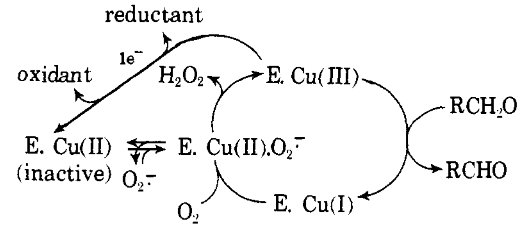
Scheme I



converted by one-electron redoxants such as the iron hexacyanides. The oxidation of the alcohol by the enzymic Cu(III) presumably occurs by a mechanism similar to the oxidation of alcohols by Cr(VI)[2,14] and Cr(V).[14]

The ease by which the Cu(III) form of galactose oxidase is formed suggests that Cu(III) may well be an intermediate in other cuproenzymic reactions also. This seems especially likely in the case of tyrosinase; recent work with a tyrosinase containing only one atom of Cu per molecule[15] indicates that it exists in two redox states (differing by two electrons), neither of which is EPR active. Very possibly these are the Cu(I) and Cu(III) forms as in the case of galactose oxidase.

References and Notes

(1) This research was supported by a research grant (AM 13448) from the National Institute of Arthritis, Metabolism, and Digestive Diseases, Public Health Service. The EPR spectrometer used in this research was purchased using funds partially supplied by an equipment grant from the National Science Foundation to the Chemistry Department.

(2) G. A. Hamilton, R. D. Libby, and C. R. Hartzell, *Biochem. Biophys. Res. Commun.*, **55**, 333 (1973).

(3) In papers published at about the same time as our own[2] Kosman and co-workers (L. D. Kwiatkowski and D. J. Kosman, *Biochem. Biophys. Res. Commun.*, **53**, 715 (1973); D. J. Kosman, R. D. Bereman, M. J. Ettinger, and R. S. Giordano, *ibid.*, **54**, 856 (1973)) reported results and conclusions which seem at variance with ours. However, the different results are due entirely to the different conditions under which they were obtained. Thus, Kosman and co-workers observed little effect of superoxide dismutase because EDTA was not present in their assays, and trace metal ions perform the same function as superoxide dimutase.[2] Also, no effect of superoxide dismutase on the intensity of the EPR signal from the galactose oxidase copper was observed because their experiments were performed under nonturnover conditions; our results[2] indicate that thousands of turnovers must occur before the dismutase effect is observed. Suffice it to say, that in our hands enzyme prepared and supplied by Kosman shows very similar (only slight quantitative differences) kinetic effects to our own in the presence of various additives.[2] We thank Professor Kosman for supplying us with some of his enzyme.

(4) Private communication from several investigators. See also L. Cleveland, R. E. Coffman, P. Coon, and L. Davis, *Biochemistry*, **14**, 1108 (1975).

(5) (a) R. D. Libby, Ph.D. Thesis, The Pennsylvania State University, 1974; (b) G. A. Hamilton, J. de Jersey, and P. K. Adolf in "Oxidases and Related Redox Systems (Proceedings of the 2nd International Symposium)", T. E. King, H. S. Mason, and M. Morrison, Ed., University Park Press, Baltimore, Md., 1973, p 103.

(6) D. J. Kosman, M. J. Ettinger, R. E. Weiner, and E. J. Massaro, *Arch. Biochem. Biophys.*, **165**, 456 (1974).

(7) "Enzyme Nomenclature", American Elsevier, New York, N.Y., 1972, p 26.

(8) The smaller concentration of chloroiridate required for maximum activation is expected because of its higher redox potential (0.899 V compared to 0.424 V for ferricyanide).[9]

(9) (a) E. Jackson and D. A. Pantony, *J. Appl. Electrochem.*, **1**, 113 (1971); (b) J. E. O'Reilly, *Biochim. Biophys. Acta*, **292**, 509 (1973).

(10) From experiments at other pH's (not illustrated), we found the potential for the enzymic group is dependent on pH; experiments are continuing to clarify the pK_a of the group(s) involved. However, below pH 7 the main reaction occurring is $E_{ox} + e^- + H^+ \rightleftharpoons E_{red}$.

(11) M. J. Ettinger, *Biochemistry*, 13, 1242 (1974).

(12) (a) J. J. Bour, P. J. M. W. L. Birker, and J. J. Steggerda, *Inorg. Chem.*, **10**, 1202 (1971); (b) D. C. Olson and J. Vasilevskis, *ibid.* **10**, 463 (1971); (c) L. F. Warren, and M. A. Bennett, *J. Am. Chem. Soc.*, **96**, 3340 (1974); (d) F. J. Hollander, M. L. Caffery, and D. Coucouvanis, *ibid.*, **96**, 4682 (1974); (e) D. W. Margerum, K. L. Chellappa, F. P. Bossu, and G. L. Burce, *ibid.*, **97**, 6894 (1975); (f) G. L. Burce, E. B. Paniago, and D. W. Margerum, *J. Chem. Soc., Chem. Commun.*, 261 (1975).

(13) (a) M. Anbar, R. A. Munoz, and P. Rona, *J. Phys. Chem.*, **67**, 2708 (1963); (b) A. Levitzki, M. Anbar, and A. Berger, *Biochemistry*, **6**, 3757 (1967).

(14) (a) J. Rocek and A. E. Radkowsky, *J. Am. Chem. Soc.*, **95**, 7123 (1973); M. Rahman and J. Roček, *ibid*, **93**, 5455, 5462 (1971); (b) K. B. Wiberg and S. K. Mukherjee, *ibid.*, **96**, 1884 (1974).

(15) S. Gutteridge and D. Robb, *Eur. J. Biochem.*, **54**, 107 (1975).

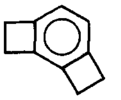
(16) NIH Special Research Fellow (GM 57203), 1975, in the laboratory of O. Hayaishi, Department of Medical Chemistry, Kyoto University, Kyoto, Japan.

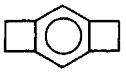
Gary R. Dyrkacz, R. Daniel Libby, Gordon A. Hamilton*[16]
Department of Chemistry, The Pennsylvania State University
University Park, Pennsylvania 16802
Received October 20, 1975

Benzo[1,2:3,4]dicyclobutene

Sir:

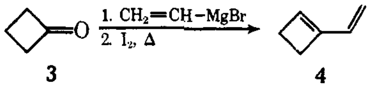
We wish to report the synthesis of benzo[1,2:3,4]dicyclobutene (**1**), a benzene molecule upon which two cyclobutene rings are fused meta to one another. The isomeric benzo[1,2:4,5]dicyclobutene (**2**) has been reported by Cava and coworkers who prepared this system by the thermal extrusion of two molecules of sulfur dioxide from the corresponding disulfone.[1]


1


2

Lawrence and MacDonald have determined the x-ray structure of **2**.[2] They found little variation in the bond lengths of the six-membered ring. The two bridging bonds measured 1.35 Å while the remaining bonds in the benzene ring were found to be 1.38 Å. The interior benzene bond angles were substantially distorted from the normal 120°, measuring 108° at the four bridgehead carbons and 126° at the two remaining positions. A theoretical consideration of the hybridization of **2** utilizing the maximum overlap method has lent further support to the highly strained nature of **2**.[3] The potential for similar comparisons between **1** and **2** prompted us to synthesize the meta-fused isomer.

The key reaction employed in the synthesis of **1** is the Diels–Alder addition of 1-vinylcyclobutene (**4**) to dimethyl cyclobutene-1,2-dicarboxylate (**5**). The preparation of diene **4** is as yet unreported but could be accomplished in a straightforward manner. The addition of vinyl magnesium bromide to cyclobutanone provided 1-vinylcyclobutanol in 66% yield. When this alcohol was heated in the presence of a small amount of iodine crystals, dehydration occurred and 1-vinylcyclobutene was distilled from the mixture in 72% yield, bp 82° (760 mm). The NMR spectrum of **4** showed an ABX pattern at δ 6.5–4.9 for the three vinyl protons, an olefinic resonance at δ 5.83, and the allylic ring protons as a multiplet at δ 2.5.

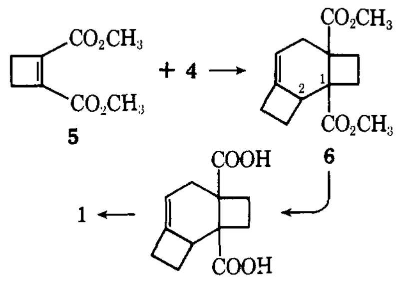


3 4

The 2 + 4 cycloaddition of **4** and **5** provided 1,8-dicarbomethoxytricyclo[6.2.0.0^{2,5}]dec-5-ene (**6**) which showed two overlapping peaks at long VPC retention time. This product mixture could be explained by competing exo and endo modes of Diels–Alder addition which should provide a molecule which is epimeric at the tertiary carbon, C-2. An NMR spectrum of the mixture exhibited three groups of signals in the ratio of 1:6:11, lending support to the gross overall structure of **6**. Hydrolysis of **6** with potassium hydroxide in refluxing aqueous methanol provided the corresponding diacid **7** whose NMR spectrum showed a two proton signal at δ 9.8 as well as the disappearance of the methyl ester singlets.

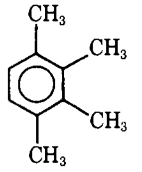
Table I. Melting Point (°C) and Ultraviolet (nm) Absorption Data

Compound	mp	$\lambda_{max}^{95\%EtOH}$ (ϵ)		
1	36	266 (1360)	269 (1370)	275 (1540)
8	−6	267 (301)	272 (244)	276 (235)
2[1]	101	276 (4570)	280 (5125)	286 (3890)
9	79	268 (712)	273 (654)	278 (727)

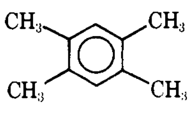


Utilizing 2 equiv of lead tetraacetate in a manner previously described,[4] the bis decarboxylation of 1.11 g of **7** and subsequent aromatization were achieved in a single reaction. Chromatography of the crude product on silica gel, eluting with 20% ether–hexane, provided 70 mg of material which was 50% of a single component by VPC. A pure sample of **1**, mp 36°,[5] was obtained by preparative gas chromatography on a Carbowax 20M column.

A high resolution mass spectrum of the purified product showed a parent peak at 130.0782 (calcd for $C_{10}H_{10}$ 130.0783) as well as significant peaks at *m/e* 115 (rel intensity 90, loss of $\cdot CH_3$) and *m/e* 102 (rel intensity 12, loss of $CH_2{=}CH_2$). In the infrared spectrum, the only noteworthy absorption below 1200 cm^{-1} was a sharp, strong band at 821 cm^{-1} which corresponds to the characteristic out-of-plane bending for a 1,2,3,4-substituted benzene.[6] The 100-MHz NMR spectrum of **1** showed a two proton singlet at δ 6.74 and an eight proton singlet at δ 3.08, again indicating a tetrasubstituted benzene ring. The uv data recorded in Table I further support the existence of a benzene nucleus and differentiate clearly between structures **1** and **2**. The only structure for **1** which is completely consistent with all the above spectroscopic evidence is benzo[1,2:3,4]dicyclobutene.



8



9

The upfield singlet in the NMR spectrum of **1** must be explained by the two nonequivalent benzylic methylenes having coincidental chemical shifts.[7] In the open-chain analogue, **8**, the nonequivalent methyl groups exhibit a 5 Hz difference in chemical shifts. Even more surprising is the aromatic signal whose chemical shift is identical with that of prehnitene. By comparison, the ortho ring protons of benzocyclobutene show a chemical shift of δ 6.91[8] which is 0.19 ppm upfield from the value reported for *o*-xylene.[9]

An examination of the uv data recorded in Table I reveals an interesting difference between isomers **1** and **2**. Cava points out that the distortion due to the strain caused by two fused four-membered rings gives rise to a substantial bathochromic shift on going from durene, **9**, to **2**.[1] When the two rings are fused meta, however, a slight hypsochromic shift is observed by comparison of **1** with prehnitene, **8**. A comparable increase in the intensity of absorption is observed for both strained systems. Since the strain inherent in **1** and **2** should be nearly equal, the position at which the second four-membered ring is fused to the benzene nucleus must be of importance in determining the electronic characteristics of the molecule. Investigations into the properties of meta and para bis-annelated benzene systems are currently being carried out.

Acknowledgment. Financial support from the Research Corporation and the Robert A. Welch Foundation is gratefully acknowledged.

References and Notes

(1) M. P. Cava, A. A. Deana, and K. Muth, *J. Am. Chem. Soc.*, **82**, 2524 (1960).
(2) J. L. Lawrence and S. G. G. MacDonald, *Acta Crystallogr., Sect. B*, **25**, 978 (1969).
(3) M. Randic and Z. B. Maksic, *J. Am. Chem. Soc.*, **93**, 64 (1971).
(4) R. Thummel, *J. Chem. Soc., Chem. Commun.*, 899 (1974).
(5) The lesser degree of symmetry of **1** as compared with **2** is demonstrated by its substantially lower melting point. A similar difference is observed between prehnitene, **8**, and durene, **9** (see Table I).
(6) K. Nakanishi, "Infrared Absorption Spectroscopy", Nakado Co. Ltd., Tokyo, 1962, p 27.
(7) We have observed this same magnetic equivalence in other unsymmetrical benzocyclobutenes.
(8) M. A. Cooper and S. L. Manatt, *J. Am. Chem. Soc.*, **92**, 1605 (1970).
(9) Varian NMR Spectra Catalog, Vol. I, Varian Associates, 1962, spectrum no. 201.

Randolph P. Thummel
Department of Chemistry, University of Houston
Houston, Texas 77004
Received September 15, 1975

---

^{59}Co Nuclear Quadrupole Resonance Spectra and Low Temperature ^{13}C Magnetic Resonance Spectra of $X_3SnCo(CO)_4$ Compounds[1]

Sir:

As the initial stage in an investigation of intramolecular rearrangements in five-coordinate molecules using ^{13}C and ^{31}P magnetic resonance, we have studied the ^{13}C NMR spectra of several compounds of the form $X_3SnCo(CO)_4$. All these compounds possess idealized trigonal symmetry at cobalt, with two distinct chemical environments for the CO groups, axial and radial, in the ratio 1:3.

Observation of the ^{13}C NMR spectra associated with the CO groups in metal carbonyl compounds of manganese and cobalt often proves to be rather difficult. The ^{13}C NMR absorptions may be very broad at room temperature because of relaxation of the ^{13}C spin system due to scalar relaxation of the second kind.[2,3] The salutary effect of lower temperatures on the relaxation behavior of spin $\frac{1}{2}$ systems scalar-coupled to spin systems with $I > \frac{1}{2}$ has been noted for ^1H in boranes and carboranes,[4] and for carbonyl compounds of Co, Mn, and Re.[5]

Tribenzyltintetracarbonylcobalt (I) exhibits solid-state nuclear quadrupole transitions (27 °C) at 21.51 and 14.24 MHz. By analogy with other similar compounds[6,7] these are assigned to ν_3 and ν_2, respectively, corresponding to a quadrupole coupling constant of 100.4 MHz, and an asymmetry parameter η of 0.15. These may be compared with values of 96.8 MHz and $\eta = 0.03$ for trimethyltintetracarbonylcobalt,[6] and 104.1 MHz and $\eta = 0.05$ for triphenyltintetracarbonylcobalt.[7]

The ^{13}C NMR spectrum of I at room temperature consists of a single very broad line centered at about 198.6 ppm relative to Me_4Si.[8] As the temperature is lowered this line sharpens, and appears as a single line of about 10 Hz half-width at −60 °C.