Table I. N.m.r. Spectral Data on Tricyclo[3.2.2.0^{2,4}]nonane Derivatives[a]

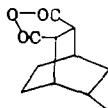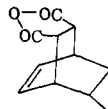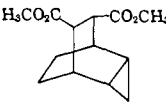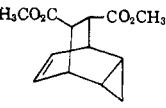| No.	Compd.	Assignable proton	Chemical shift,[b] τ-value	Additional shift value due to the cyclopropane ring, p.p.m.		
				Obsd.[c]	Calcd. by point dipole approxn.	Calcd. by eq. A
I[d]	H_3CO_2C— / H_3CO_2C— (structure)	$H_1(H_5)$	7.68(m)[e]	−0.30	−0.19	−0.36
		$H_8(H_9)$	6.97(q)[e]	−0.11	−0.24	−0.14
		CO_2CH_3	6.36(s)	0.00		
II	H_3CO_2C— / H_3CO_2C— (structure)	$H_1(H_5)$	6.85(m)[e]	−0.23	−0.13	−0.28
		$H_2(H_4)$	9.05(m)[e]			
		$H_6(H_7)$	4.13(q)[f]	+0.46	+0.43	+0.35
		$H_8(H_9)$	6.91(s)[e]	−0.09	−0.25	−0.14
		CO_2CH_3	6.42(s)	0.00		
III	O—OC / OC— (structure)	$H_1(H_5)$	7.40(m)[e]	−0.37	−0.19	−0.36
		$H_8(H_9)$	6.70(q)[e]	−0.17	−0.24	−0.14
IV	O—OC / OC— (structure)	$H_1(H_5)$	6.55(m)[e]	−0.23	−0.13	−0.28
		$H_2(H_4)$	8.87(m)[c]			
		$H_6(H_7)$	4.10(q)[f]	+0.43	+0.43	+0.35
		$H_8(H_9)$	6.70(q)	−0.14	−0.25	−0.14
V	H_3CO_2C—CO_2CH_3 (structure)	$H_1(H_5)$	7.56(m)[e]	−0.37	−0.19	−0.36
		H_8	6.82(q)[g]	−0.06	+0.09	+0.06
		H_9	6.73(q)[g]	−0.15	−0.24	−0.14
		CO_2CH_3	6.27(s)[e]	−0.03		
VI	H_3CO_2C—CO_2CH_3 (structure)	H_6	4.11(o)[g]	+0.51	+0.43	+0.35
		H_7	4.29(o)[g]	+0.50	+0.43	+0.35
		H_8	7.06(q)[g]	−0.03	+0.08	+0.08
		H_9	6.67(q)[g]	−0.14	−0.25	−0.14
		$CO_2CH_3(8)$	6.27(s)	−0.01		
		$CO_2CH_3(9)$	6.35(s)	0.00		

[a] The spectra were taken with a Varian A-60 spectrometer on about 10% (w./v.) solutions in deuteriochloroform containing tetramethylsilane as an internal reference at room temperature. Calibration of the spectrometer was checked by the usual side-band technique. Accuracies of chemical shifts are within about $\tau \pm 0.02$. [b] For the procedure of the signal assignment, refer to ref. 11. Peak multiplicities are represented by s (singlet), q (quartet), o (octet), and m (multiplet). [c] Observed shift values were evaluated by comparing chemical shifts with those of the corresponding bicyclo[2.2.2]octanes reported in ref. 11. [d] Prepared from II by catalytic reduction over Adams' platinum catalyst in methanol, m.p. 65–67°. [e] Not well-resolved peaks. [f] An A_2X_2-type pattern. [g] The A-part of an ABXY system.

The calculated shift values by using eq. A with this constant and the geometries obtained from Dreiding models are given in the last column of Table I, and agree well with the observed values.[14]

Testing the applicability of eq. A, we calculated the shift values of the methyl signal in 1,1-dimethylcyclopropane[15] and of the bridgehead proton signal of nortricyclene[16] due to the cyclopropane ring to be −0.08 and −0.44 p.p.m., respectively, from eq. A with the geometries obtained from Dreiding models. These values are consistent with the respective values of −0.15 and −0.30 p.p.m. observed by Patel, et al.[3]

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(14) The contribution of an ordinary C–C bond was subtracted from that of the C_2–C_4 bond in the compounds I–VI because this bond was present before a cyclopropane ring was introduced

(15) The average position of the methyl protons was taken at the center of a circle drawn by the protons according to A. D. Cross and I. T. Harrison, J. Am. Chem Soc., 85, 3223 (1963).

(16) This example is not quite pertinent, since an appreciable change in the molecular geometries is caused by proceding from bicyclo[2.2.1]heptane to nortricyclene.[6]

trans Opening of Monomer Double Bonds in Anionic Polymerization of Methyl Acrylate Initiated by Lithium Aluminum Hydride

Sir:

In a previous paper[1] we have reported that the double bond of methyl acrylate opens in a definite mode (cis or trans) in the anionic polymerization (initiated by lithium aluminum hydride in toluene) giving an isotactic polymer, while both cis and trans openings occur in equal probabilities in free-radical polymerization. The present communication is concerned with determining which of the cis and trans openings occurs in anionic polymerization.

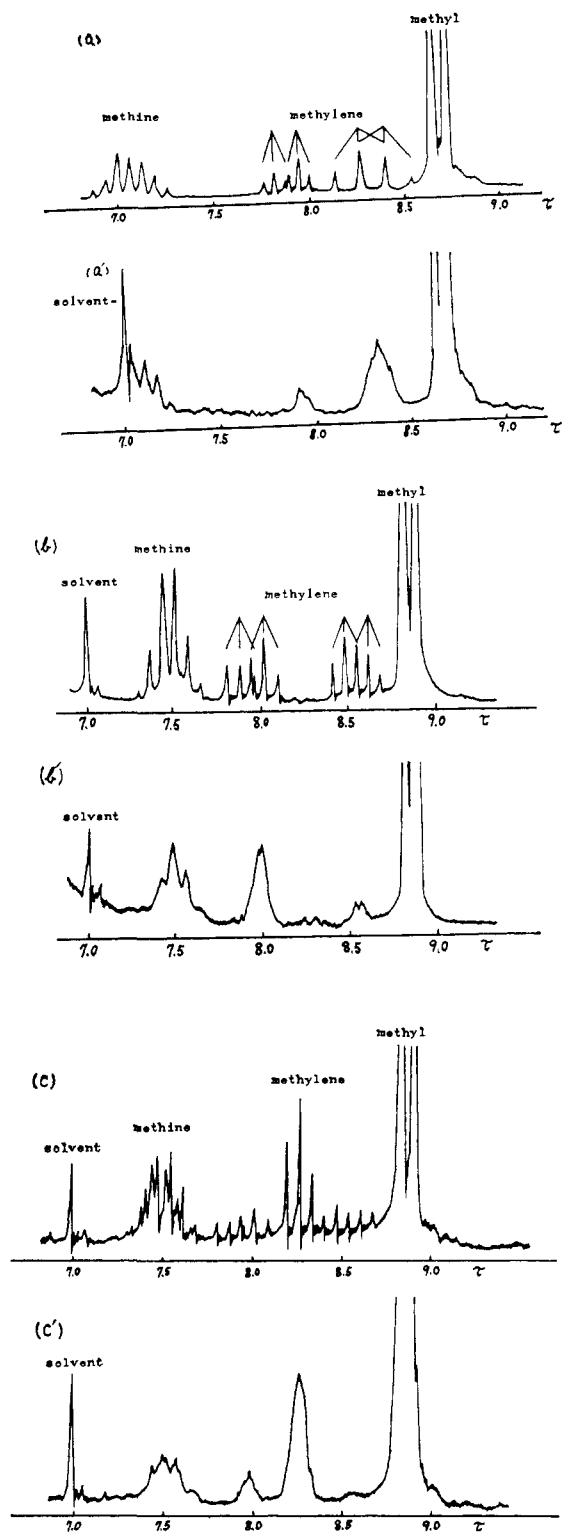(1) T. Yoshino, J. Komiyama, and M. Shinomiya, J. Am. Chem. Soc., 86, 4482 (1964).

Figure 1. N.m.r. spectra of (a) *meso*-α,α'-dimethylglutaric anhydride: (a') partially deuterated *meso*-α,α'-dimethylglutaric anhydride with the ratio of the nonequivalent methylene protons different from unity, (b) methyl *meso*-α,α'-dimethylglutarate, (b') partially deuterated methyl *meso*-α,α'-dimethylglutarate obtained by acid hydrolysis of a', and succeeding esterification, (c) methyl α,α'-dimethylglutarate (*meso–dl* mixture), and (c') partially deuterated methyl α,α'-dimethylglutarate (*meso–dl* mixture). The spectra were measured on *ca.* 15% solutions in methyl formate by a Varian HR-100 spectrometer. Coincidence of the centers of all the proton multiplets between a and a', b and b', and c and c' confirms that the deuterated compounds a', b', and c' with unresolved multiplet structures have the same skeletal configurations as the nondeuterated compounds a, b, and c, respectively, which were easily identified by their n.m.r. and infrared spectra.

The β-protons of a *meso*-methylene group of poly-methyl acrylate are chemically nonequivalent, and the centers of the n.m.r. multiplets due to the methylene protons of these two types are separated by about 0.5 τ.[1] When isotactic polymethyl acrylate-α,β-d_2 is prepared by the anionic polymerization mentioned above from a mixture of methyl acrylate-α,*trans*-β-d_2 and -α,*cis*-β-d_2 with molar ratio of these isomers different from unity, the intensity ratio of the higher- to the lower-field methylene proton multiplet of the polymer is equal to the molar ratio of the α,*cis*-β-d_2 to the α,*trans*-β-d_2 monomer.[1] We can, therefore, conclude that in the anionic process one of the methylene protons responsible for the higher-field multiplet comes from the β-proton of methyl acrylate monomer oriented *trans* to the carboxyl group, and the other methylene proton from the *cis* proton of the monomer. Thus the determination of the mode of monomer double bond opening can be reduced to assigning these multiplets to the nonequivalent methylene protons oriented *trans* and *gauche* to the carboxyl group for the hypothetical planar zigzag skeletal conformation.

As the first step to the assignment, the methylene proton multiplets of *meso*-α,α'-dimethylglutaric anhydride were assigned to the chemically nonequivalent methylene protons by the following procedure.

Two isomeric forms, ee and aa, are conceivable for the anhydride in solution. The ee form with two equatorial methyl groups is considered to be much more abundant than the aa form with two axial methyl groups. One of the methylene protons of the anhydride, denoted by A, is oriented *trans* and *gauche* to the equivalent α-protons in the ee and the aa form, respectively, while the other methylene proton, denoted by B, is oriented *gauche* to the α-protons in both forms. The observable chemical shifts and coupling constants of the A and B proton are averaged over the isomeric forms. Two triplets are expected for the A proton and two for the B proton owing to strong geminal proton coupling between the A and the B proton and vicinal proton coupling. Since the coupling constant between protons in the *trans* configuration is known to be much larger than that between protons in the *gauche* configuration,[2] the peak separations in the triplets of A are expected to be much larger than those of B.

The proton multiplets in the observed spectrum of the anhydride were assigned to the methyl, methylene, and methine groups, and the signal lines in the methylene proton multiplets were correlated as shown in Figure 1. Two methylene proton triplets at higher fields, each with lines eparations of 13 c.p.s., were ascribed to the A proton, and the others, each with line separations of 5.5 c.p.s., to the B proton.

In Figure 1 is shown the n.m.r. spectrum of partially deuterated *meso*-α,α'-dimethylglutaric anhydride (α,α',-β-d_3 isomers are the main components) in which the ratio of A to B protons is larger than unity. The α- and α'-deuterons were introduced in order to concentrate the intensities of the methylene proton multiplets at their centers and to measure the ratio of A to B protons accurately.

(2) J. A. Pople, W. G. Schneider, and H. J. Bernstein, "High-resolution Nuclear Magnetic Resonance," McGraw-Hill Book Co., Inc., New York, N. Y., 1959, pp. 381, 397; H. S. Gutowsky, *Pure Appl. Chem.*, 7, 93 (1963).

The n.m.r. spectrum of partially deuterated methyl meso-α,α'-dimethylglutarate obtained by acid hydrolysis of the deuterated anhydride and succeeding esterification by diazomethane is shown in Figure 1. Absence of dl-isomer signals in the spectrum indicates that the configurations around the respective asymmetric carbons are not altered by these treatments. The intensity ratio of the lower- to the higher-field methylene proton multiplet, κ, of the deuterated meso ester and κ of the deuterated meso acid are equal to 1/κ of the deuterated anhydride. The higher-field multiplet of the deuterated meso ester is, therefore, ascribed to the methylene proton oriented trans to the carboxyl groups for the hypothetical planar zigzag conformation of the Me–C–C–C–Me chain, and the lower-field multiplet to the other methylene proton.

Since methyl meso-α,α'-dimethylglutarate is a good model compound of isotactic polymethyl acrylate, and the centers of the methine and methylene proton multiplets of the glutarate appear at nearly the same positions as those of the polymer (at τ 7.7, 8.10, and 8.46 for a methyl formate solution), respectively, we may conclude that the higher-field multiplet of the polymer is due to the methylene proton oriented trans to the carboxyl group for the hypothetical planar zigzag skeletal conformation and the lower-field multiplet to the other methylene proton.[3] This result shows that trans opening of the double bond occurs in the anionic polymerization of methyl acrylate initiated by lithium aluminum hydride in toluene, in contrast to cis opening reported on cationic polymerization of β-chlorovinyl alkyl ethers[4] and polymerization of propylene[5,6] and ethylene[7] by the Ziegler catalyst.

The deuterated and nondeuterated anhydrides were prepared by the following procedures. Ethyl α,α'-dimethylglutaconate-α-d_1 was prepared according to Thole and Thorpe's method[8] except that EtOD was used in place of EtOH in the step removing the ethoxycarbonyl group from ethyl α-ethoxycarbonyl-α,α'-dimethylglutaconate, and the deuterated glutaconate was acid hydrolyzed. Heavy hydrogen was added at 40° to the deuterated acid dissolved in heavy water using platinum black as catalyst. A mixture of deuterated α,α'-dimethylglutaric acids of meso and dl modifications thus obtained (meso/dl ratio = 0.5) was dissolved in acetyl chloride at room temperature. After the volatile fraction was almost all evacuated at room temperature, the solution was cooled to 10°. Deuterated meso-α,α'-dimethylglutaric anhydride deposited from the solution was recrystallized by an equivolume mixture of ethyl acetate and ligroin. The unresolved structures of the methylene proton multiplets of the deuterated anhydride show that the anhydride contains, besides α,α',β-d_3 components, various isomers different in deuterium substitution, as expected for catalytic addition of heavy hydrogen.

(3) In a recent communication (J. Am. Chem. Soc., **86**, 4481 (1964)), Schuerch, et al., gave a "very probable" assignment of the methylene proton resonances of polyisopropyl acrylate. The assignment is the same as that obtained here. However the reason for their assignment is not clear.
(4) G. Natta, M. Peraldo, M. Farina, and G. Bressan, Makromol. Chem., **55**, 139 (1962).
(5) T. Miyazawa and Y. Ideguchi, J. Polymer Sci., **B1**, 389 (1963).
(6) H. Tadokoro, M. Ukita, M. Kobayashi, and S. Murahashi, ibid., **B1**, 405 (1963).
(7) M. Tasumi, T. Shimanouchi, H. Tanaka, and S. Ikeda, ibid., **A2**, 1607 (1964).
(8) F. B Thole and J. F. Thorpe, J. Chem. Soc., **99**, 2187 (1911).

Ethyl α,α'-dimethylglutaconate was prepared by the method of Thole and Thorpe.[8] A mixture of meso- and dl-α,α'-dimethylglutaric acids was obtained by hydrogenation of the glutaconate at 20° using palladium–carbon catalyst and succeeding hydrolysis. meso-α,α'-Dimethylglutaric anhydride was obtained from the mixture by the method of Auwers and Thorpe.[9]

(9) K. Auwers and J. F. Thorpe, Ann., **285**, 310 (1895).

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The Synthesis of Azomycin

Sir:

The antibiotic azomycin was first isolated by Maeda[1] in 1953 from a strain resembling Nacardia mesenterica. In 1955, Nakamura[2] established its structure as the hitherto unknown[3] 2-nitroimidazole. Until now, 2-nitroimidazole and its homologs had not been prepared by total synthesis despite the fact that these structurally simple compounds offered a tempting challenge to chemists seeking potentially active chemotherapeutic agents.[4] A possible route to these compounds was suggested by the work of Jones and Robins[5] who, by the action of nitrous acid, were able to convert 8-aminopurines, via 8-diazopurines, to 8-nitropurines. Thus a nitro group was introduced into the 2-position of the imidazole moiety in the purine ring system. However, when 2-aminoimidazole was caused to react at room temperature with an excess of sodium nitrite at about pH 6, the diazo compound was not isolated and the desired 2-nitroimidazole which has a characteristic ultraviolet peak at 374 mμ (in 0.1 N NaOH) was not formed (Figure 1). If, after standing at room temperature for a short time, this reaction mixture was boiled, spectrophotometry indicated that 2-nitroimidazole had been formed to the extent of 6%, and 1% was indeed isolated. At room temperature, the reaction apparently took a different course because, when heating was delayed for 16 hr., no 2-nitroimidazole was formed. This circumstance may explain the failures of previous investigators[6] who diazotized 2-aminoimidazole. In the presence of cupric sulfate, however, the desired reaction proceeded at room temperature and gave appreciable yields (Figure 1). Thus 15.7 g. of 2-aminoimidazole sulfate,[7] 41 g. of sodium nitrite, and 297 g. of cupric sulfate pentahydrate were dissolved in 18 l. of distilled water[8] and the solution was allowed to stand at room temperature for 16 hr. The pH of the reaction mixture was adjusted to 2.0 with dilute nitric acid, and the solution was extracted with 24 l. of ethyl acetate in a Karr Recipro-

(1) K. Maeda, T. Osato, and H. Umezawa, J. Antibiotics (Tokyo), **6A**, 182 (1953).
(2) S. Nakamura, Pharm. Bull. (Tokyo), **3**, 379 (1955).
(3) K. Hofmann, "Imidazole and Its Derivatives, The Chemistry of Heterocyclic Compounds," Vol. 6, A. Weissberger, Ed., Interscience Publishers, Inc., New York, N. Y., 1953.
(4) Nitroimidazoles have significant antiprotozoal activity; see, e.g., C. Cosar and L. Julou, Ann. Inst. Pasteur, **96**, 238 (1959).
(5) J. W. Jones and R. K. Robins, J. Am. Chem. Soc., **82**, 3373 (1960).
(6) R. G. Fargher and F. L. Pyman, J. Chem. Soc., **115**, 217 (1919).
(7) B. T. Storey, W. W. Sullivan, and C. L. Moyer, J. Org. Chem., **29**, 3118 (1964).
(8) This high dilution favored the yield.