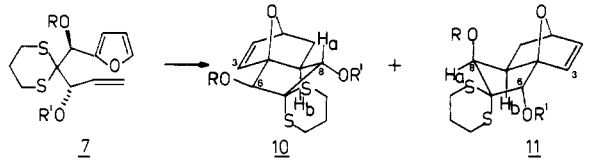
Table II. Substituent Effects on Diels–Alder Product Isomer Ratios of 10 and 11



7 10 11

	R	R′	10:11	% yield 10 + 11 (time, days)	δ H_a[a] (J, Hz) 10	11
A	H	H	1:1	95 (4)	3.65 (9.2)[b]	4.20 (4.9)[b]
B	Ac	Ac	2:1	90 (2)	5.80 (10.0)[c]	6.00 (6.5)[c]
C	Bn	Bn	1.1:1	84 (2)	4.10 (9.1)[c]	4.01 (5.0)[c]
D	THP	Bn	9:1[d]	89 (3)	4.13 (9.1)[c]	

[a] 250-MHz spectra referenced to either $CHCl_3$ or benzene. [b] $CDCl_3$ used as solvent. [c] Benzene-d_6 used as solvent. [d] Traces of this isomer were observed in the NMR spectrum of the mixture. This value represents an upper limit.

is at C-8. When both alcohols are protected the α-stereochemistry (pseudoequatorial) predominantes at C-8. This is the same trend that is observed with isomer **6**. Apparently the stereochemical preference at C-6 is also α. Thus in the cyclization of isomer **6** both effects are additive while in the cyclization of isomer **7** the steric effects are opposing, thus accounting for a somewhat smaller ratio.

The stereochemical assignments of these isomers are based on ^1H NMR data and correlation with an X-ray crystal structure of **9D**[7] (Figure 1). The X-ray results determined that all the compounds in Table I were derived from **6**, thus defining **7** as the precursor for the compounds in Table II. The stereochemical outcome of the intramolecular Diels–Alder reaction (i.e.; **8** vs. **9** and **10** vs. **11**) could be determined by examination of the coupling between H_a and H_b. Isomers **9** and **10** exhibited 8–10-Hz coupling, consistent with the dihedral angle of 164 (3)° obtained from the X-ray data of **9D**. The opposite configuration at C-8 in isomers **8**,**11** produced a much smaller coupling of 4–6.5 Hz, indicative of the smaller dihedral angle between the hydrogens in these isomers.

In summary, we have found that the desired Diels–Alder adduct **9D** can be produced in high yield. These results required two stereoselective reactions. First, the stereoselective addition of vinyl lithium to an aldehyde, and second, a stereoselective intramolecular Diels–Alder reaction. Synthetic applications of compound **9D** are in progress.

Acknowledgment. We thank the donors of the Petroleum Research Fund, administered by the American Chemical Society, and the Research Corporation for partial support of this work.

Registry No. **4**, 91280-56-7; (*R**,*R**)-**5** (R = THP), 91265-48-4; (*R**,*S**)-**5** (R = THP), 91265-49-5; **6A**, 91265-50-8; **6B**, 91265-51-9; **6C**, 91265-52-0; **6D**, 91265-53-1; **6** R = THP, R^1 = H, 91265-54-2; **7A**, 91265-55-3; **7B**, 91265-56-4; **7C**, 91265-57-5; **7D**, 91326-48-6; **7** R = THP, R^1 = H, 91326-49-7; **8A**, 91265-58-6; **8B**, 91265-59-7; **8C**, 91265-60-0; **8D**, 91265-61-1; **9A**, 91326-50-0; **9B**, 91326-51-1; **9C**, 91326-52-2; **9D**, 91326-53-3; **10A**, 91326-54-4; **10B**, 91326-55-5; **10C**, 91326-56-6; **10D**, 91326-57-7; **11A**, 91326-58-8; **11B**, 91326-59-9; **11C**, 91326-60-2; **11D**, 91265-62-2; 2-carboethoxydithiane, 20462-00-4; 1,2-dibromoethane, 106-93-4; magnesium bromide, 7789-48-2; 2-carboethoxydithiane lithium enolate, 79348-08-6; furfural, 98-01-1; ethyl (*R**,*R**)-3-(2-furyl)-2-oxo-3-(2-tetrahydropyranyloxy)propanoate 1,3-propanedithio acetal, 91265-63-3; dihydropyran, 25512-65-6; ethyl (*R**,*S**)-3-(2-furyl)-2-oxo-3-(2-tetrahydropyranyloxy)propanoate 1,3-propanedithio acetal, 91265-64-4; 1-(2-furyl)-3-hydroxy-1-(2-tetrahydropyranyloxy)-2-propanone 1,3-propanedithio acetal, 91265-65-5.

Supplementary Material Available: Full experimental details along with spectral data for the compounds in Scheme I; crystal data for **9D** including tables of atomic coordinates, thermal parameters, bond lengths and valency angles, and torsion angles (20 pages). Ordering information is given on any current masthead page.

(7) Crystallographic parameters appear in the supplementary material section. Publication of complete crystallographic details is planned.

Daniel D. Sternbach,* Debby M. Rossana
Department of Chemistry
Duke University
Durham, North Carolina 27706

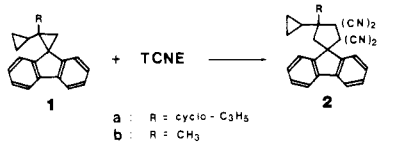
Kay D. Onan
Department of Chemistry
Northeastern University
Boston, Massachusetts 02115
Received October 18, 1983

Facile Thermal [$_\sigma$2 + $_\pi$2] Cycloadditions of Some Cyclopropanes with TCNE. A Remarkable Effect of the Fluorene Unit Fused in a Spiro Fashion[1]

Summary: The fact that **1a**, as well as similarly spiro-activated **1b** and **5**, readily reacted with TCNE to afford a [$_\sigma$2 + $_\pi$2] cycloadduct, whereas **3** was practically unreactive, suggests an initial electron transfer in the cycloaddition.

Sir: Efficient [$_\sigma$2 + $_\pi$2] cycloadditions between cyclopropanes and ethylenes would be a promising way to prepare five-membered carbocycles. In fact, several reports describe such cycloadditions,[2] and all previous results indicate that the [$_\sigma$2 + $_\pi$2] cycloaddition successfully occurs when the donor–acceptor pairing of the reactants is properly attained.[3] We report here that certain cyclopropanes react very readily with TCNE in such a manner. The extremely reactive cyclopropanes carry a fluorene unit, linked in a spiro fashion to the cyclopropane, and good cation-stabilizing substituents on the three-membered ring. Remarkably, the lack of the fluorene unit resulted in a marked reduction in the reactivity.

On being mixed in an appropriate solvent, 1,1-dicyclopropyldibenzo[*d*,*f*]spiro[2.4]heptane (**1a**) and TCNE gave



a colored solution, but the color faded after a short period of time. The time required to give the colorless solution depended on the polarity of the solvent used (less than 1 s in acetonitrile or in nitromethane, 1–2 s in acetone, ca.

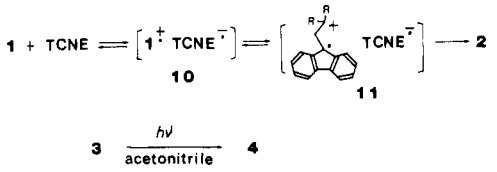
(1) This work was supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture of Japan, to whom we are grateful.

(2) (a) Magrill, D. S.; Altmann, J.; Ginsberg, D. *Isr. J. Chem.* **1969**, *7*, 479. (b) Martini, T.; Kampmeier, L. A. *Angew. Chem., Int. Ed. Engl.* **1970**, *9*, 236. (c) Nishida, S.; Moritani, I.; Teraji, T. *J. Chem. Soc., D* **1971**, 36. (d) Kataoka, F.; Nishida, S. *Chem. Lett.* **1980**, 1115. (e) Noordstrand, A. A. P.; Steinberg, H.; de Boer, Th. J. *Tetrahedron Lett.* **1975**, 2611. (f) Wiering, P. G.; Steinberg, H. *J. Org. Chem.* **1981**, *46*, 1663. (g) Wiering, P. G.; Verhoeven, J. W.; Steinberg, H. *J. Am. Chem. Soc.* **1981**, *103*, 7675. See also: (h) Berkowitz, W. F.; Grenetz, S. C. *J. Org. Chem.* **1976**, *41*, 10.

(3) Tsuji, T.; Nishida, S. *Acc. Chem. Res.* **1984**, *17*, 56.

0022-3263/84/1949-3428$01.50/0

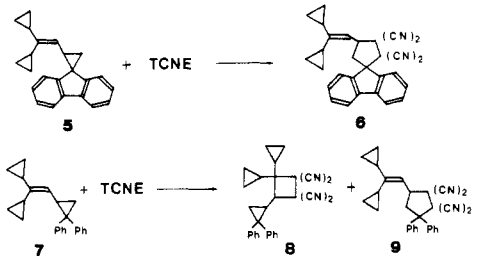
Scheme I



30 s in dichloromethane, ca. 24 min in ethyl acetate, 1.5 h in benzene). From the resultant colorless solution, a crystalline, 1:1 adduct, 3,3-dicyclopropyldibenzo[*f*,*h*]spiro[4.4]nonane-1,1,2,2-tetracarbonitrile (**2a**),[4] was obtained in 66% yield. The reaction of **1b** with TCNE proceeded slowly but analogously to give **2b** (overnight in dichloromethane at room temperature, 55%). In contrast, 1,1-dicylopropyl-2,2-diphenylcyclopropane (**3**) was practically

unreactive with TCNE under similar reaction conditions, although **3** differs from **1a** only in that **3** lacks a bond between the two phenyl groups to accomplish the fluorene skeleton. In acetonitrile at room temperature, the consumption of **3** was only 6% even after 20 h, although the formation of a trace amount of **4** was noted by the HPLC analysis of the crude reaction mixture.

The 2,2-dicyclopropylvinyl derivative **5** also reacted very readily with TCNE to give **6** (few seconds in dichloromethane, 83%). In contrast, **7** produced two cycloadducts,



8 (72%) and **9** (9%), in its slow reaction with TCNE (2 days in dichloromethane at room temperature). Since **5** and **7** are trisubstituted ethylenes, we expected that [$_\pi$2 + $_\pi$2] cycloadditions might take place.[2d,3,5] This was indeed the case in the reaction of **7**, but **5** produced exclusively **6**. Here, the effect of the fluorene unit was observed for the second time.

Now, the marked difference in the reactivity observed between **1a** and **3**, as well as between **5** and **7**, is evidently due to the presence or the absence of the fluorene unit in the substrates. According to Scott et al.,[6] an electron transfer is thermodynamically favored when the difference between the ionization potential (IP) of the donor and the electron affinity (EA) of the acceptor is less than 4–5 eV. Thus, on the basis of the fact that the IP of dibenzo[*d*,*f*]spiro[2.4]heptane (spiro[cyclopropane-1,9′-[9*H*]fluorene], IP^v = 7.84 eV)[7] is substantially lower than that of 1,1-diphenylcyclopropane (IP^v = 8.48 eV),[7] we propose that the electron transfer from the substrate to TCNE (EA = 2.8–2.9 eV) might readily occur to a considerable extent in the reactions of **1** and **5** but not in the reaction of **3**. As shown in Scheme I, the resultant **10** will open its cyclopropane ring when the three-membered ring carries good cation-stabilizing groups.[8] The second cation radical **11** will then react with a nearby TCNE anion radical to afford **2**.

It was further observed that thermally very low reactive **3** could react with TCNE in a reasonable rate under illumination with a halogen lamp (42% conversion at 12 °C in acetonitrile after 4 h) to give **4** (37%). The charge-transfer complex [λ_{max} 363 (sh) nm] might be excited by the illumination and the resultant excited state would collapse to an ion radical pair similar to **10**, which underwent subsequent transformations. Thus, the adequacy of Scheme I may be justified.

Registry No. **1a**, 37568-24-4; **1b**, 91266-61-4; **2a**, 91266-62-5; **2b**, 91266-63-6; **3**, 54159-42-1; **4**, 91549-28-9; **5**, 91549-29-0; **6**, 91266-66-9; **7**, 91266-64-7; **8**, 91266-65-8; **9**, 91266-67-0; **12**, 91266-68-1; **13**, 91266-69-2; TCNE, 670-54-2.

Supplementary Material Available: Spectral data of the products (8 pages). Ordering information is given on any current masthead page.

(4) Spectral data of the products are available in the supplementary material section.

(5) Nishida, S.; Moritani, I.; Teraji, T. *J. Org. Chem.* **1973**, *38*, 1878.

(6) Scott, L. T.; Erden, W. R.; Brunsvold, W. R.; Schultz, T. H.; Houk, K. N.; Paddon-Row, M. N. *J. Am. Chem. Soc.* **1982**, *104*, 3659.

(7) Jason, M. E.; Gleiter, R., unpublished results. We are very grateful to them for sending us the IP^v values prior to the publication.

(8) We propose that **10** will open its cyclopropane ring prior to the attack by TCNE anion radical. The alternative possibility that the TCNE anion radical attacks **10**, yielding a biradical intermediate, which in the next step gives **2** (suggested by the referee), appears to be unlikely. This is because (i) **2** was 3,3-disubstituted spirononane-1,1,2,2-tetracarbonitrile but was not 4,4-disubstituted spirononane-1,1,2,2-tetracarbonitrile (the structural proof of **2** is given in the supplementary material), (ii) the reaction of **1a** proceeded significantly more rapidly than that of **1b**, and (iii) the zwitterionic intermediate derived from **11** was successfully trapped by methanol in the reaction of **1b** with TCNE (unpublished observations).

(9) Present address: Department of Chemistry, Faculty of Science, Kyushu University, Fukuoka 812, Japan.

Shinya Nishida,* Masashi Murakami, Tetsuo Mizuno Takashi Tsuji, Hirofumi Oda, Nobujiro Shimizu[9]

Department of Chemistry, Faculty of Science Hokkaido University Sapporo, Hokkaido 060, Japan

Received March 28, 1984

Synthesis of Antibiotic X-14547A[1]

Summary: A highly stereoselective 16-step synthesis of antibiotic X-14547A is described.

Sir: Antibiotic X-14547A (**1**), a structurally unique member of the ionophore class,[4] has attracted considerable attention since its structure was reported in 1978.[5,6]

(1) Taken in part from the Ph.D. Thesis of S. M. Peseckis, Massachusetts Institute of Technology, Cambridge, MA, 1983.

(2) Holder of the Firmenich Career Development Chair in Natural Products Chemistry; Fellow of the Alfred P. Sloan Foundation, 1982–84.

(3) National Cancer Institute Predoctoral Trainee (Training Grant No. T32-CA-09112).

(4) (a) Westley, J. W., Ed. "Polyether Antibiotics: Naturally Occurring Acid Ionophores"; Marcel Dekker: New York, 1983; Vol. I and II. (b) Dobler, M. "Ionophores and Their Structures"; Wiley: New York, 1981. (c) Westley, J. W. *Adv. Appl. Microbiol.* **1977**, *22*, 177. (d) Pressman, B. C. *Annu. Rev. Biochem.* **1976**, *45*, 501.

(5) (a) Westley, J. W.; Evans, R. H., Jr.; Liu, C.-M.; Hermann, T.; Blount, J. F. *J. Am. Chem. Soc.* **1978**, *100*, 6784. (b) Liu, C.-M.; Hermann, T. E.; Liu, M.; Bull, D. N.; Palleroni, N. J.; Prosser, B. L. T.; Westley, J. W.; Miller, P. A. *J. Antibiot.* **1979**, *32*, 95. (c) Westley, J. W.; Evans, R. H., Jr.; Sello, L. H.; Troupe, N.; Liu, C.-M.; Blount, J. F. *Ibid.* **1979**, *32*, 100.

0022-3263/84/1949-3429$01.50/0