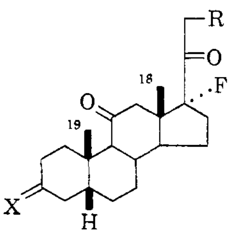
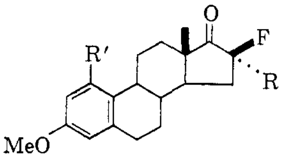
fluorosteroids where the fluorine has a 5α- or 6α-orientation. 4-Fluoro-Δ^4-3-ketones, 6α-trifluoromethyl-Δ^4-3-ketones and 6-fluoro-$\Delta^{4,6}$-diene-3-ones likewise showed unsplit angular methyl 3-proton singlets. Conversely, *every one of 33 6β-fluorosteroids* examined had a split 19-H absorption.[8] Two 17α-fluoropregnanes, I and II,[9] both showed long-range coupling between the 17α-fluorine and 18-protons[10] (Table I). This result, a recent report that 18-methyl protons long-range couple with 12α-fluorine (J, 2c./s.)[11], and further work on 17-fluorosteroids in the Syntex Laboratories[12] suggests that when the coupling is taking place through only four σ bonds the angular methyl protons may show coupling with α-fluorine substituents.[13] However, no coupling of 19-H with either 5α-F or 9α-F has been observed. An empirical limiting stereochemical requirement for proton–fluorine long-range coupling through five or more bonds in fluorosteroids may now be advanced on the basis of the accumulated results. *Long-range coupling between angular methyl protons and fluorine may occur only when a vector directed along the C–F bond and originating at the carbon atom, converges upon and intersects a vector drawn along an angular methyl C–H bond in the direction of the proton and originating at the methyl carbon.*[14,15] This expression uniquely encompasses all our results.

16,16-Difluoroestrone methyl ether (III)[16] and its 1-methyl analog IV[17] both show a split angular methyl proton resonance absorption and from an examination of molecular models it is apparent that it is the 16β-F which is involved in the H–F spin-spin coupling. 16β-Fluoro-1-methylestrone methyl ether (V)[17] shows a similar splitting.

TABLE I

LONG-RANGE H–F SPIN-SPIN COUPLING[a]

	18-H resonance frequency	$J_{\text{H-F}}$	Minimum no. of bonds connecting coupling nuclei	Ref.
				
I, R = OAc, X = O	41.4	0.8	4	9
II, R = H; X$^{\cdot\text{H}}_{\text{OAc}}$	36.0	0.8	4	9
				
III, R = F, R′ = H	66.7	*ca.* 1.5	5	16
IV, R = F, R′ = Me	68.3	*ca.* 1.0	5	17
V, R = H, R′ = Me	59.0	*ca.* 0.5	5	17

[a] Chemical shifts, δ, are expressed as c./s. from the tetramethylsilane reference, and coupling constants, J, as c./s. Accuracies are of the order of ±1 c./s. for δ, and ±0.3 c./s. for J.

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(8) Nuclear magnetic resonance (n.m.r.) spectra were determined with deuteriochloroform solutions containing tetramethylsilane as an internal reference. Measurements were taken on Varian-A-60 or HR-60 spectrometers, all spectra from the former being calibrated, *via* a reference sample, against the higher resolution instrument. The latter was equipped for calibration by the standard side-band technique. A. D. C. thanks Prof. A. Sandoval and the Universidad Nacional Autónoma de México for time on the A-60 instrument.

(9) These two compounds were kindly supplied by Dr. H. Herzog of the Schering Corporation to whom we express our thanks.

(10) Strong coupling occurs also between the 17α-F and 21-protons in these two compounds.

(11) Reported by P. A. Diassi, J. Fried, R. M. Palmere and P. A. Principe at the International Congress on Hormonal Steroids, Milan, May, 1962.

(12) L. H. Knox, S. Berger, D. Cuadriello, E. Velarde and A. D. Cross, *Tetrahedron Letters*, submitted for publication.

(13) Strong coupling of 18-H or 19-H with β-fluorine through four σ bonds is expected to occur, though so far no examples have been available for study.

(14) This expression is derived solely by examination of our experimental findings. No mathematical analysis has been attempted. We are indebted to a Referee who suggested the possibility of such an empirical relation.

(15) From this relation it is possible to predict that coupling may be observable between 18-H and 15β-F, 19-H and 2β-F and 4β-F, but not 19-H and 7β-F. *Both* 18- and 19- angular methyl proton absorptions may be split by either the 11β-F or 8β-F. Except for the possibility that 1α-F and 14α-F substituents may couple with 19-H and 18-H, respectively, no strong coupling of other α-fluorines with these protons is expected. When the number of bounds separating the fluorine and angular methyl protons is large (*e.g.*, 10β-F steroids) coupling may be so small as to be unobservable, even though steric requirements are met.

(16) C. H. Robinson, N. F. Bruce, E. P. Oliveto, S. Tolksdorf, M. Steinberg and P. L. Perlman, *J. Am. Chem. Soc.*, **82**, 5256 (1960).

(17) P. Crabbé, M. J. Durazo and A. Bowers, manuscript in preparation.

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RECEIVED JULY 9, 1962

THE CONFORMATION OF *cis,cis*-MUCONIC ACID

Sir:

As part of a research program[1] on the solid-state photochemistry of unsaturated acids and the dependence of the reaction on the crystal structure of the reacting species we are investigating the behavior toward ultraviolet of solid *cis,cis*- and *trans,trans*-muconic acids. The crystallographic constants of the two acids are: *cis*-isomer: $a = 9.55$ Å., $b = 8.89$ Å., $c = 3.84$ Å., $\beta = 99.9°$; space group $P2_1/a$; $n = 2$; $d_{\text{calcd}} = 1.48$ g./cm.^{3}; molecular symmetry $\bar{1}$. *trans*-isomer: $a = 6.98$ Å., $b = 3.76$ Å., $c = 7.01$ Å., $\alpha = 123.2°$, $\beta = 88.5°$, $\gamma = 101.7°$; space group $P\bar{1}$ (or P1); $n = 1$; $d_{\text{calcd}} = 1.38$ g./cm.^{3}; molecular symmetry $\bar{1}$ (or 1).

In keeping with our results on other systems that parallel contact of >C=C< groups of 4 Å. or less permits photochemical reaction,[1] we find that both acids are light sensitive; the products of their photo-reactions are currently being investigated.

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(1) See, *e.g.*, Sadeh and Schmidt, *J. Am. Chem. Soc.*, **84**, in press.

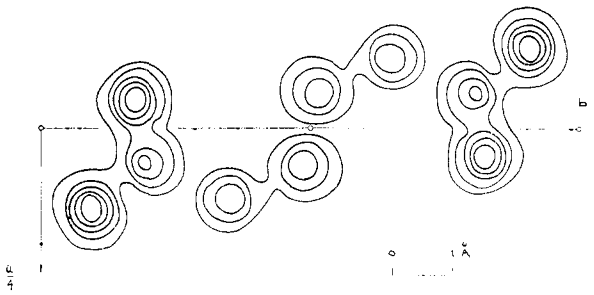
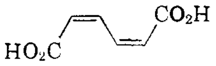


Fig. 1.—Electron-density projection $\rho(x,y)$; contours at intervals of $2\,e/\text{Å}.^2$, starting at $2e/\text{Å}.^2$.

The centric symmetry of the *cis*-isomer is surprising in view of its preparation from benzene derivatives (peracetic acid oxidation of phenol[2] and enzymatic oxidation of catechol[3]). To confirm the crystallographically required conformation (I) we have carried out a partial structure analysis based on the (*hk*0) data collected photographically. A trial structure was derived for the molecule lying along the shorter of the two long axes, with hydrogen bonded $-CO_2H$ contacts across the centers at (0,0) and (0,1) and with the center of the $>$CH–CH$<$ bond at $(0,{}^1/_2)$. This model was smoothly refined, by means of an anisotropic least-squares program, to $R = 0.112$ ($F_0 = 0$ excluded). The electron-density projection $\rho(x,y)$ based on 90 out of 98 observed reflections is shown in Fig. 1.



I

Three-dimensional structure analyses of the two isomers are being undertaken.

Acknowledgment.—We thank Dr. T. Sadeh for the preparation of *cis,cis*-muconic acid.

(2) J. A. Elvidge, R. P. Linstead, B. A. Orkin, P. Sims, H. Baer and D. B. Pattison, *J. Chem. Soc.*, 2232 (1950).

(3) O. Hayaishi, M. Katagiri and S. Rothberg, *J. Biol. Chem.*, **229**, 905 (1957).

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RECEIVED AUGUST 16, 1962

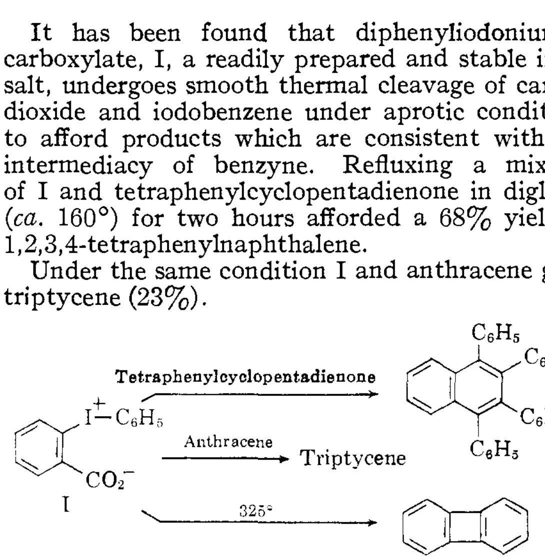
APROTIC GENERATION OF BENZYNE FROM DIPHENYLIODONIUM-2-CARBOXYLATE[1]

Sir:

While it has been demonstrated that benzyne[2] can be generated under aprotic conditions by fragmentation of appropriate *ortho*-disubstituted benzenes,[3] most of the reported methods are of limited synthetic utility.

It has been found that diphenyliodonium-2-carboxylate, I, a readily prepared and stable inner salt, undergoes smooth thermal cleavage of carbon dioxide and iodobenzene under aprotic conditions to afford products which are consistent with the intermediacy of benzyne. Refluxing a mixture of I and tetraphenylcyclopentadienone in diglyme (*ca.* 160°) for two hours afforded a 68% yield of 1,2,3,4-tetraphenylnaphthalene.

Under the same condition I and anthracene gave triptycene (23%).



Flash pyrolysis of solid I at 325° affords, among other products, biphenylene (gas chromatographic retention time and ultraviolet spectrum identical with that of an authentic sample) and iodobenzene.

Diphenyliodonium-2-carboxylate, I, is prepared readily in high yields.[4] To a concentrated sulfuric acid (170 ml.) solution of *o*-iodobenzoic acid (20 g.) at 0° was added potassium persulfate (42 g.). After one-half hour 75 ml. of benzene was added and the mixture stirred at 25–35° for 18 hours. This mixture was poured over ice, made alkaline with strong aqueous sodium hydroxide keeping the temperature below 40°, and finally extracted with chloroform. Evaporation of most of the chloroform gave a crystalline slurry to which ether was added. There was collected 21.7 g. (84%) of white crystalline I, m.p. 220.5–221° (dec.); reported[5] m.p. 229–230°. It exhibited a broad peak at $6.15\ \mu$ (chloroform) consistent with the inner salt formulation.

The author wishes to express his appreciation to Dr. J. Gordon for his valuable suggestions, to R. B. LaCount and C. J. Lindemann for their skillful assistance, and to Dr. H. Günther for the authentic biphenylene.

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(1) *Chemical Abstracts* nomenclature: (o-carboxyphenyl)-phenyliodonium hydroxide, inner salt.

(2) A number of recent reviews on benzyne are available: (a) H. Heaney, *Chem. Rev.*, **62**, 81 (1962); (b) J. F. Bunnett, *J. Chem. Ed.*, **38**, 278 (1961); (c) R. Huisgen in "Organometallic Chemistry," edited by H. Zeiss, Reinhold Publishing Corp., New York, N. Y., 1960, pp. 36–87.

(3) (a) L. Horner and H. Bruggemann, *Ann.*, **635**, 22 (1960); (b) M. Stiles and R. G. Miller, *J. Am. Chem. Soc.*, **82**, 3802 (1960); (c) R. S. Berry, G. N. Spokes and R. M. Stiles, *ibid.*, **82**, 5240 (1962); (d) G. Wittig and H. F. Ebel, *Angew. Chem.*, **72**, 564 (1960); (e) G. Wittig and H. F. Ebel, *Ann.*, **650**, 20 (1961); (f) G. Wittig and R. W. Hoffmann, *Angew. Chem.*, **73**, 435 (1961).

(4) This procedure is a modification of a previously described preparation in which the yields of I were unstated.[5]

(5) F. M. Beringer and I. Lillien, *J. Am. Chem. Soc.*, **82**, 725 (1960).

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RECEIVED AUGUST 1, 1962

CYCLOBUTANE-1,3-DIONE

Sir:

Despite considerable interest[1,2,3,4], in the properties of four-membered cyclic β-diketones, the parent compound in this series, cyclobutane-1,3-dione,[5,6] has hitherto proved inaccessible. We now

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(1) R. B. Woodward and G. Small, Jr., *J. Am. Chem. Soc.*, **72**, 1297 (1950).

(2) E. A. LaLancette and R. E. Benson, *ibid.*, **83**, 4867 (1961).

(3) E. F. Silversmith and J. D. Roberts, *ibid.*, **80**, 4083 (1960).

(4) E. J. Smutny, M. C. Caserio and J. D. Roberts, *ibid.*, **82**, 1793 (1960).

(5) In the earlier literature the cyclobutane-1,3-dione structure was assigned to ketene dimer. For a review of this subject, see R. N. Lacey, "Ketene in Organic Synthesis," "Advances in Organic Chemis-