Table 1. Resonance assignments of heme methyl and propionate protons of *Dv*MF ferricytochrome c_3 at p^2H 7.0 and 30 ℃

Heme number	Position	Chemical shift/ppm
	2^1CH_3	18.92 (F)
	7^1CH_3	9.60 (M)
	12^1CH_3	18.07 (G)
1	18^1CH_3	29.27 (B)
h2′	13^1CH_2	0.41, −3.92
	13^2CH_2	1.42, −2.20
	17^1CH_2	5.79, 4.46
	17^2CH_2	2.65, 2.41
	2^1CH_3	6.44 (O)
	7^1CH_3	20.21 (D)
	12^1CH_3	20.49 (C)
2	18^1CH_3	7.51 (N)
h3′	13^1CH_2	11.36, 4.67
	13^2CH_2	0.67, −0.63
	17^1CH_2	2.22, 0.71
	17^2CH_2	−0.35, −0.57
	2^1CH_3	13.46 (J)
	7^1CH_3	10.30 (L)
	12^1CH_3	19.91 (E)
3	18^1CH_3	0.42 (P)
h4′	13^1CH_2	17.67, 16.05
	13^2CH_2	0.08, −1.18
	17^1CH_2	6.71, −2.32
	17^2CH_2	0.80, −3.60
	2^1CH_3	17.47 (H)
	7^1CH_3	10.64 (K)
	12^1CH_3	16.51 (I)
4	18^1CH_3	30.46 (A)
h1′	13^1CH_2	−0.23, −3.76
	13^2CH_2	0.20, 0.60
	17^1CH_2	9.62, 6.12
	17^2CH_2	3.62, 3.35

( ), labels of the heme methyl signals in the text and hi′, the heme numbering according to the order of the major reduction.

2-CH_3 of heme 3 (J). The TOCSY connectivity of the last propionate is shown in Figure 3.

From NOESY cross peaks, the heme methyl group in the proximity (signal N) could be identified (Figure 3). On irradiation at signal N, an NOE signal was observed at signal O (the spectrum is not shown). Since the second nearest heme methyl group from 2-CH_3 of heme 2 (O) is that at C-18 of heme 2, signal N can be assigned to it. This was confirmed by an NOESY cross between the β proton of 17-propionate of heme 2 and His67 C_4H, the interproton distance of which is 0.326 nm according to the crystal structure. Now, signal L is the only one left and should be ascribed to 7-CH_3 of heme 3. The assignment could be carried out consistently just by moving signal J from h3′ to h4′. The assignments of heme methyl groups and propionate groups were summarized in Table 1.

The heme assignment was revised for hemes 2 and 3 (sequential heme number). Our next target is to elucidate the structural factors which determine the redox potentials of each of the four hemes on the basis of the assignments established in this work.

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Intramolecular Hydrodimerization of Activated Dienes Mediated by Magnesium in Methanol

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It has been reported that the electrochemical hydrodimerization of α,β-unsaturated ketones, esters, and nitriles proceeds *via* anion radicals in aprotic media in the absence of metal cations, and allyl radicals in protic media, respectively.[1] As previously noted for sequential C-C bond formation *via* one electron transfer, methods for intramolecular β-coupling reaction of activated olefins have been limited to electrochemical hydrodimerization and n-Bu_3SnH.[2] Recently, it has been reported that intramolecular cyclization of activated dienes with magnesium metal in methanol at room temperature proceeds smoothly.[3] we proposed that reactions proceed *via* allyl radical intermediate resulting from one electron transfer to activated olefins followed by protonation of anion radicals in the presnece of proton donor, methanol.[4]

Here we report that intramolecular hydrodimerization of

Table 1. Intramolecular Hydrodimerization of Activated Bisolefins with Magnesium Powder in Absolute Methanol at −43 ℃ in the presence of catalytic amount of $HgCl_2$

Substrates[a]		Ratio of products[c,d]	Isolated yields (%)
1		**1t/1c-cis/1c-trans**	**1t+1c-cis+1c-trans**
COMe, COMe	**1A** (2Z, 7Z)	10.5/2.4/1.0	94
	1B (2Z, 7E)	5.1/2.4/1.0	95
	1C (2E, 7E)	5.3/2.3/1.0	94
2		**2t/2c/2s**	**2t+2c+2s**
CO_2Me, CO_2Me	**2A** (2Z, 7Z)	15.3/1.0/6.0	100
	2B (2Z, 7E)	2.0/2.0/1.0	100
	2C (2E, 7E)	2.0/2.0/1.0	100
3[b]		**(3t+3c)/3s**	**3t+3c+3s**
CN, CN		1.0/1.6	100

[a] Substrates were prepared from the reaction of 25% glutaraldehyde with the corresponding triphenylphosphorylidenes in methanol at 50 ℃ followed by the separation with the silica gel column chromatography. [b] Isomeric mixture. [c] **t** and **c** designates *trans* and *cis* relationships between the functional group appendage when cyclized, and *s* designates the simple reduction product not cyclized. [d] **Cis** and **trans** designate *cis* and *trans* relationship between 1-H and 2-acetyl group in bicyclic products, respectively. [e] Ratios were determined by 500 MHz ^1H NMR.

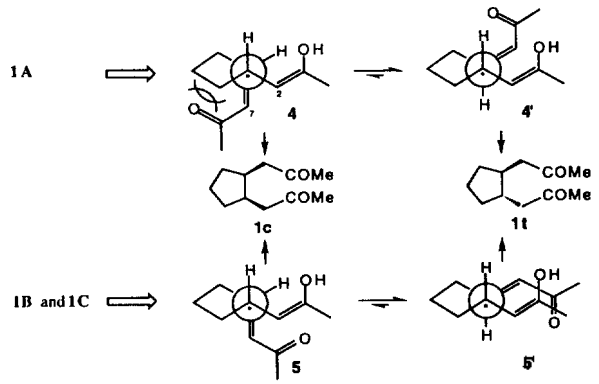


Figure 1.

activated bisolefins proceeds *via* stepwise irreversible 1,4-addition of allyl radical resulting from one electron transfer to an activated olefins to afford substituted cyclopentane rings (Table 1). When geometric isomers of bisolefins activated with ketone group (**1A**, **1B**, and **1C**) were treated with 3 equiv magnesium powder in absolute methanol at −43 ℃ in the presence of a catalytic amount of mercuric chloride, a *trans* product **1t** and cyclized products (**1c-cis** and **1c-trans**) derived from the *cis* product **1c**, presumably *via* 1,4-addition of ally radical intermediate was obtained in 94% yield. Regardless of the configuration of carbon-carbon double bond the major product was *trans* isomer. It might be mostly due to the steric hindrance caused by the vicinal appendage (acetyl group) in the course of cyclopentane ring formation. It is noteworthy that the *trans/cis* product ratio from **1B** and **1C** was approximately the same, on the other hand the ratio

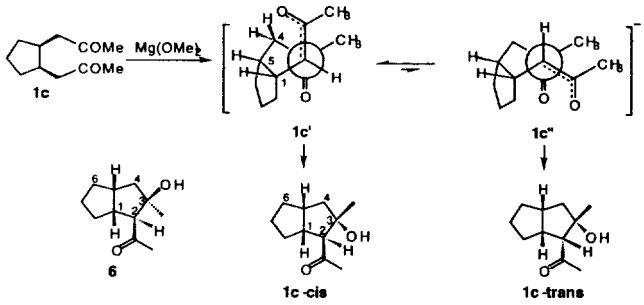


Figure 2.

from **1A** was twice as high as the other two. It can be explained considering that once an electron is transferred to either Z-enone part of **1B**, which is preferred electron acceptor to the corresponding E-enone part,[1a] or E-enone part of **1C** at C-2 atoms, rapid thermodynamic equilibrium occurs before the cyclization step takes places due to the low rotation barrier of C_2-C_3 bond of allyl radical to give the identical equilibrium mixture with *s-trans* configuration as a major.

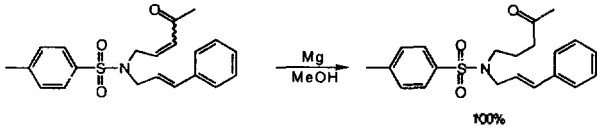
In the case of **1A**, while the configuration of the allyl radical part resulting from an electron transfer to Z-enone part followed by protonation of the anion radical with methanol is the same as that of **1B** and **1C**, the configuration of remaining Z-enone part is different from E-enone part of **1B** and **1C**. Such a configurational difference of allyl radical acceptor plays a crucial role in determining stereochemistry of cyclopentane ring (Figure 1).

Since the steric repulsion between acetyl group in endo position and cyclopentane ring in allyl radical intermediate **4** is severer compared to that between the acetyl group in exo position and the cyclopentane ring in the allyl radical intermediate **5**, stereoselectivity of *trans* and *cis* products seems to be larger in **1A** than in **1B** and **1C**. Simutaneous aldol condensation of the *cis* product **1c** under the basic media, $Mg(OMe)_2$, affords stereoisomeric [3.3.0]bicyclic products, **1c-cis** and **1c-trans** (Figure 2). When the aldol condensation takes place, the transition state **1c'** is more stable than the transition state **1c"** so that **1c-cis** was obtained as a major product. Although **1c'** is sterically less favorable than **1c"** due to the steric hindrance between H-4 atom and acetyl group, electronically **1c'** is more favorable than **1c"**. As a result, electronic effect prevails in determining the stereochemistry of the products.[4a]

And the steric hindrance between the methyl group and the pentane ring gives the *cis* relationship between 1-H atom and 3-CH_3 group. Stereochemistry of **1c-cis** and **1c-trans** was determined by analysis of 600 MHz NOESY spectrum.[5] In contrast to the Mg/MeOH case, when **1c** was treated with n-Bu_3SnH a single bicyclic isomer **6** of the *trans* relationship between 1-H and 3-CH_3 and **1t** was obtained in the ratio of 1 : 3.5.[2a]

In the case of bisolefins **2** where ester group was attached as an activating group, similar stereochemical trends were observed. However, higher stereoselectivity (*trans/cis* : 15/1) was attained for **2A** compared to **2B** and **2C**. Interestingly, bisolefin **1** did not give any simple reduction product at all, whereas bisolefins **2** and **3** gave the simple reduction products (**2s** and **3s**) in 25% and 60% yields, respectively. The similiar result was observed when the α,β-unsaturated

nitrile group tethered to the ketone was cyclized with magnesium metal in absolute methanol, a large amount of saturated product was obtained.[4a] In an attempt to trap a radical intermediate, an α,β-unsaturated ketone tethered to a good radical acceptor as shown below was subjected to the same reaction condition as above, however, we only obtained the simple reduction product in quantitative yield instead of the expected 5-*exo-trig.* cyclized product.



Although the mechanistic explanation of magnesium in methanol had been suggested to proceed through the β-coupling of radical anion intermediate,[6] exact mechanism is needed to be defined further.

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5. **1c-cis**: needle-type white crystal; R_f 0.22 (hexane/ethyl acetate, 5/1, v/v); mp 71-72 °C (hexane); ^{1}H NMR (500 MHz, $CDCl_3$) d 2.70-2.87 (m, 2H, H-1 and OH), 2.55 (d, J=9.8 Hz, 1H, H-2), 2.33-2.44 (m, 1H, H-5), 2.25 (s, 3H, CH_3CO), 1.99 (dd, J=12.1 and 8.2 Hz, 1H, H-4), 1.52-1.69 (m, 4H, H-8, H-7, and H-6), 1.49 (dd, J=12.1 and 11.2 Hz, 1H, H-4'), 1.30-1.43 (m, 2H, H-8' and H-6'), 1.13 (s, 3H, CH_3); ^{13}C NMR ($CDCl_3$) d 210.67 (CO), 80.62 (C-3), 68.04 (C-2), 49.55 (C-4), 41.66 (C-1), 37.81 (C-5), 32.94 (C-6), 32.83 (C-8), 31.24 (CH_3CO), 24.73 (C-7), 23.17 (CH_3); IR (neat) 3407 (OH), 2957, 1691 (CO), 1456, 1425, 1374, 1291, 1241, 1179, 1140, 1100, 1066, 1037, 978, 940, 823 cm^{-1}; MS m/e (*rel* intensity) 184 (M^++2, 3.0), 183 (M^++1, 9.2), 182 (M^+, 1.0), 165 (34.0), 125 (18.2), 124 (100), 121 (22.6), 109 (11.4), 97 (13.0), 86 (15.1), 84 (26.6), 81 (17.7), 71 (13.3), 66 (23.0), 43 (71.5). Anal. Calcd for $C_{11}H_{18}O_2$: C, 72.49; H, 9.95. Found: C, 72.54; H, 9.91.
1c-trans: colorless oil; R_f 0.35 (hexane/ethyl acetate, 5/1, v/v); ^{1}H NMR (500 MHz, $CDCl_3$) d 4.10 (brs, 1H, OH), 2.76-2.85 (m, 1H, H-5), 2.69-2.76 (m, 1H, H-1), 2.35 (d, J=9.7 Hz, 1H, H-2), 2.23 (s, 3H, CH_3CO), 2.00 (dd, J=13.2 and 8.1 Hz, 1H, H-4), 1.70-1.79 (m, 1H, H-8), 1.54-1.70 (m, 4H, H-6, H-7, and H-8'), 1.32-1.41 (m, 1H, H-6'), 1.30 (s, 3H, CH_3), 1.14 (dd, J=13.2 and 9.8 Hz, 1H, H-4'); ^{13}C NMR ($CDCl_3$) d 214.56 (CO), 82.52 (C-3), 65.97 (C-2), 47.97 (C-4), 47.37 (C-1), 41.74 (C-5), 32.97 (C-8), 32.56 (C-6), 31.95 (CH_3CO), 25.95 (CH_3), 25.30 (C-7); IR (neat) 3395 (OH), 2962, 1683 (CO), 1464, 1427, 1384, 1360, 1289, 1257, 1187, 1158, 1136, 1097, 1031, 1006, 957, 852, 639, 582 cm-1; MS m/e (rel intensity) 163 (M^+-1-H_2O), 149 (9.2), 125 (23.2), 124 (71.7), 123 (15.8), 121 (33.2), 111 (9.3), 97 (13.3), 93 (20.2), 86 (18.7), 84 (80.0), 79 (23.9), 71 (16.0), 67 (21.0), 57 (21.0), 43 (100). Anal. Calcd for $C_{11}H_{18}O_2$: C, 72.49; H, 9.95. Found: C, 72.57; H, 9.96.
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A Convenient Method for the Preparation of Nitriles and Carbodiimides Using *N*-Methyl-2-Pyridinecarbamoyl Chloride

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In connection with our study on the synthetic utility of active carbamoyl chloride, we have reported that *N*-methyl-2-pyridinecarbamoyl chloride is an efficient coupling reagent of carboxylic acids.[1] We now wish to report that nitriles can be prepared from aldoximes in high yields and thioureas are cleanly converted into the corresponding carbodiimides using *N*-methyl-2-pyridinecarbamoyl chloride.

N-Methyl-2-pyridinecarbamoyl chloride was new conveniently prepared by addition of an equimolar solution of 2-(methylamino)pyridine and triethylamine in methylene chloride to a solution of one-third equivalent of bis(trichloromethyl)carbonate("triphosgene"),[2] a crystalline, stable solid, in methylene chloride at 0 °C (eq. 1).