A Novel Synthesis of Trienes by Nucleophilic Ring Cleavage of Tropone Oxime Tosylate[1,2]

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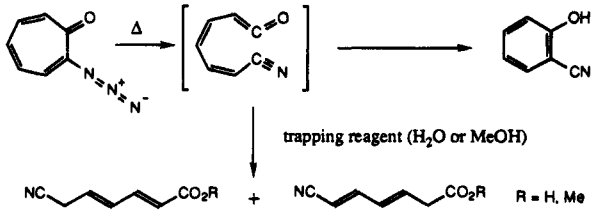
Abstract: In contrast to chemical reactions of troponoid ([7]annulenone) compounds reported so far, the tosylate of tropone oxime reveals a novel ring opening reaction under mild conditions at the temperature between −20 and 0 °C. This nucleophilic reaction affords exclusively and stereoselectively a variety of 6-substituted (*Z,Z,Z*)-1,3,5-hexatrienecarbonitriles, as the sole products in high yields. The opening reaction is caused by the intramolecular (HOMO → σ*) charge transfer in the Meisenheimer tetrahedral intermediate.

Although extensive reactions of troponoid compounds have been known,[4] there are no ring-opening reactions. The ring skeleton is retained in nucleophilic and electrophilic reactions.[4] One specific and exceptional reaction in Scheme 1 has been reported.[5] The thermal decomposition of 2-azidotropone in aqueous dioxane, methanol, or aniline gives a Schmidt-type rearrangement product. This product is converted to a benzenoid compound or a mixture of conjugated transoid dienecarboxylic acids or esters.

Scheme 1. Thermal Decomposition of 2-Azidotropone



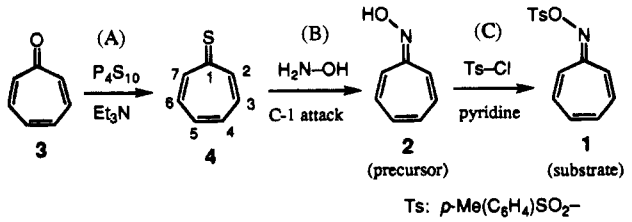
The troponoid ring contains the hexatriene moiety. If this cisoid moiety can be picked up from the ring by a new method in mild conditions, it can be a useful tactic for synthesizing *Z,Z,Z*-trienes. Generally, the triene synthesis has been confined to thermodynamically stable all-transoid compounds. It requires various different procedures for the desired trienes.[6]

In this work, we report a novel and surprisingly facile nucleophilic ring opening of tropone oxime tosylate (**1**) to produce *all-cisoid trienes* stereoselectively. Our preliminary report has dealt with a part of the reaction, however, the reaction mechanism has been entirely unresolved.[7] It will be theoretically analyzed why and when the σ bond of troponoid compounds is cleaved in spite of coexistence of their highly reactive conjugated π bonds.

Results and Discussion

Generation of the Substrate, Tropone Oxime Tosylate (1). The precursor of the substrate is tropone oxime (**2**), which cannot be efficiently obtained from a reaction between tropone (**3**) and hydroxylamine, since the reaction gives mainly 2-aminotropone and the desired **2**, is merely a trace-amount byproduct.[8] Alternatively, in Scheme 2, we have succeeded in preparation of **2** and subsequent **1** starting from tropothione[9] (**4**). The thione **4** and its derivatives are readily synthesized by direct sulfurization of the corresponding tropones under mild conditions in high yields.[10,11]

Scheme 2. Generation of the Tropone Oxime Tosylate, **1**



The contrast of the C-2 attack of **3** and the C-1 attack of **4** is rationalized in terms of the frontier-orbital theory. LUMO of

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(1) This paper is dedicated to the memory of the late Professor Yoshio Kitahara on the occasion of the 20th anniversary of his death.

(2) Abbreviations used: nuclear Overhauser effect, NOE; 1D, one-dimensional; 2D, two-dimensional; COSY, shift-correlation spectroscopy; COLOC, shift-correlation spectroscopy by long-range couplings; CPD, composite proton decoupling; SEL, selective proton decoupling; LSPD, long-range selective proton decoupling; MO, molecular orbital.

(3) (a) Saitama University. (b) Nara University of Education. (c) Nara University. (d) Kao Corporation.

(4) (a) Lloyd, D. *The Chemistry of Conjugated Cyclic Compounds*; Wiley: New York, NY, 1990; pp 1−185. (b) Asao, T.; Oda, M. In *Carbocyclische π-Electronen-Systeme: Houben-Weyl, Methoden der organischen Chemie*; Müller, E., Bayer, O., Eds.; Georg Thieme: Stuttgart, Germany, 1986; Vol. 5/2c, pp 49−85, 710−780. (c) Lloyd, D. *Nonbenzenoid Conjugated Carbocyclic Compounds*; Elsevier: Amsterdam, 1984; pp 1−431. (d) Nozoe, T. In *Nonbenzenoid Aromatic Compounds*; Kotake, M., Ed.; Comprehensive Organic Chemistry; Asakura-Shoten: Tokyo, 1973; Vol. 13. (e) Pietra, F. *Chem. Rev.* **1973**, *73*, 293−364.

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(6) E.g.: (a) Solladie, G.; Stone, G. B.; Andrés, J.-M. *Tetrahedron Lett.* **1993**, *34*, 2835−2838. (b) Takayama, H.; Suzuki, T. *J. Chem. Soc., Chem. Commun.* **1988**, 1044−1045.

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(9) Machiguchi, T.; Hasegawa, T.; Ishii, Y.; Yamabe, S.; Minato, T. *J. Am. Chem. Soc.* **1993**, *115*, 11536−11541 and references therein.

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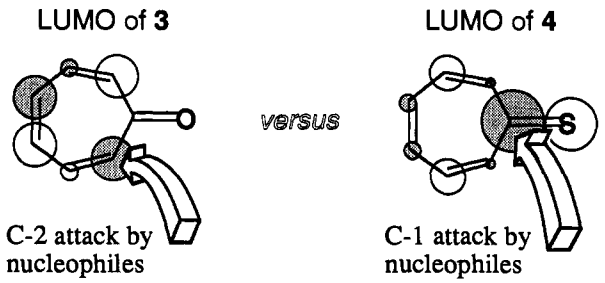
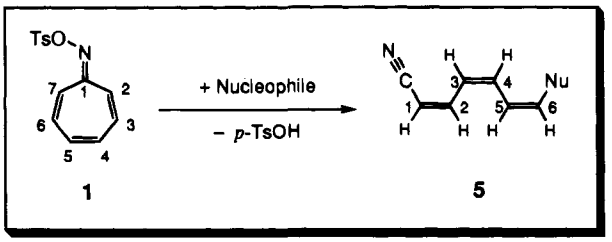
3 has the same shape as that of hexatriene, and the p_π component of C-2 or C-7 is the largest one. On the other hand, LUMO of **4** is of a $\pi^*_{C=S}$ character, where the C-1 component is the largest. Thus, nucleophiles attack naturally C-2 (or C-7) of tropone and C-1 of tropothione, respectively.



Ring-Opening Reactions of Tropone Oxime Tosylate. We have found that the tosylate **1** reacts quite readily with a variety of nucleophilic reagents in low temperatures between −20 and 0 °C. They always give the sole hexatriene products **5** with (*Z,Z,Z*) configuration in excellent yields. Scheme 3 summarizes results of these reactions.

Scheme 3. Facile Ring Opening of the Tosylate (**1**) of Tropone Oxime by the Nucleophiles under Mild Conditions To Give 6-Substituted (*Z,Z,Z*)-1,3,5-Hexatrienecarbonitriles (**5**)[a-c]



Nu: **a**, N⬠; **b**, NMe_2; **c**, NEt_2; **d**, N⬡;
e, OMe; **f**, OEt; **g**, Me; **h**, Ph

[a] Conditions: **5a**, pyrrolidine, CH_2Cl_2, −20 °C, 1 h, 97%; **5b**, Me_2NH, CH_2Cl_2, −20 °C, 2 h, 96%; Me_2NH, no solvent, −20 °C, 30 min, 98%; **5c**, Et_2NH, no solvent, 0 °C, 2.5 h, 97%; **5d**, morpholine, no solvent, 0 °C, 40 min, 96%; **5e**, MeONa, THF, 0 °C, 4 h, 96%; **5f**, EtONa, THF, 0 °C, 30 min, 98%; **5g**, MeMgI,[c] THF, 0 °C, 4 h, 52%; **5h**, PhMgBr,[c] THF, 0 °C, 3 h, 67%. [b] Yield isolated. [c] When methyl- or phenyllithium was used as a nucleophile, the yield was significantly lower (< 10%).

This reaction affords stereoselectively (*Z,Z,Z*)-1,3,5-hexatrienecarbonitriles (**5a−h**). These trienes are thermodynamically unstable and are different from dienes of the reaction of 2-azidotropone reported in Scheme 1.

Identification of Structures of Products 5a−h. The products **5a−h** were identified by spectroscopic analysis. Microanalytical and molecular weight data are clearly consistent with 1:1 adducts of the tosylate **1** and nucleophiles minus the elements of *p*-toluenesulfonic acid (*p*-TsOH). The mass spectral fragmentations[12] as well as the UV−visible spectra[13] indicate that the products are hexatrienecarbonitriles. The IR spectra are consistent with the conjugated cisoid carbonitriles.[14]

^{1}H NMR spectra of **5a−h** show well resolved first-order amenable ABCDEF patterns. (These ^{1}H NMR charts are given in the supplementary material). The vicinal coupling constants ($^3J_{1,2}$, $^3J_{3,4}$, and $^3J_{5,6}$) indicate all-cisoid structures (Table 1). (*Z*) Configurations of all the products were further confirmed not only by large long-range couplings through five bonds (i.e., zig-zag couplings of $^5J_{1,4}$ and $^5J_{5,6}$) but also by the enhancement (15−26%) of NOE between H(1) and H(2), H(3) and H(4), H(5) and H(6), and H(2) and H(5) (see supplementary material).

^{13}C NMR spectra of the products show one cyano carbon and six olefinic carbons at around δ 118 and 90−145 ppm, respectively, together with those of substituents at upfield regions (Table 2). The former signal appears as a singlet signal and the latter six olefinic carbons appear as all doublet signals by off-resonance experiments. The spectral data in Table 2 show that the structures of the products are all-cisoid hexatrienecarbonitriles (**5**). Terminal positions (C-1 and C-6) of the hexatriene moiety were clearly assigned through $^2J_{N\equiv C-C(2)H}$, $^3J_{N\equiv C-C-C(3)H}$, and $^3J_{C(6)-X-C(substituent)H}$ (X = C, N, or O).[15]

We accomplished full assignments of NMR (^{1}H and ^{13}C) spectra by the accurate analyses (see supplementary material) using not only modern 1D NMR methods (resolution-enhanced spectra with Gaussian- and sine-bell wind functions[16]) but also 2D ones (^{1}H−^{1}H COSY,[17] ^{1}H−^{1}H COLOC,[18] ^{13}C−^{1}H COSY,[19] ^{13}C−^{1}H COLOC[20] with an aid of CPD, gated decoupling, ^{13}C−^{1}H SEL, and ^{13}C−^{1}H LSPD[21]).

All the spectra show unambiguously that the product structures are 6-substituted 1,3,5-hexatrienecarbonitriles with the (*Z,Z,Z*) configuration.

Position of Nucleophilic Attack. The attacking position of the substrate **1** by the nucleophiles is investigated in two ways, A and B in Scheme 4. A is the ^{1}H → ^{2}H isotope substitution in **1**. The tosylate of [2,7-$^2H_2$]tropone oxime, 1-d_2 (isotopic purity: 96.3% $^2H_2$, 3.7% $^2H_1$, measured by mass spectrometry), has been subjected to the reaction with pyrrolidine. The product is [1,6-$^2H_2$]hexatrienecarbonitrile (**5a**-d_2) (isotopic purity: 95.8% $^2H_2$, 4.2% $^2H_1$). This result demonstrates that the nucleophilic attack occurs at the C-2 or C-7 (α-carbon) of the substrate **1** and the C(1)−C(2) or the C(1)−C(7) bond is cleaved by the attack without any sigmatropic rearrangement in the ring.

(10) Machiguchi, T. *Tetrahedron*, in press. Machiguchi, T.; Otani, H.; Ishii, Y.; Hasegawa, T. *Tetrahedron Lett.* **1987**, *28*, 203−206.

(11) Machiguchi, T.; Hasegawa, T.; Kano, Y. *Bull. Chem. Soc. Jpn.* **1993**, *66*, 3699−3706. Machiguchi, T.; Kano, Y.; Hasegawa, T. *Chem. Lett.* **1990**, 563−566.

(12) Mass spectra of the products **5** have shown the molecular ion peaks (e.g., *m/z* 174 for 6-1′-pyrrolidinyl derivative, **5a**) as the base peak. When the ion loses the substituent group Nu at C-6 position, a trienecarbonitrile cation radical (NC−CH=CH−CH=CH−CH=CH$^{\bullet+}$) peak has appeared at *m/z* 104. The fragment loses acetylene (HC≡CH) stepwisely to form C_5H_4N (*m/z* 78, NC−CH=CH−CH=CH$^{\bullet+}$) (this fragment appears in all the product **5a**−h), and C_3H_2N *m/z* 52, NC−CH=CH$^{\bullet+}$). Then the *m/z*-52 fragment loses hydrogen radical to form C_3NH (*m/z* 51, NC−C≡CH$^{\bullet+}$) and C_3N (*m/z* 50, NC−C≡C$^{\bullet+}$).

(13) UV−visible spectra of **5a**−h display peaks at λ_{max} = 295−377 nm (hexane), which are consistent with structures of ζ-substituted hexatrienecarbonitriles. Scott, A. I. *Interpretation of the Ultraviolet Spectra of Natural Products*; Pergamon: New York, 1964.

(14) IR spectra of **5a**−h show the characteristic absorptions of very strong stretching vibrations of the conjugated cyano group and carbon−carbon double bonds at around 2190 and 1620−1555 cm^{-1}, respectively. An out-of-plane C−H bending vibration of the products appear at around 730 cm^{-1} according to cisoid −HC=CH− bonds.

(15) Marshall, J. L. In *Carbon−Carbon and Carbon−Proton NMR Couplings: Applications to Organic Stereochemistry and Conformational Analysis*; Marchand, A. P., Ed.; Methods in Stereochemical Analysis 2; Verlag Chemie International: Deerfield Beach, FL, 1983.

(16) Derome, A. E. In *Modern NMR Techniques for Chemistry Research*; Baldwin, J. E., Ed.; Organic Chemistry Series 6; Pergamon: Oxford, England, 1987.

(17) Aue, W. P.; Bartholdi, E.; Ernst, R. R. *J. Chem. Phys.* **1976**, *64*, 2229−2246. Nagayama, K.; Kumar, A.; Wuethrich, K.; Ernst, R. R. *J. Magn. Reson.* **1980**, *40*, 321−334.

(18) Bax, A.; Freeman, R. *J. Magn. Reson.* **1981**, *44*, 542−561. Steffens, J. C.; Roark, J. L.; Lynn, D. G.; Riopel, J. L. *J. Am. Chem. Soc.* **1983**, *105*, 1669−1671.

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(21) Takeuchi, S.; Uzawa, J.; Seto, H.; Yonehara, H. *Tetrahedron Lett.* **1977**, 2943−2946. Seto, H.; Sasaki, T.; Yonehara, H.; Uzawa, J. *Tetrahedron Lett.* **1978**, 923−926.

Table 1. Selected ^1H NMR (400 MHz, $CDCl_3$, Me_4Si) Spectral Data for the Products, 6-Substituted (*Z,Z,Z*)-1,3,5-Hexatrienecarbonitriles (**5a–h**), in Scheme 3[a,b]

6-substituent (−Nu)	product	chemical shift[c] (δ)						coupling constant (Hz)				
								vicinal coupling			zig-zag coupling	
		H(1)	H(2)	H(3)	H(4)	H(5)	H(6)	$^3J_{1,2}$	$^3J_{3,4}$	$^3J_{5,6}$	$^5J_{1,4}$	$^5J_{3,6}$
1-pyrrolidinyl	**5a**	4.88	7.29	5.97	6.90	5.12	6.23	10.8	10.6	9.1	1.1	1.1
$-NMe_2$	**5b**	4.91	7.28	5.99	6.93	5.05	5.97	10.8	10.8	9.5	2.1	2.1
$-NEt_2$	**5c**	4.89	7.30	5.99	6.74	4.99	5.97	10.6	11.1	9.6	1.3	1.1
4-morpholinyl	**5d**	5.03	7.26	6.13	6.78	5.16	5.88	10.7	10.7	9.3	1.2	1.2
−OMe	**5e**	5.15	7.21	6.31	6.81	5.46	6.18	10.8	10.8	6.4	1.6	1.7
−OEt	**5f**	5.12	7.21	6.28	6.83	5.45	6.25	11.0	11.1	6.2	1.1	1.1
−Me	**5g**	5.24	7.31	6.47	6.74	6.48	5.88	10.9	11.0	10.7	1.6	1.1
−Ph	**5h**	5.29	7.40	6.58	6.91	6.68	6.77	10.5	11.0	11.7	1.3	1.3

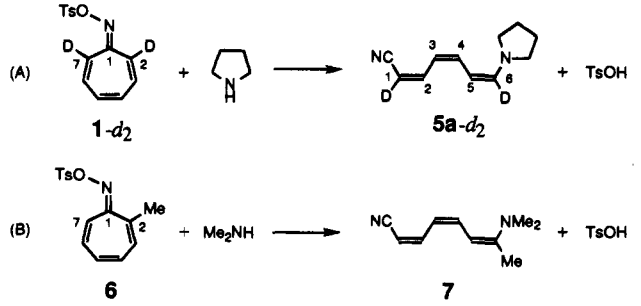
[a] The numbering for hydrogens in **5a–h** follows that for carbons in Scheme 3. [b] Signal and coupling assignment are confirmed by 2D $^1H-^1H$ COSY and $^1H-^1H$ COLOC spectra as well as $^1H\{^1H\}$ homonuclear decoupling experiments. The magnitudes of J_{H-H} are determined from ^1H NMR spectra treated with Gaussian and sine-bell wind functions. [c] Chemical shifts (δ) of substituent part are as follows: **5a**, 3.46 and 1.90; **5b**, 3.02; **5c**, 3.25 and 1.19; **5d**, 3.73 and 3.30; **5e**, 3.75; **5f**, 3.95 and 1.30; **5g**, 1.85; **5h**, 7.39–7.29. Full coupling constants and assignments of the products **5a–h** are shown in supplemenatry material.

Table 2. Selected ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) Spectral Data for the Products, 6-Substituted (*Z,Z,Z*)-1,3,5-Hexatrienecarbonitriles (**5a–h**), in Scheme 3[a,b]

6-substituent (−Nu)	product	chemical shift[c] (δ)							coupling constant (Hz)		
		C≡N	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	$^2J_{NC-H(1)}$	$^3J_{NC-H(2)}$	$^3J_{C(6)-H(Nu)}$[d]
1-pyrrolidinyl	**5a**	118.25	89.73	144.05	114.34	135.95	92.68	139.32	2.7	15.3	1.7
$-NMe_2$	**5b**	118.04	90.48	143.86	115.05	135.31	92.76	142.51	2.6	14.8	2.7
$-NEt_2$	**5c**	118.08	90.11	143.96	114.91	135.28	91.35	140.45	2.6	14.9	3.7
4-morpholinyl	**5d**	117.42	93.07	143.56	117.79	134.29	95.78	141.79	3.0	14.6	1.8
−OMe	**5e**	116.83	95.27	143.88	120.68	131.09	101.46	152.07	2.1	15.1	5.2
−OEt	**5f**	116.97	95.11	144.02	120.49	131.47	101.40	150.91	2.5	15.2	4.8
−Me	**5g**	116.50	96.97	143.57	123.61	132.62	123.51	133.37	2.4	15.1	7.2
−Ph	**5h**	116.32	97.54	143.23	125.80	134.00	123.47	135.75	2.0	14.8	2.6

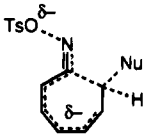
[a] For the atomic numbering in **5a–h**, see Scheme 3. [b] Signal and coupling assignment are confirmed by gated decoupling, 2D $^{13}C-^1H$ COSY and $^{13}C-^1H$ COLOC, and $^{13}C-^1H$ LSPD spectra. The magnitudes of J_{C-H} are determined by gated decoupling spectra resolution-enhanced with Gaussian wind function as well as LSPD experiments. [c] Chemical shifts (δ) of substituent part are as follows: **5a**, 52.24 and 25.69; **5b**, 43.78; **5c**, 48.08 and 14.05; **5d**, 66.49 and 50.96; **5e**, 60.71; **5f**, 69.35 and 15.30; **5g**, 13.59; **5h**, 136.28, 129.36, 128.43, and 128.08. Full coupling constants and assignments of the products **5a–h** are shown in supplemenatry material. [d] Abbreviation "Nu" denotes a substituent.

Scheme 4. Determination of the Attacking Position of Tosylates (**1** and **6**) by the Nucleophiles



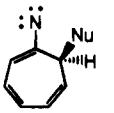
The other investigation is made so as to judge whether the C-2 or the C-7 atom is attacked by nucleophiles. This judgment is feasible by the α substitution to the substrate **1**. The tosylate (**6**) of 2-methyltropone oxime may have, basically, two configurations, *syn* and *anti*, relative to the *N*-tosylate. We assigned unequivocally the tosylate configuration to *anti* to the methyl group in the ring based on quantitative difference $^1H\{^1H\}$ NOE spectra as well as X-ray crystallographic analysis (see supplementary material I). When the substrate **6** undergoes the nucleophilic attack by dimethylamine, the product **7** is generated in Scheme 4. The experimental result shows that the nucleophile Me_2NH attacks the C-2 position of the substrate **6** despite the steric crowd due to the methyl group. Thus, the *anti* C-2 attack to the tosyl group by a nucleophilic reagent brings about the C(1)–C(2) bond cleavage as well as the N–O bond scission.

Here, the mechanistic interest is directed to the character of the intervening species **X**. As a candidate of **X**, a nitrene-type intermediate **Y** was implied in our communication.[7] The intermediate **Y** stems from the formation of the C(2)–Nu new bond and the scission of the O–N bond with retention of the C(1)–C(2) bond. In order to test intervention of the nitrene **Y**, an olefin, 4-methyl-2-pentene,[22] has been added under the same conditions as those in Scheme 3. However, no cycloadduct of an azacyclopropane has been detected. The species **Y**, if it exists, would be a short living intermediate.



X

tetrahedral intermediate



Y

nitrene

Theoretical Inspection of the Ring Opening. PM3 calculations[23] have been carried out for a nucleophilic reaction between the substrate (**1**) and methoxide ion [Nu: = (e) MeONa in Scheme 3]. The first step of the reaction is formation of an anti tetrahedral intermediate in the top side of Figure 1. The substrate **1** has the same-type LUMO as that of tropone (and hexatriene). According to its largest extension, the nucleophile

(22) Maconaghy, J. S., Jr.; Lwowski, W. *J. Am. Chem. Soc.* **1967**, *89*, 2357–2364. Maconaghy, J. S., Jr.; Lwowski, W. *J. Am. Chem. Soc.* **1967**, *89*, 4450–4456. For review of nitrene chemistry, see, e.g.: Gilchrist, T. L. In *Nitrogen Ions and Radicals, Nitrenes, and Related Species*; Barton, D., Ollis, W. D., Sutherland, I. O., Eds.; Comprehensive Organic Chemistry; Pergamon: Oxford, U. K., 1979; Vol. 2, pp 273–301.

(23) (a) PM3 method: Stewart, J. J. P. *J. Comput. Chem.* **1989**, *10*, 209–220. Stewart, J. J. P. *J. Comput. Chem.* **1989**, *10*, 221–264. (b) MOPAC program version 6, QCPE No. 455, Department of Chemistry, Indiana University, Bloomington, IN 47405, 1990.

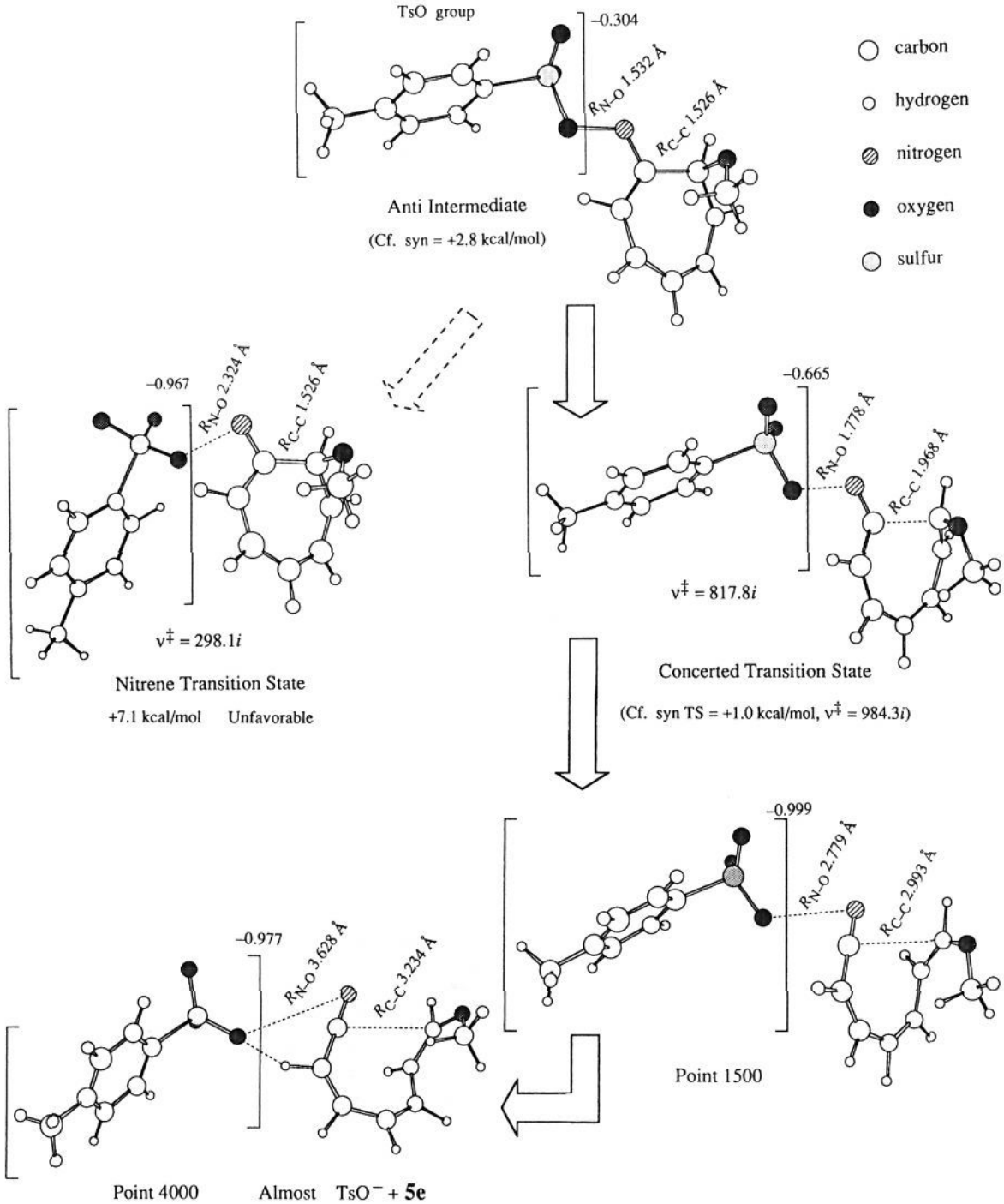
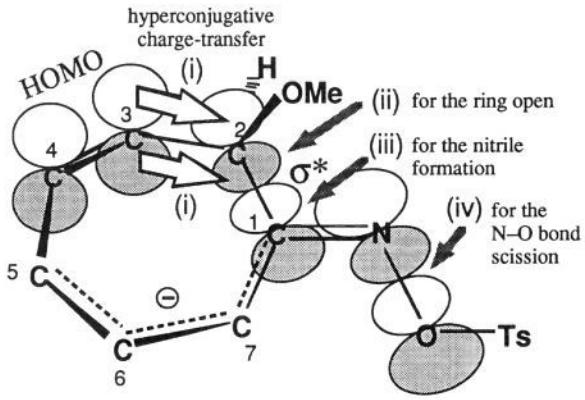


Figure 1. The reaction path of the ring opening computed with the PM3 method.[23] The tetrahedral intermediate is composed of **1** and methoxide ion MeO^-. In parentheses, energy differences between the anti species and the corresponding syn one are shown by kcal/mol. These positive values indicate that anti intermediate and anti concerted transition state (TS) are more favorable than syn ones. The nitrene-forming TS is 7.1 kcal/mol less favorable than the concerted ring-opening TS. At TS's, sole imaginary frequencies $\nu^{\ddagger}$'s are shown in cm^{-1}. Frames attached to the OTs moiety denote net electronic charges (negative, anionic). Points 1500 and 4000 are late points on the intrinsic reaction coordinate. The changes of net charges, −0.999 (point 1500) → −0.977 (point 4000), along the reaction progress seems to be curious. This apparent reversal arises from the (artificial, i.e., gas-phase) hydrogen-bond formation as the dotted line in point 4000 shows.

MeO^- attacks C-2 (anti) or C-7 (syn) of **1**. In agreement with the result in Scheme 4, the *anti* intermediate is 2.8 kcal/mol more stable than the *syn* one in Figure 1.

The next step is either the concerted C(1)−C(2) and N−O bond scission or the N−O bond scission and the nitrene formation. Each transition state is shown in the middle of Figure 1. The concerted path is much more favorable than the nitrene path (the E_a difference = 7.1 kcal/mol). This computed result of absence of the nitrene is consistent with no quenching in the experimental result. At a late stage (point 4000) of the concerted path, almost the *Z,Z,Z*-triene with cyano and methoxy groups is completed. The driving force of this concerted ring opening can be found in frontier orbitals of the anti tetrahedral intermediate. In the intermediate, HOMO is almost an out-of-plane π orbital to represent its anionic character. There is also a low-lying σ^* vacant orbital in the intermediate. The hyper-

conjugative HOMO → σ* charge transfer reasonably leads to the ring opening. The charge acceptance of σ* results in the



following bond interchange of i, ii, iii, and iv. Thus, theoretical calculations reproduce beautifully the reaction feature.

Concluding Remarks

Troponoid experts tend to think that [7]annulenone skeletons are rigid and cannot be broken usually. In this sense, the present ring opening is really surprising. Advantages of the unprecedented reaction are smooth occurrence under mild conditions, high yields, and stereoselectivity. The HOMO → σ* internal charge transfer in the anti tetrahedral intermediate is the driving force for the concerted ring opening.

Experimental Section

Reagents and Starting Material. Tropone (**3**),[24] tropothione (**4**),[10] [2,7-$^2H_2$]tropothione (**4**-d_2),[25] and 2-methyltropothione[11] were prepared as described previously. Grignard reagents were prepared according to published procedures[26] and titrated with *sec*-butanol using with 1,10-phenanthroline as an indicator.[27] Deuterium oxide (isotopic purity: 99.97%) (Merck) was used for deuterium-labeling experiments. Chloroform and dichloromethane were freshly distilled at reduced pressure to remove HCl. For column chromatography, Merck Kieselgel 60 (0.063−0.200 mm) was employed unless otherwise specified. Thin-layer chromatographic (TLC) analyses were performed on glass plates (Merck silica gel 60 GF_{254} and alumina 60 GF_{254}) with 0.2-mm layer thickness.

Instrumentation/Analytical Procedures. Melting points were determined on a Büchi 510 apparatus in open capillary tubes and are uncorrected. Elemental analyses were performed at the Analytical Laboratory, Department of Chemistry, the University of Tokyo, Hongo, Tokyo as well as at the Chemical Analysis Center, Saitama University. IR spectra were recorded in a KBr disk on a Hitachi 260-50 spectrometer. UV−visible spectra were taken with a Hitachi 340 spectrometer in hexane. Electron impact mass spectra (EI-MS) were obtained at 70 eV, unless otherwise specified, with a JEOL DX 303 double focusing spectrometer using a direct inlet. The values of *m/z* in significant ions were reported with relative intensities in parentheses (percent for the base peak) for low resolution analyses. NMR (^{13}C and ^1H) spectra were recorded on a JEOL FX 90Q (90 MHz) and Bruker AM-400 (400 MHz) Fourier transform NMR instruments in $CDCl_3$, unless otherwise specified, with Me_4Si as the internal standard. The experimental details for each type of NMR spectroscopy are described in the supplementary material. The quantitative difference $^1H\{^1H\}$ NOE measurements were performed in degassed $CDCl_3$ solutions at 27 °C.

Tropone Oxime (2). A solution of tropothione (2.24 g, 18.4 mmol) in 100 mL of chloroform was cooled to 0 °C, and then a solution of hydroxylamine (1.77 g, 53.6 mmol) in 20 mL of ethanol was added. The reaction mixture was stirred at 0 °C for 5 h. Workup gave 2.07 g (93%) of **2** as deep red prisms: mp 71.5−72 °C; IR ν_{max} 980 (s) cm^{-1}; ^1H NMR (90 MHz) δ 9.48 (br s, 1 H, OH), 6.95 (d, 1 H, J = 12.9 Hz, H-7), 6.50−6.04 (complex m, 5 H); ^{13}C NMR (22.5 MHz) δ 156.62 (s), 133.81 (d), 132.78 (d), 132.19 (d), 130.45 (d), 129.69 (d), 125.31 (d); EI-MS *m/z* 121 (M^+, 28), 78 (100). Anal. Calcd for C_7H_7ON: C, 69.41; H, 5.82; N, 11.56. Found: C, 69.38; H, 5.86; N, 11.44.

2-Methyltropone Oxime. By the similar preparation, 2-methyltropone oxime was synthesized from 1.34 g (1.12 mmol) of 2-methyltropothione and hydroxylamine (1.27 g, 38.5 mmol) in 15 mL of ethanol in 92% yield as deep red needles: mp 93−94 °C; IR ν_{max} 980 (s) cm^{-1}; ^1H NMR (90 MHz) δ 2.07 (s, 3 H, Me); ^{13}C NMR (22.5 MHz) δ 23.24 (q, Me); EI-MS *m/z* 135 (M^+, 18). Anal. Calcd for C_8H_9NO: C, 71.09; H, 6.71; N, 10.36. Found: C, 71.11; H, 6.80; N, 10.29.

[2,7-$^2H_2$]Tropone Oxime (2-d_2). Similarly to the above preparation of tropone oxime (**2**) from tropothione (**4**), [2,7-$^2H_2$]tropothione (**4**-d_2) (612 mg, 4.94 mmol) with hydroxylamine (475 mg, 14.4 mmol) gave 554 mg (91%) of **2**-d_2, deep red prisms: mp 72−73 °C; ^1H NMR (90 MHz) δ 9.41 (br s, 1 H, OH), 6.43−5.93 (complex m, 4 H); ^{13}C NMR (22.5 MHz) δ 156.56 (s), 133.34 (small abundant t, C-2 or C-7), 132.73 (d), 132.02 (d), 130.40 (d), 129.53 (d), 124.87 (small abundant t, C-2 or C-7); EI-MS (30 eV) *m/z* 123 (M^+, 91) (d_2: 96.3; d_1: 3.7%).

Tropone Oxime Tosylate (1). A solution of 5.49 g (45.3 mmol) of tropone oxime (**2**) in 14 mL of pyridine was added slowly to a solid of 9.05 g (47.5 mmol) of *p*-toluenesulfonyl chloride over a period of 30 min. The reaction mixture was stirred at 0 °C for 3 h. Workup gave yellow crystalline solid (12.1 g, 97%), which was purified by recrystallization from ethanol giving **1** as yellow needles: mp 94−95 °C; IR ν_{max} 1360 (s), 1185 (s) cm^{-1}; ^1H NMR (90 MHz) δ 7.84 (d, 2 H, J = 8.0 Hz, H-9 and H-13), 7.32 (d, 2 H, J = 8.0 Hz, H-10 and H-12), 6.93 (d, 1 H, J = 11.9 Hz, H-7), 6.40−6.24 (m, 5 H, H-2,-3, -4,-5, and -6), 2.44 (s, 3 H, Me); ^{13}C NMR (22.5 MHz) δ 161.98 (s, C-1), 144.86 (s, C-8), 135.38 (d), 134.08 (d), 133.54 (d), 133.00 (s, C-11), 131.59 (d), 131.48 (d), 129.53 (d, C-10 and C-12), 128.77 (d, C-9 and C-13), 124.22 (d, C-7), 21.62 (q, Me); EI-MS *m/z* 275 (M^+, 10), 120 (100), 90 (67). Anal. Calcd for $C_{14}H_{13}NO_3S$: C, 61.07; H, 4.76; N, 5.09; S, 11.65. Found: C, 61.13; H, 4.59; N, 5.08; S, 11.80.

2-Methyltropone Oxime Tosylate (6). Similar synthetic method was applied to obtain **6** (93% yield) using 2-methyltropone oxime (449 mg, 3.32 mmol), *p*-toluenesulfonyl chloride (677 mg, 3.55 mmol), and pyridine (1 mL). The obtained solid was purified by recrystallization from ethanol giving yellow needles (893 mg, 93%): mp 76−76.5 °C; IR ν_{max} 1363 (s), 1189 (s) cm^{-1}; ^1H NMR (90 MHz) δ 2.41 (s, 3 H, Me), 2.01 (s, 3 H, Me); ^{13}C NMR (22.5 MHz) δ 23.13 (q, Me), 21.51 (q, Me); EI-MS *m/z* 289 (M^+, 5%), 134 (64), 104 (64). Anal. Calcd for $C_{15}H_{15}NO_3S$: C, 62.26; H, 5.23; N, 4.84; S, 11.08. Found: C, 62.28; H, 5.33; N, 4.71; S, 11.02.

[2,7-$^2H_2$]Tropone Oxime Tosylate (1-d_2). In a similar way to the undeuteriated experiment, the tosylate was prepared from [2,7-$^2H_2$]-tropone oxime (**2**-d_2) (528 mg, 4.29 mmol), *p*-toluenesulfonyl chloride (870 mg, 4.56 mmol), and pyridine (1 mL) to afford **1**-d_2 (1.10 g, 3.97 mmol) in 93% yield as yellow needles: mp 94.5−95.5 °C; ^1H NMR (90 MH) δ 7.87 (d, 2 H, J = 8.4 Hz, H-9 and H-13), 7.32 (d, 2 H, J = 8.4 Hz, H-10 and H-12), 6.40−6.20 (m, 4 H, H-3,-4,-5, and -6), 2.43 (s, 3 H, Me); ^{13}C NMR (22.5 MHz) δ 161.98 (s, C-1), 144.86 (s, C-8), 135.27 (d), 134.08 (d), 133.38 (d), 133.11 (s, C-11), 131.59 (d), 131.32 (small abundant t), 129.53 (d, C-10 and C-12), 128.83 (d, C-9 and C-13), 124.06 (small abundant t), 21.62 (q, Me); EI-MS (30 eV) *m/z* 277 (M^+, 50) (d_2: 96.3; d_1: 3.7%).

General Procedure for Ring-opening Reactions of Tropone Oxime Tosylate (1) with Nucleophiles. In a typical case, to a stirred solution of the tosylate of tropone oxime (2.02 g, 7.34 mmol) in 30 mL of dichloromethane (or chloroform) was added an amine (5 equiv, 36.7 mmol) keeping the temperature below −20 °C. The completion of the reaction was confirmed by TLC on silica gel [benzene−methanol (99:1) elution], unless otherwise specified, as well as by intermittent ^1H-NMR monitoring. After evaporation of volatile material at −20 °C, cold dichloromethane or ether (10 mL) was added to the residue.

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(25) Machiguchi, T.; Mizuno, H.; Hasegawa, T.; Ishii, Y.; Otani, H. *Chem. Lett.* **1987**, 1893−1896.
(26) Fieser, L. F.; Fieser, M. *Reagents for Organic Synthesis*; John Wiley and Sons: New York, 1967; Vol. 1, pp 415−424.
(27) Watson, S. C.; Eastham, J. F. *J. Organomet. Chem.* **1967**, *9*, 165−168.

The obtained solution was washed with saturated aqueous NaCl solution (4 × 3 mL) and then dried over $MgSO_4$. Solvent removal in vacuo at −20 °C left the crude product, which was purified by recrystallization or medium-pressure column chromatography. Analytical samples were obtained by further recrystallization.

Reaction of Tropone Oxime Tosylate (1) with Pyrrolidine. The general procedure was followed, using **1** (2.02 g, 7.34 mmol) and pyrrolidine (3.00 mL, 35.9 mmol) in 30 mL of dichloromethane keeping the temperature below −20 °C. The solution changed from yellowish brown to dark reddish brown almost instantaneously. The reaction mixture was stirred at −20 °C for 1 h. Workup left reddish brown solid. Recrystallization from ethanol gave 6-1′-pyrrolidinyl-(*Z,Z,Z*)-1,3,5-hexatrienecarbonitrile (**5a**) (1.24 g, 97%) as yellow prisms (mp 53−54 °C, dec). An analytical sample was obtained by further recrystallization from ether.

5a: IR ν_{max} 2190 (s) cm^{-1}; UV−vis λ_{max} 377 nm (log ϵ 4.52); EI-MS *m/z* 174 (M^+, 100), 108 (51), 104 (23), 78 (18). Anal. Calcd for $C_{11}H_{14}N_2$: C, 75.82; H, 8.10; N, 16.08. Found: C, 75.71; H, 7.98; N, 16.19.

Reaction of Tropone Oxime Tosylate (1) with Dimethylamine. The general procedure was followed, using **1** (2.01 g, 7.31 mmol) in 10 mL of dichloromethane and dimethylamine (2.45 mL, 37.1 mmol) in 20 mL of dichloromethane keeping the temperature below −20 °C. The reaction mixture was stirred at −20 °C for 2 h. Workup left reddish brown solid. Recrystallization from ether gave 6-(dimethylamino)-(*Z,Z,Z*)-1,3,5-hexatrienecarbonitrile (**5b**) (517 mg, 96%) as yellow needles (mp 56−57 °C, dec). The reaction of **1** (1.00 g, 3.63 mmol) and dimethylamine (20.0 mL, 302 mmol) without solvent at −20 °C was completed for 30 min to give **5b** in 98% yield.

5b: IR ν_{max} 2195 (s) cm^{-1}; UV−vis λ_{max} 368 nm (log ϵ 4.59); EI-MS *m/z* 148 (M^+, 100), 104 (26), 82 (52), 78 (16). Anal. Calcd for $C_9H_{12}N_2$: C, 72.94; H, 8.16; N, 18.90. Found: C, 73.20; H, 8.43; N, 18.84.

Reaction of Tropone Oxime Tosylate (1) with Diethylamine. The general procedure was followed, using **1** (2.01 g, 7.30 mmol) and diethylamine (18.9 mL, 183 mmol) keeping the temperature below −20 °C. The reaction mixture was stirred at 0 °C for 2.5 h. Workup left brownish crystalline. Sublimative distillation gave 6-(diethylamino)-(*Z,Z,Z*)-1,3,5-hexatrienecarbonitrile (**5c**) (1.25 g, 97%) as yellow liquid [bp 19−20 °C (0.02 Torr)]. Recrystallization from cold ether gave 6-(diethylamino)-(*Z,Z,Z*)-1,3,5-hexatrienecarbonitrile (**5c**) as yellow prisms (the melting range between −2.5 and −0.5 °C).

5c: IR ν_{max} 2198 (s) cm^{-1}; UV−vis λ_{max} 374 nm (log ϵ 4.58); EI-MS *m/z* 176 (M^+, 100), 110 (54), 104 (24), 78 (14). Anal. Calcd for $C_{11}H_{16}N_2$: C, 74.95; H, 9.15; N, 15.90. Found: C, 74.81; H, 9.25; N, 15.60.

Reaction of Tropone Oxime Tosylate (1) with Morpholine. The general procedure was followed, using **1** (2.99 g, 10.9 mmol) and morpholine (23.7 mL, 274 mmol) keeping the temperature below 0 °C. The reaction mixture was stirred at 0 °C for 40 min. Workup left reddish brown solid. The solid was washed with ethanol at −40 °C and recrystallized from ether to afford 6-4′-morpholinyl-(*Z,Z,Z*)-hexatrienecarbonitrile (**5d**) (1.99 g, 96%) as yellow prisms (mp 44−45 °C, dec).

5d: IR ν_{max} 2190 (s) cm^{-1}; UV−vis λ_{max} 359 nm (log ϵ 4.54) ; EI-MS *m/z* 190 (M^+, 100), 124 (44), 104 (23), 78 (19). Anal. Calcd for $C_{11}H_{14}N_2O$: C, 69.44; H, 7.42; N, 14.73. Found: C, 69.29; H, 7.47; N, 14.54.

Reaction of Tropone Oxime Tosylate (1) with Sodium Methoxide. The general procedure was followed, using **1** (3.00 g, 10.9 mmol) in 50 mL of anhydrous tetrahydrofuran (THF) and sodium methoxide (21.8 mmol) in 10 mL of methanol keeping the temperature below 0 °C. The solution changed from yellowish brown to deep purple almost instantaneously. The reaction mixture was stirred at 0 °C for 4 h. The completion of this reaction was confirmed by TLC on alumina (benzene elution). One hundred milliliters of cold water was added to the reaction mixture, and the aqueous mixture was extracted with ether repeatedly. Solvent removal gave reddish brown solid. Recrystallization from ether gave 6-methoxy-(*Z,Z,Z*)-1,3,5-hexatrienecarbonitrile (**5e**) (1.42 g, 96%) as colorless needles (mp 54−55 °C).

5e: IR ν_{max} 2200 (s) cm^{-1}; UV−vis λ_{max} 314 nm (log ϵ 4.48); EI-MS *m/z* 135 (M^+, 93), 120 (15), 104 (21), 78 (18). Anal. Calcd for C_8H_9NO: C, 71.09; H, 6.71; N, 10.36. Found: C, 71.02; H, 6.90; N, 10.57.

Reaction of Tropone Oxime Tosylate (1) with Sodium Ethoxide. By the similar experiment using **1** (3.00 g, 10.9 mmol) in 50 mL of anhydrous THF and sodium ethoxide (21.8 mmol) in 10 mL of ethanol, 6-ethoxy-(*Z,Z,Z*)-1,3,5-hexatrienecarbonitrile (**5f**) (1.59 g, 98%) was obtained as colorless needles (mp 42−43 °C).

5f: IR ν_{max} 2200 (s) cm^{-1}; UV−vis λ_{max} 318 nm (log ϵ 4.48); EI-MS *m/z* 149 (M^+, 92), 120 (14), 104 (26), 78 (23). Anal. Calcd for $C_9H_{11}NO$: C, 72.46; H, 7.43; N, 9.39. Found: C, 71.90; H, 7.37; N, 9.14.

Reaction of Tropone Oxime Tosylate (1) with Methyl Magnesium Iodide. The general procedure was followed, using **1** (3.00 g, 10.9 mmol) in 43 mL of THF and an ethereal solution (11.4 mL) of methyl magnesium iodide (16.4 mmol) . The reaction mixture was stirred at 0 °C for 4 h. The mixture was added 60 mL of aqueous ammonium chloride solution (0.28 mol) at once at −18 °C. The resultant ethereal solution was washed with cold saturated solution of sodium chloride several times until a neutral solution was obtained. Solvent removal left brownish oily residue. The residue was passed through short florizil column chromatography eluted with dichloromethane and then was purified by silica gel column chromatography eluted with benzene to give yellowish crystals (669 mg, 52%). Recrystallization from ether gave 6-methyl-(*Z,Z,Z*)-1,3,5-heptatrienecarbonitrile (**5g**) as colorless needles (mp 42−43 °C).

5g: IR ν_{max} 2220 (s) cm^{-1}; UV−vis λ_{max} 295 nm (log ϵ 4.49), EI-MS *m/z* 119 (M^+, 67), 118 (54), 78 (15). Anal. Calcd for C_8H_9N: C, 80.63; H, 7.61; N, 11.76. Found: C, 80.37; H, 7.34; N, 12.03.

Reaction of Tropone Oxime Tosylate (1) with Phenyl Magnesium Bromide. The general procedure was followed, using **1** (3.00 g, 10.9 mmol) in 45 mL of THF and an ethereal solution (10.0 mL) of phenyl magnesium bromide (16.4 mmol). The reaction mixture was stirred for 3 h at 0 °C. Workup similar to the above case of MeMgI left an oily residue. The residue was purified by silica gel column chromatography eluted with benzene to give yellowish crystals (1.33 g, 67%). Recrystallization from ether gave 6-phenyl-(*Z,Z,Z*)-1,3,5-hexatrienecarbonitrile (**5h**) as colorless needles (mp 35−36 °C).

5h: IR ν_{max} 2210 (s) cm^{-1}; UV−vis λ_{max} 318 nm (log ϵ 4.52); EI-MS *m/z* 181 (M^+, 71), 180 (100), 153 (53), 78 (18). Anal. Calcd for $C_{13}H_{11}N$: C, 86.15; H, 6.12; N, 7.73. Found: C, 86.19; H, 6.22; N, 7.67.

Reaction of 2-Methyltropone Oxime Tosylate (6) with Dimethylamine. The general procedure was followed, using **6** (1.57 g, 5.43 mmol) in 1 mL of dichloromethane and 15.0 mL of dimethylamine (226 mmol) keeping the temperature at −20 °C. The reaction mixture was stirred at −10 °C for 2 h. Workup keeping the temperature below 0 °C similar to the above case of dimethylamine left yellowish brown crystalline material. Recrystallization from cold methanol gave 6-(dimethylamino)-(*Z,Z,Z*)-1,3,5-heptatrienecarbonitrile (**7**) (830 mg, 95%).

7: yellow cubes, mp 5−7 °C (dec); ^1H NMR (400 MHz, −45 °C) δ 7.33 (ddd, 1 H, J = 12.1, 10.7, 1.1 Hz, H-2), 6.79 (dddd, 1 H, J = 12.7, 10.6, 1.3, 1.1 Hz, H-4), 5.91 (ddd, 1 H, J = 12.1, 10.5, 1.1 Hz, H-3), 5.20 (d, 1 H, J = 12.9 Hz, H-5), 4.91 (ddd, 1 H, J = 10.7, 1.3, 1.1 Hz, H-1), 3.04 (s, 6 H, NMe_2), 1.98 (s, 3 H, Me); ^{13}C NMR (100.6 MHz, −45 °C) δ 118.75 (s, C≡N), 40.14 (q, NMe_2), 14.98 (q, Me); quantitative difference NOE experiment; irr δ 6.79 (H-4), enhanced δ 5.91 (21%, H-3), 3.04 (15%, NMe_2); irr δ 5.20 (H-5), enhanced δ 7.33 (18%, H-2), 1.98 (20%, Me); irr δ 3.04 (NMe_2), enhanced δ 6.79 (15%, H-4); irr δ 1.98 (Me), enhanced δ 5.20 (21%, H-5). HR MS calcd mass for $C_{10}H_{14}N_2$ 162.1157, found 162.1163.

Further recrystallization from boiling ether gave the *Z,Z,E*-isomer, 6-(dimethylamino)-(*Z,Z,E*)-1,3,5-heptatrienecarbonitrile (**8**) by thermal isomerization.

8: yellow needles, mp 74.5−75.5 °C (dec); IR ν_{max} 2190 (s) cm^{-1}; UV−vis λ_{max} 376 nm (log ϵ 4.59); EI-MS *m/z* 162 (M^+, 100); ^1H NMR (400 MHz) δ 7.31 (ddd, 1 H, J = 12.4, 10.7, 1.1 Hz, H-2), 6.66 (dddd, 1 H, J = 12.5, 10.6, 1.3, 1.1 Hz, H-4), 5.95 (ddd, 1 H, J = 12.4, 10.6, 1.0 Hz, H-3), 5.40 (d, 1 H, J = 12.5 Hz, H-5), 4.83 (ddd, 1 H, J = 10.7, 1.3, 1.0 Hz, H-1), 2.94 (s, 6 H, NMe_2), 2.03 (s, 3 H, Me); ^{13}C NMR (100.6 MHz) δ 118.34 (s, C≡N), 40.04 (q, NMe_2), 14.86 (q, Me); quantitative difference NOE experiment; irr δ 6.66 (H-4), enhanced δ 5.95 (19%, H-3), 2.03 (20%, Me); irr δ 5.40 (H-5),

enhanced δ 7.31 (19%, H-2), 2.94 (16%, NMe_2); irr δ 2.94 (NMe_2), enhanced δ 5.40 (20%, H-5); irr δ 2.03 (Me), enhanced δ 6.66 (24%, H-4). Anal. Calcd for $C_{10}H_{14}N_2$: C, 74.03; H, 8.70; N, 17.29. Found: C, 73.82; H, 8.69; N, 16.98.

The *Z,Z,E*-isomer (**8**) was dissolved in dichloromethane and passed through alumina column chromatography [Wako alumina (200 mesh)]. Solvent removal in vacuo at −20 °C afforded the *E,E,E*-isomer (**9**).

9: yellow needles, mp 83−84 °C (dec); IR ν_{max} 2180 (s) cm^{-1}; UV−vis λ_{max} 376 nm (log ϵ 4.49); EI-MS *m/z* 162 (M^+, 100); ^1H NMR (400 MHz) δ 7.02 (ddd, 1 H, J = 15.7, 11.5, 0.7 Hz, H-2), 6.79 (ddt, 1 H, J = 14.3, 11.7, 0.7 Hz, H-4), 5.96 (dd, 1 H, J = 14.3, 11.5 Hz, H-3), 5.11 (d, 1 H, J = 11.7 Hz, H-5), 4.89 (dd, 1 H, J = 15.7, 0.7 Hz, H-1), 2.93 (s, 6 H, NMe_2), 2.03 (s, 3 H, Me); ^{13}C NMR (100.6 MHz) δ 120.88 (s, C≡N), 40.01 (q, NMe_2), 15.09 (q, Me); quantitative difference NOE experiment; irr δ 2.03 (Me), enhanced δ 6.79 (17%, H-4). Anal. Calcd for $C_{10}H_{14}N_2$: C, 74.03; H, 8.70; N, 17.29. Found: C, 73.88; H, 8.73; N, 16.99.

Reaction of [2,7-$^2H_2$]Tropone Oxime Tosylate (1-d_2) with Pyrrolidine. The general procedure was followed using **1**-d_2 (326 mg, 1.18 mmol) in 2 mL of dichloromethane and pyrrolidine (0.55 mL, 6.58 mmol) keeping the temperature at −20 °C. The reaction mixture was stirred at −20 °C for 1 h. Workup similar to the above pyrrolidine case left yellowish brown crystalline compounds . Recrystallization from ether gave 6-1′-pyrrolidinyl-(*Z,Z,Z*)-1,3,5-[1,6-$^2H_2$]hexatrienecarbonitrile (**5a**-d_2) (204 mg, 98%) as yellow prisms, mp 52−53 °C (dec).

5a-d_2: EI-MS *m/z* (30 eV) 176 (M^+, 100); ^1H NMR (400 MHz) δ 7.29 (dtd, 1 H, J = 11.9, 1.7, 1.0 Hz, H-2), 6.90 (ddd, 1 H, J = 13.2, 10.6, 1.0 Hz, H-4), 5.97 (ddd, 1 H, J = 11.9, 10.6, 0.6 Hz, H-3), 5.12 (dtd, 1 H, J = 13.2, 1.3, 0.6 Hz, H-5), 3.46 (t, 4 H, J = 6.6 Hz, H-2′,5′), 1.90 (m, 4 H, H-3′,4′); ^{13}C NMR (100.6 MHz) δ 143.79 (d, C-2), 139.07 (small abundant t, C-6), 135.74 (d, C-4), 118.07 (s, C≡N), 114.52 (d, C-3), 92.57 (d, C-5), 89.49 (small abundant t, C-1), 52.14 (t, C-2′,5′), 25.55 (t, C-3′,4′).

Computational Methods. Semiempirical MO[23] calculations were carried with the CONVEX C-220 computer in the Information Processing Center of Nara University of Education and with CONVEX C-3420 computer in the Computer Center of Nara University.

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Supplementary Material Available: An ORTEP plot illustrating anti-configuration of 2-methyltropone oxime tosylate (**6**), a table of atomic coordinates and thermal parameters for the X-ray diffraction analysis of **6**, full spectral data of IR, UV−vis, MS, ^1H NMR and quantitative difference $^1H\{^1H\}$ NOE for the reported compounds, tables of ^{13}C NMR full spectral data for the reported compounds (**5a**−**h**), NMR spectral charts for representatives (**5a**, **5e**, and **5g**) of the reported compounds [400-MHz ^1H NMR (Lorentz-transformed spectra and those resolution-enhanced with Gaussian and sine-bell wind functions), 2D NMR $^1H-^1H$ COSY and $^1H-^1H$ COLOC, 100.6-MHz ^{13}C NMR with CPD, gated decoupling (resolution-enhanced with Gaussian wind function), 2D NMR $^{13}C-^1H$ COSY and $^{13}C-^1H$ COLOC spectra], and Z-matrices of PM3 optimized geometries in Figure 1 (69 pages). This material is contained in many libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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