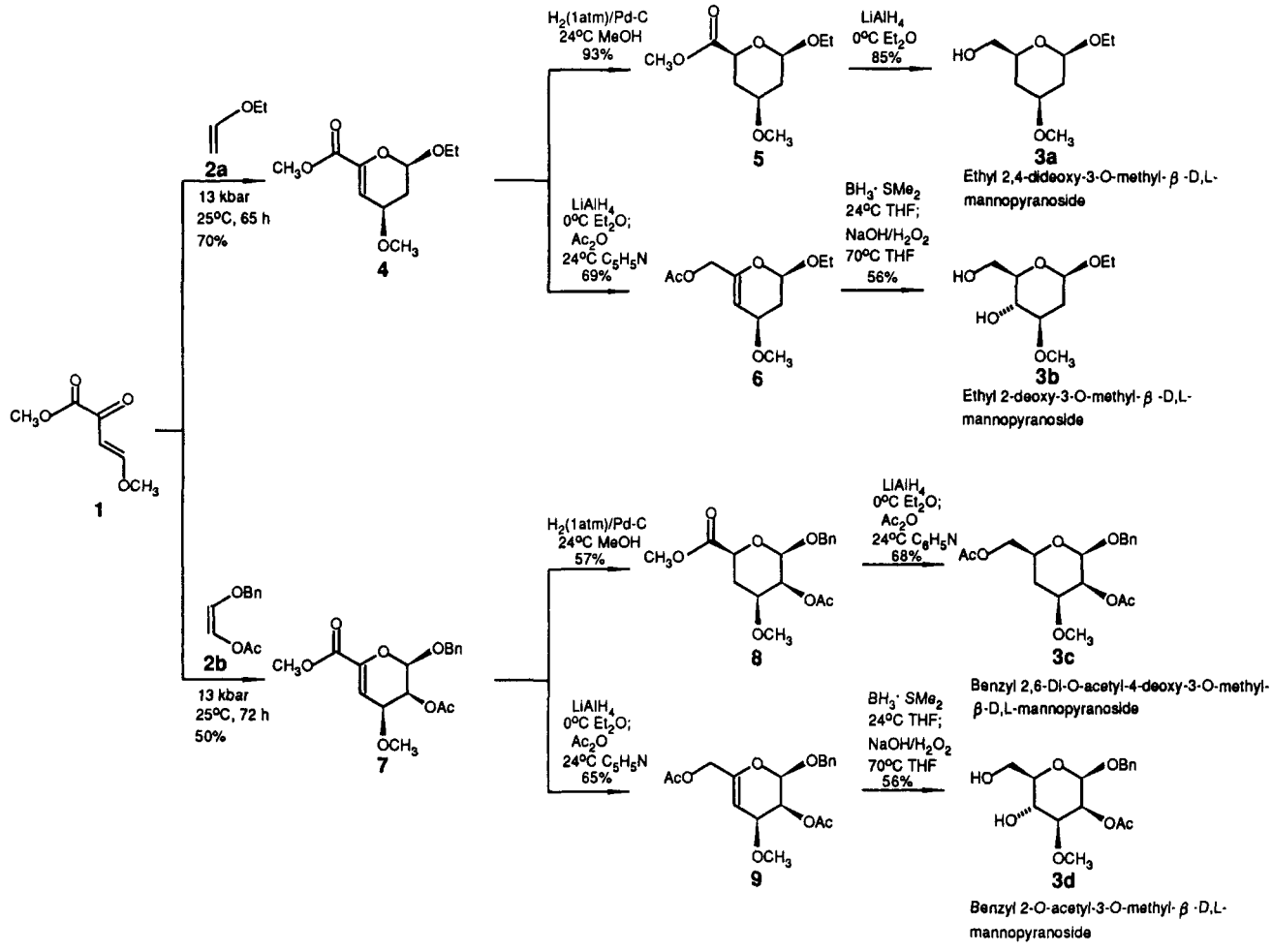
(10) Trowitzsch, W. *Z. Naturforsch., B: Anorg. Chem., Org. Chem.* **1977**, *32(B)*(9), 1068.

(11) (a) Oele, P. C.; Louw, R.; Tinkelenberg, A. *Tetrahedron Lett.* **1972**, 5159. (b) Allyl benzyl ether, see: Watanabe, W. H.; Conlon, L. E.; Hwa, J. C. H. *J. Org. Chem.* **1958**, *23*, 1666. (c) Ozonolysis conditions, see: Muller, N.; Hoffman, W. *Synthesis* **1975**, 781. (d) 2-(Benzyloxy)-acetaldehyde, see: Rigby, W. *J. Chem. Soc.* **1950**, 1907. Danishefsky, S. J.; DeNinno, M. P. *J. Org. Chem.* **1986**, *51*, 2617. Garner, P.; Park, J. M. *Synth. Commun.* **1987**, *17*, 189.



(12) All products exhibited the expected or previously reported ^1H NMR, IR, and MS characteristics consistent with the assigned structure. All new compounds provided satisfactory HRMS exact mass information or satisfactory C,H elemental analysis.

Scheme II



thermal, pressure-promoted, and Lewis acid catalyzed [4 + 2] cycloaddition reaction of **1** and **2a** as well as the pressure-promoted reaction of **1** and **2b** proved to proceed predominantly through an endo transition state, and the endo selectivity was found to increase as the temperature of the reaction was decreased and the pressure increased (25 °C, 6–13 kbar > 110 °C, 1 atm).[14] In comparison with the reaction of **1** with ethyl vinyl ether or benzyl vinyl ethyl, the pressure-promoted [4 + 2] cycloaddition of **1** and **2b** provided a single cycloadduct **7**[15] (>45:1) which proved to be derived from the predictably regiospecific participation of **2b** in an endo-specific [4 + 2] cycloaddition reaction.

Attempts to promote the thermal [4 + 2] cycloaddition of **1** with (*Z*)-1-acetoxy-2-(benzyloxy)ethylene (**2b**) failed to provide **7**, and although the presence of the α-dicarbonyl in **1** had been shown to facilitate the implementation of a Lewis acid catalyzed [4 + 2] cycloaddition of the diene with **2a**,[16,17] dienophile **2b** required stoichiometric ethylaluminum chloride to effect [4 + 2] cycloaddition and resulted in the formation of a complex mixture of products from which the desired endo cycloadduct **7** was isolated in low yield. In addition, the comparative pressure-promoted (13 kbar, 25 °C, CH_2Cl_2) [4 + 2] cycloaddition of **1** with (*Z*)-1-(benzoyloxy)-2-(benzyloxy)ethylene (**2c**)[11] failed to provide the desired cycloadduct and afforded diene dimer[7,15] as the major reaction product. Presumably, the rate deceleration of the endo [4 + 2] cycloaddition (**1** + **2c**/**1** + **2b** versus **1** + **2a**) due to the destabilizing diene–dienophile (COPh > $COCH_3$ ≫ H) steric interaction coupled with the further electronic deactivation of the dienophile (reactivity: H > $COCH_3$ > COPh) permits diene dimerization to effectively compete with the desired [4 + 2] cycloaddition of **1** with **2c**. Thus, the substantial increased diastereoselectivity observed in the pressure-promoted [4 + 2] cycloaddition reaction of **2b** versus ethyl or benzyl vinyl ether (**2a** and **2d**, Table I) is observed in the presence of the additional destabilizing steric inter-

(13) In comparison, the reaction of 3-methoxypropenal and methyl vinyl ether proceeds at 240 °C to afford the diastereomeric cis and trans [4 + 2] cycloadducts in an unstated ratio in 60% yield: Eskenazi, C.; Maitte, P. *C. R. Seances Acad. Sci., Ser. C* **1974**, *279*, 233. See also: Berti, G.; Catelani, G.; Colanna, F.; Monti, L. *Tetrahedron* **1982**, *38*, 3067.

(14) Tietze, L. F.; Hubsch, T.; Voss, E.; Buback, M.; Tost, W. *J. Am. Chem. Soc.* **1988**, *110*, 4065. This report of the carefully demonstrated and significant pressure-induced diastereoselectivity observed in a related inverse electron demand Diels–Alder reaction ($\Delta\Delta V^*$ endo:exo = 5.8 ± 0.5 cm^3 mol^{-1}) suggests that the added dienophile cis substituent in **2b** may further increase the difference in the activation volume between the reaction paths leading to the endo and exo diastereomers, respectively, thus accounting for the observed exclusive formation of **7**.

(15) The decreased reactivity of dienophile **2b** resulted in the observation of a competitive dimerization ([4 + 2] cycloaddition) of **1**. This competitive dimerization reaction could be suppressed by increasing the relative concentration of dienophile and thereby increasing the rate of the productive [4 + 2] cycloaddition of **1** and **2b**. The use of 4 equiv of **2b** proved optimal for the formation of the desired [4 + 2] cycloadduct **7**.

(16) The ethylaluminum dichloride catalyzed [4 + 2] cycloaddition of **1** with **2a** proved to be the most effective and manageable reaction and has been found to proceed at temperatures as low as −100 °C (0.1 equiv, 1 min).

(17) Under the conditions of Lewis acid catalysis, the predominant kinetic endo cycloadduct **4** suffers subsequent C-2 epimerization to provide the more stable isomer, ref **7** and the following: (a) John, R. A.; Schmidt, V.; Wyler, H. *Helv. Chim. Acta* **1987**, *70*, 600. (b) Tietze, L. F.; Voss, E.; Harms, K.; Sheldrick, G. M. *Tetrahedron Lett.* **1985**, *26*, 5273.

actions that must accompany the endo cycloaddition. This substantial increase in the observed pressure-induced diastereoselectivity must then be attributed to the additional difference in the volume of activation between the reaction paths leading to the endo and exo diastereomers due to the additional dienophile C-2 cis substituent.

The cycloadducts **4** and **7** were converted into the complementary series of carbohydrates through implementation of one of two established[18,19] two-step reaction sequences. Catalytic hydrogenation of **4** and **7** followed by lithium aluminum hydride reduction provided 2,4-dideoxymannopyranoside **3a** and 4-deoxymannopyranoside **3c**, respectively, as the exclusive reaction products, Scheme II. Hydrogen delivery in the catalytic hydrogenation of **4** and **7** occurs from the α-face, anti to the proximal C-4 methoxy substituent and distal C-2/C-3 substituents, and provides **5** and **8** in which the C-6 methoxycarbonyl groups occupy a stable equatorial position. Alternatively, lithium aluminum hydride reaction of **4** and **7** and acetylation of the resulting alcohols followed by stereoselective hydroboration–oxidation provided 4-deoxymannopyranoside **3b** and mannopyranoside **3d**,[20] respectively. The predictably regiospecific hydroboration proceeds from the α-face, anti to the proximal C-4 methoxy substituent, in agreement with prior observations.[13,26,27]

The readily accessible dienophile **2b**,[12] which has proven convenient to secure on a preparative scale, and its demonstrated capabilities for productive participation in regiospecific, endo-selective inverse electron demand Diels–Alder reactions should prove to be of general synthetic utility in the diastereoselective preparation of selectively protected cyclic *cis*-1,2-diols. The pressure-promoted [4 + 2] cycloaddition reactions of β,γ-unsaturated α-keto ester **1** with dienophiles **2a** and **2b** provided productive, regiospecific endo-selective $LUMO_{diene}$-controlled [4 + 2] cycloadditions suitable for the divergent, de novo synthesis of fully functionalized and selectively protected carbohydrates. The continued exploration of the [4 + 2] cycloaddition reactions of β,γ-unsaturated α-keto esters and their applications are in progress and will be reported in due course.

Acknowledgment. We gratefully acknowledge the financial support of the National Institutes of Health (CA 42056, 41986) and the Alfred P. Sloan Foundation.

Supplementary Material Available: Experimental procedures and full spectral and physical characterization of **2b**, **3a–d**, and **4–9** (15 pages). Ordering information is given on any current masthead page.

Dale L. Boger,*[28] Kirk D. Robarge
Department of Chemistry
Purdue University
West Lafayette, Indiana 47907
Received June 30, 1988

Diels–Alder Reactions of α-Oxy-*o*-xylylenes†

Summary: Treatment of benzocyclobutenols or their acetates with *n*-butyllithium at 0 °C or less can generate the corresponding α-oxy-*o*-xylylenes, which can then undergo Diels–Alder reactions.

Sir: The formation of the reactive but elusive *o*-xylylenes (5,6-bis(methylene)-1,3-cyclohexadienes) followed by their Diels-Alder reactions constitutes a powerful synthetic sequence for the construction of many cyclic natural products.[1] However, the typical temperatures (>25 °C) employed for this sequence have frequently been dictated by the rates at which the initial *o*-xylylene can be formed from its various stable precursors.[2] Since electron-donating groups at sp^3 carbons of a benzocyclobutenyl ring lower the energy barriers toward xylylene formation,[3] we surmise that α-anionic centers at those sp^3 carbons could further lower the temperature (<0 °C) for the thermal electrocyclic ring opening[4] and that the associated cation M of the resulting *o*-xylylene could then behave as a Lewis acid center for a succeeding Diels–Alder reaction at the same temperature. This hypothetical sequence has been realized with dimethyl maleate (**7**), dimethyl fumarate (**8**), and γ-crotonolactone (**9**) as dienophiles (see Scheme I).

Typical Experimental Procedure (Method A, M = Li). To a cooled (−78 °C), dry 0.05 M THF solution of substrate **1**[5a] or **2**[5b] was added dropwise *n*-BuLi in hexane (1.1 equiv for alcohols or 2.2 equiv for acetates). After stirring at −78 °C for 30 min, dienophile (2 equiv) was added (neat for **7** and **9** or concentrated THF solution for **8**) dropwise and the resulting mix was allowed to stir at the temperature and time shown in Table I. The following observations were noted: First the solutions of these presumed oxy-*o*-xylylenes (M = Li) are colored. While the deep magenta color of **6** instantly appears after the addition of *n*-BuLi at −78 °C, the burgundy red color of **5** slowly appears after warming to −25 °C in the absence of dienophiles.[6a] Second, without added dienophiles, the color of **6** appears to persist for hours at −78 °C, while that of **5** slowly fades at 0 °C, thus indicating the instability of **5** toward other modes of decomposition near the temperature of its formation. Lastly, addition of relatively unreactive **9**[6b] would discharge both of these colors within seconds even in the case where the colored solution of **5** was cooled to −78 °C. The resulting mix was quenched at −78 °C with saturated aqueous NH_4Cl solution and extracted with Et_2O. The organic phases were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The adducts shown in Table I[7] were separated from the

(18) Moe, O. A.; Warner, D. T.; Buckley, M. I. *J. Am. Chem. Soc.* **1951**, *73*, 1062.
(19) (a) Micovic, M. V.; Mihailovic, M. LJ. *J. Org. Chem.* **1953**, *18*, 1190. (b) Hochstein, F. A.; Brown, W. G. *J. Am. Chem. Soc.* **1948**, *70*, 3484.
(20) The confirmed assignment of stereochemistry for mannopyranoside **3d** is based on a ^1H NMR comparison with 4,6-di-*O*-acetyl-3-*O*-carbamoyl-1,2-*O*-(1-ethoxyethylidene)-β-D-mannopyranose,[21] in which the following coupling constants have been reported: $J_{2,3}$ = 3.9, $J_{3,4}$ = 10.0, $J_{4,5}$ = 9.7, $J_{5,6A}$ = 12.4, 2.5, $J_{5,6B}$ = 12.4, 4.8 Hz. The coupling constants for **3d**: $J_{2,3}$ = 3.5, $J_{3,4}$ = 9.4, $J_{4,5}$ = 9.4, $J_{5,6A}$ = 11.8, 3.6, $J_{5,6B}$ = 11.8, 5.5 Hz. In addition, the chemical shift and multiplicity of H-2 (**3d**) correlate well with those reported for H-2 in methyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-β-D-mannopyranoside[22] (5.61 ppm, 1 H, br d; versus 5.35, 1 H, t, $J_{1,2}$ = $J_{2,3}$ = 2 Hz, for α-D-mannopyranoside). For **3d**: H-2, 5.54 ppm, 1 H, d, $J_{2,3}$ = 3.5 Hz. The C-1 (anomeric) stereochemistry of **3d** was further confirmed by ^{13}C NMR, which showed a signal for C-1 at 97.70 ppm with $^1J_{CH}$ = 155.0 Hz in good agreement with the observations of Bock and Pedersen. ($^1J_{CHax}$ = 155.9 Hz, $^1J_{CHeq}$ = 170.6 Hz).[22-25]
(21) Millar, A.; Kim, H. P.; Minster, D. K.; Ohgi, T.; Hecht, S. M. *J. Org. Chem.* **1986**, *51*, 189.
(22) Ogawa, T.; Katano, K.; Sasajima, K.; Matsui, M. *Tetrahedron* **1981**, *37*, 2779.
(23) Bock, K.; Lundt, I.; Pedersen, C. *Tetrahedron Lett.* **1973**, 1037.
(24) Bock, K.; Pedersen, C. *J. Chem. Soc., Perkins Trans. 2* **1974**, 293.
(25) Bock, K.; Pedersen, C. *Acta Chem. Scand., Ser B* **1975**, *B29*, 258.
(26) Anselmi, C.; Catelani, G.; Monti, L. *Gazz. Chim. Ital.* **1983**, *113*, 167.
(27) Barili, P. L.; Berti, G.; Catelani, G.; Colonna, F.; Mastrorilli, E. *J. Chem. Soc., Chem. Commun.* **1986**, 7.
(28) National Institutes of Health research career development award recipient, 1983–1988 (CA 01134); Alfred P. Sloan research fellow, 1985–1989.

† This communication is dedicated to Professor Satoru Masamune on the occasion of his 60th birthday.

0022-3263/88/1953-5796$01.50/0