590-19-2; cis-3,4-dimethyl-cis-1,2-bis(tosyloxymethyl)cyclobutane, 32388-90-2; cis-3,4-dimethyl-cis-1,2-bis-(iodomethyl)cyclobutane, 32388-91-3.

Acknowledgment.—We thank the donors of the Petroleum Research Fund for partial support (2754 A1,4) of this work.

Dehydration of 3,4-Dimethyl-3,4-hexanediol to the Six Possible C₈H₁₄ Dienes and Proof of Structure of the Substituted Butadienes¹

WILKINS REEVE* AND DONNA M. REICHEL

Chemistry Department, University of Maryland, College Park, Maryland 20742

Received May 5, 1971

3,4-Dimethyl-3,4-hexanediol (1) has been dehydrated, using a variety of reagents, to mixtures of the six isomeric C_8H_{14} dienes. The use of acidic reagents, or iodine in propionic anhydride, favors the formation of *cis,cis*-3,4-dimethyl-2,4-hexadiene (2) and *cis,trans*-3,4-dimethyl-2,4-hexadiene (3), the dehydration following the Saytzeff pathway. An initial cis double bond is favored over an initial trans configuration because the conformations of the diol leading to a cis double bond exhibit less steric crowding. Phenyl isocyanate as a dehydrating agent is unusual in that double bond formation predominately follows the Hofmann pathway; even 2,3-diethylbutadiene can be prepared in this manner. The structures of the dienes follow from their spectral data. Models show that only the cis, cis isomer of the 3,4-dimethyl-2,4-hexadienes can exist in a conformation with the double bonds coplanar, and only this isomer absorbs strongly in the uv. Infrared and nmr spectra follow a consistent pattern to support the structural assignments. The boiling points of the six isomers range from 104 to 134° (760 mm).

Dehydration of a mixture of meso and dl pinacol 1, 3,4-dimethyl-3,4-hexanediol, prepared from ethyl methyl ketone can give rise to six substituted isomeric butadienes of the formula C_8H_{14} . The purpose of this work was to prepare and characterize these dienes. Previously, two of the dienes (2 and 3) have been satis-



factorily characterized by Criegee;^{2a} the other four are new compounds. Recently, 4 has been reported to be formed in the thermal decomposition of 2-butenylsilver. No yield was given.^{2b} The synthesis of $7^{3.4}$ and of a mixture of 5 and 6^4 has been claimed by earlier workers but Criegee² has shown the assignments of Gostunskaya, *et al.*, to be in error, and the later synthesis of 7,³ based on an abnormal Grignard reaction, appears to be doubtful. The isolation was by distillation, the boiling point does not agree with ours, and neither glpc nor nmr spectra were used to characterize the fraction obtained.

Dehydration of 3,4-Dimethyl-3,4-hexanediol.-The dehydration of pinacol, 2,3-dimethyl-2,3-butanediol, has been studied over the past hundred years with a variety of reagents. With pinacol, only two products are possible, 2,3-dimethylbutadiene and pinacolone. It has been observed that pinacolone formation is favored by the use of less strong acids such as phosphoric or oxalic acids, whereas the use of hot strong acids such as hydrobromic acid causes dehydration to the diene to predominate. Iodine⁵ and phenyl isocyanate⁶ are known to be effective reagents for dehydrating pinacol to butadiene with little pinacolone formation. With 3.4-dimethyl-3.4-hexanediol, dehydration can lead to the two isomeric pinacolones or any of the six isomeric dienes.

We have studied the dehydration of a dl-meso mixture of the 3,4-dimethyl-3,4-hexanediols with a variety of reagents and the results are tabulated in Table I. The pinacol was obtained by the reduction of ethyl methyl ketone with magnesium and was an approximately 1:1 mixture of the dl and meso isomers.

The data in Table I show that iodine in propionic anhydride is the reagent of choice for the preparation of a diene mixture consisting mostly of the cis-cis (2) and cis-trans (3) isomers. The use of iodine alone is somewhat less desirable. Of the six possible isomers, these two are the ones preferentially formed in most of the dehydration reactions. The third most easily formed isomer is 5; this is the major product when phenyl isocyanate is used as the dehydrating agent. This latter reagent is unique in that it preferentially forms a methylene rather than an ethylidene bond. Thus, 7 is also a major product using phenyl isocyanate whereas it is only a minor product in all of the other dehydration reactions. Sulfuric acid and hydrogen bromide also cause isomers 2, 3, and 5 to predominate, and with the latter reagent only small amounts of the pinacolones are formed. The use of potassium acid

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	DEHY	DRATION C	F PINACOL	(I) WITH V	ARIOUS REA	AGENTS			
	% yield of diene fraction	Composition of diene fraction, % ^b							
Reagent		2	3	4	5	6	7	EtCOAm ^c	MeCOHxd
Iodine with propionic									
anhydride	74	35	38	1	13	3	3	Tr^{e}	\mathbf{Tr}
Iodine	63	34	39	2	8	3	3	. 1	2
PhNCO	26	16	6	\mathbf{Tr}	41	3	28	\mathbf{Tr}	\mathbf{Tr}
KHSO₄	52	41	18	\mathbf{Tr}	18	1	7	3	5
H_2SO_4	30	38	5	0	10	0	2	13	29
HBr	47	44	28	0	10	3	6	2	2
Potassium alum	53	37	4	0	28	0	5	7	14
P_2O_5	24	32	11	1	19	3	7	8	10
H ₈ PO ₄	33	14	41	\mathbf{Tr}	5	\mathbf{Tr}	2	11	24
Polyphosphoric acid	27	11	11	0	2	\mathbf{Tr}	1	23	51
Al ₂ O ₈	40	9	8	3	6	5	4	19	43

TABLE I

^a All dehydrations were carried out in the liquid phase at 120–140° except with alumina which dehydration was in the vapor phase at 250°. ^b Data are glpc percentages. ^e 4,4-Dimethyl-3-hexanone. ^d 3-Ethyl-3-methyl-2-pentanone. ^e Tr = trace.

sulfate causes the same three isomers to predominate, whereas potassium alum favors 2 and 5. Vapor phase dehydration over alumina gives an indiscriminate mixture of all isomers. It was the method used to prepare the trans-trans isomer 4; while the yield of this is only about 1%, most of the other procedures give even less.

Two facts stand out from the above. The formation of a cis double bond occurs preferentially to a trans, and the double bond formation occurs according to the Saytzeff rule, except with phenyl isocyanate. While this reagent has been used to dehydrate pinacol itself,⁶ it has not been used with higher members of the pinacol series. One might expect on statistical grounds a three to two ratio of the Hofmann to Saytzeff pathways, assuming steric effects are not a factor. From the phenyl isocyanate data in Table I, it can be calculated that 53% of the double bonds formed are via the Hofmann pathway, whereas with iodine or the acidic reagents only 13-19% of the double bonds are formed by this pathway. Earlier investigators studying the use of this reagent have speculated that the dehydration mechanism is analogous to that of acetate pyrolysis at 500°.6

The reason for the preferential cis double bond formation becomes apparent after an examination of the possible conformations leading to a reaction. The hydrogens of the number two methylene group can exist in four such conformations with the hydroxyl group



on carbon number three. Fisher-Taylor-Hirschfelder models show that neither of the two conformations [one

staggered (8), one eclipsed (9)] which might lead to an initial cis double bond exhibit severe steric crowding; much more severe steric interactions do occur with the two conformations (10, 11) leading to the trans double bond, particularly with the meso isomer of the pinacol. Furthermore, in a stepwise conversion of the pinacol to the dienes with the first double bond being trans, the intermediate, trans-3,4-dimethyl-4-hexen-3-ol, has much more severe steric interactions than does its cis isomer; this factor alone would strongly favor the formation of the initial double bond with a cis configuration. Once the first double bond is formed, the molecular geometry changes so that the steric effects discussed above have less influence on the conformations leading to the cis or trans second double bond.

The results of the dehydration of the high-melting form⁷ of the 3,4-dimethyl-3,4-hexanediol were contrasted with that of the approximately 1:1 mixture of the dl and meso isomers to see if the use of the meso pinacol did lead to less trans double bond formation as the study of the models suggested. The dehydrations were carried out using the iodine in propionic anhydride reagent. The diene fraction obtained from the highmelting form of the pinacol contained 63% of the ciscis isomer 2 and 4% of the cis-trans isomer 3. The approximately 1:1 mixture of the meso and dl forms of the pinacol gave 39 and 33%, respectively (see Table I). The percentages of isomers 4, 5, 6, and 7 from the meso pinacol were 0, 24, 0, and 2%, respectively. It is apparent that the diastereoisomers do behave differently, and the form presumed to be the meso isomer gives rise to less trans double bond formation as predicted.

Proof of Structure of the 3,4-Dimethyl-2,4-hexadienes.—The three geometrical isomers 2, 3, and 4 could be distinguished from the remaining three isomers by their similar nmr spectra, which showed four methyl groups and two vinyl hydrogens, and their almost identical mass spectra. Isomers 2 and 3 have been characterized previously by Criegee,² but the proof of structure given here is independent of his work. A study of Fisher-Taylor-Hirschfelder models of the three isomers showed that only the cis-cis isomer 2

⁽⁷⁾ This form is assumed to be the meso isomer by analogy with the two 4.5-octanediols where the stereochemistry has been definitely established:
S. Veibel, *Biochem. Z.*, 239, 456 (1931) [*Brit. Chem. Abstr.*, A, 1332 (1931)];
W. G. Young, L. Levanas, and Z. Jasaitis, *J. Amer. Chem. Soc.*, 58, 2274 (1936).

			\sim Nmr, δ units \sim		
Configuration	Uv max (ϵ)	Olefinic absorption, cm ⁻¹	C=CHCH ₃	C==CHCH ₃	
Cis-cis (2)	237 (17,000)	1625 (str)	1.70	5.6	
Cis-trans (3)	210 (3,600)	1650 (intermediate)	1.68,	5.22	
			1.58		
Trans-trans (4)	205 (2,000)	1650 (weak)	1.47	5.3	
		1620 (weak)			
Cis (5)		1640 (med)	1.68	5,63	
		1620 (str)			
Trans (6)		1630 (str)	1.60	5.32	

TABLE II SPECTRAL DATA ON ISOMERS

could easily exist in a conformation with the double bonds coplanar, either cisoid or transoid. This must correspond to the isomer with the uv maximum at 237 m μ (ϵ 17,000). A model of the trans-trans isomer 4 cannot exist in a coplanar form, and consequently 4 exhibits the lowest uv maximum and lowest extinction coefficient as shown by the data in Table II. The isomer with the intermediate uv spectra is assigned the cis-trans structure 3 since a model of this is intermediate between the other two isomers in the ease of forcing the double bonds into coplanarity. These structural assignments are supported by the ir spectra, by the consistent changes observed in the chemical shifts of the methyl and olefinic protons in the nmr spectra as one proceeds through the series, and by the ease of sulfone formation. The boiling points of the isomers also change in a consistent manner.

The infrared spectra of the trans-trans isomer of 3,4-dimethyl-2,4-hexadiene would be expected to have the least absorption in the 1630-cm⁻¹ region because of the relatively symmetrical arrangement around each of the double bonds. As shown in Table II this was found to be the case. The isomer assigned the cis-cis structure on the basis of its uv maximum at 237 m μ absorbed strongly, and the third geometrical isomer exhibited an absorption band of intermediate strength.

In the nmr spectra, the chemical shifts of the terminal methyl groups change in a consistent manner as one proceeds from the cis-cis to the trans-trans structures, and these shifts were used to assign the cis and trans configurations to the 2-ethyl-3-methyl-1,3-pentadienes.

The reaction of the mixture of the dienes with sulfur dioxide provided chemical evidence for the assignment of the trans-trans structure to the isomer of uv max 205 mµ. Butadiene and one of the piperylenes react with sulfur dioxide to form cyclic sulfones.⁸ The diene must be in the cisoid form for this reaction to occur, and it is known that the reaction with sulfur dioxide can be slowed down or prevented by a terminal methyl group in the position where the sulfur dioxide must approach.⁸ Accordingly, it would be expected that the trans-trans 4, with two methyl groups blocking the approach of the sulfur dioxide, would not react. This was found to be the case; most of the isomer assigned the trans-trans structure was still present unreacted after standing for 10 days with sulfur dioxide at -17° . In constrast, the isomer assigned the cis-cis structure had completely reacted as had all but small amounts of the isomer assigned the cis-trans structure.

Microboiling points were determined on the three isomers after purification by glpc and found to be 134,

(8) D. Craig, J. Amer. Chem. Soc., 65, 1006 (1943).

114, and 104° (760 mm) for the cis-cis, cis-trans, and trans-trans isomers, respectively. This rather wide range, and the higher boiling point of the cis-cis isomer, are probably related to the ability of the cis-cis mole-cule to exist in a linear form with coplanar double bonds, whereas the trans-trans isomer for steric reasons is in a nonlinear, more compact form.

Finally, our structural assignments for the cis-cis and the cis-trans isomers are in aggreement with those made by Criegee² as is shown by comparing the melting point data on the maleic anhydride adducts.

Proof of Structure of the 2-Ethyl-3-methyl-1,3pentadienes.-Two of the dienes formed in the dehydration of the pinacol are clearly the isomeric 2ethyl-3-methyl-1.3-pentadienes since they have nearly identical mass spectra and their nmr spectra show an ethyl group, two methyl groups, and three vinyl protons. As shown in Table II, the methyl doublet and the vinyl proton quartet of one have chemical shifts nearly identical with those of the cis, cis-3,4-dimethyl-2,4-dimethyl-2,4-hexadiene (2); it is accordingly the cis-2-ethyl-3-methyl-1,3-pentadiene (5). The other isomer has chemical shifts of these groups upfield from the cis isomer and nearly identical with those of trans,trans-3,4-dimethyl-2,4-hexadiene (4) and is accordingly the trans-2-ethyl-3-methyl-1,3-pentadiene (6). These structural assignments were consistent with the ir spectra of the two isomers. The cis isomer has two absorption bands of strong and medium intensity at 1620 and 1640 cm^{-1} ; the trans isomer has a single strong peak at 1630 cm^{-1} . Both exhibited strong absorption at 880-890 $\rm cm^{-1}$ due to the methylene group. The relative ease of formation of the sulfone derivatives adds further supporting evidence. The cis isomer 5 reacts completely whereas the trans isomer 6 reacts to a much lesser degree. The cis isomer is again observed to have a higher boiling point (127°) than the trans isomer (108°)

Proof of Structure of 2,3-Diethylbutadiene.—The structure of this isomer (7) is established by its nmr spectrum which clearly shows the two ethyl groups and the four terminal vinyl protons.

Experimental Section

Melting points and boiling points are corrected. The infrared spectra were determined with a Perkin-Elmer Model 337 on the neat liquid using a 0.025-mm sodium chloride cell; the ultraviolet spectra with a Cary Model 14; the mass spectra with a Varian M-66; and the nmr spectra with a Varian Model A-60A. Chemical shift values are expressed as δ values (parts per million) downfield from tetramethylsilane internal standard. Elemental microanalyses were performed by Dr. F. J. Kasler.

Dehydration with Iodine in Propionic Anhydride.—A 250-ml three-necked flask was charged with 64 ml of propionic anhydride,

130 mg of iodine, and 60 g of the dl-meso mixture of the 3,4-dimethyl-3,4-hexandiols, bp 108-114° (32 mm), obtained by the reduction of ethyl methyl ketone with amalgamated magnesium.⁹ The mixture was stirred with a magnetic stirrer and heated for 2 hr at 125°. A stream of carbon dioxide was passed through the reaction flask to sweep the volatile products through a watercooled condenser into a receiving flask immersed in an ice-salt mixture. The propionic anhydride that distilled along with the diene fraction was removed by shaking with saturated sodium bicarbonate solution. The diene mixture was 44 ml (74% of theory). Its composition is given in Table I.

Dehydration with Other Reagents.—All of the dehydrations in the liquid phase were carried out in the same way as the example above but without solvent and on a smaller scale. After the initial heating at 120°, the temperature was slowly raised over a 2-hr period to 130–140°. The data are in Table III.

TABLE 1	T	T
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Experimental Data on the Pinacol (1) Dehydrations

		Final	Reaction	Yield, ^a
1, g	Reagent	temp, °C	time, hr	\mathbf{ml}
3.4	20 mg of iodine	140	2	2
29	108 ml of PhNCO,			
	0.6 g of N-phenyl-			
	β -naphthylamine,			
	$0.2 \ g$ of lithium			
	slices	150	2	7
9.6	2.5 g of KHSO_4	140	2	5.5
4.3	5 drops of concen-			
	trated H_2SO_4	140	2	1.2
4.8	$0.2 \mathrm{~ml}$ of $48\% \mathrm{~HBr}$	140	2	2.5
4.3	1 g of potassium alum	140	2	2.5
6.7	$0.1 \text{ g of } P_2O_5$	140	2	1.5
4.8	$1 \text{ ml of } 85\% \text{ H}_3\text{PO}_4$	140	4	1.5
4.8	1 ml of poly H ₃ PO ₄	140	2	1.5
0				

^a Composition given in Table I.

Dehydration over Alumina.—This was patterned after the procedure for dehydrating pinacol.¹⁰ The mixture (40 ml) of the meso and dl isomers of the 3,4-dimethyl-3,4-hexanediol was added dropwise at about 1 ml/min to a 40-cm column of 8–14 mesh Fisher alumina electrically heated to about 250°, and the products were caught in a series of traps cooled in ice and finally Dry Ice. The product consisted of 20 g of an organic layer which gave 12 g of the diene fraction on distillation. Composition data are in Table I.

Analysis of Diene Fraction.—This was done by glpc using an F & M Model 300 vapor phase chromatograph. Of the various columns used, the best was a 2-m long, 6.3-mm o.d. copper tube packed with 10% Carbowax-1000 on 80-100 mesh silanized diatomaceous earth (Anakrom P). The glpc percentages in Table I were shown to approximate weight percentages by analyzing a mixture consisting of 71.5 mg of 3 (79.3 mg of 90% pure 3 isolated by distillation) and 25.7 mg of 2 (28.7 mg of 89% pure 2 isolated by distillation). The weight ratio of 3 to 2 was 2.78; the ratio of the areas obtained by glpc was 2.8. The retention times in minutes (at 50° with a helium flow of approximately 50 ml/min) for the compounds are as follows: 4, 4.7; 6, 5.3; 3, 6.3; 7, 7.2; 5, 10.3; rearranged product, 13; 2, 17; 4,4-dimethyl-3-hexanone, 39; and 3-ethyl-3-methyl-2pentanone, 51.

cis,cis-3,4-Dimethyl-2,4-hexadiene (2) was best prepared by the procedure using iodine in propionic anhydride. The following data are on material separated by glpc: bp 134° (760 mm)¹¹ [lit.² bp $134-135^{\circ}$ (760 mm)]; uv max (cyclopentane) 237 m $_{\mu}$ (ϵ 17,000 [lit.² uv max (solvent unspecified) 230 m $_{\mu}$ (ϵ 13,000)]; ir (neat) 3055, 3000-2900, 2865, 1625, 1450, 1385, 1055, 995, 890 (w), 815, and 795 cm⁻¹; nmr (DCCl₃) δ 5.60 (quartet, 2, $J = 6.5 \text{ Hz}, C = CHCH_3), 1.77 \text{ (s, } 6, = C(CH_3)C), 1.70 \text{ (d, } 6,$ $J = 6.5 \text{ Hz}, C = CHCH_3); mass spectrum (70 eV) <math>m/e$ (rel intensity) 110 (58), 95 (100), 81 (15), 79 (10), 77 (12), 67 (46). Anal. Calcd for C_8H_{14} : C, 87.20; H, 12.80. Found: C,

87.27; H, 12.72.

cis,trans-3,4-Dimethyl-2,4-hexadiene (3) was best prepared by the procedure using iodine in propionic anhydride. The following data are on material separated by glpc: bp 113.5° (760 mm)¹¹ [lit.² bp 113-115° (760 mm)]; uv max (cyclopentane) 210 m μ (ϵ 3600) (lit.² reported no max); ir (neat) 3015, 2970-2900, 2850, 1650 (w), 1445, 1370, 1230, 1090, 1050-1030, 1005, 840, and 810 cm⁻¹; nmr (DCCl₃) δ 5.22 (quartet, 2, J = 6 Hz, C=CHCH₃), 1.70 (s, 6, =C(CH₃)C), 1.68 (d, 3, J = 6 Hz, cis C=CHCH₃), 1.58 (d, 3, J = 6 Hz, trans C=CHCH₃); mass spectrum (70 eV) m/e (rel intensity) 110 (77), 95 (100), 81 (23), 79 (11), 77 (16), 67 (66).

Anal. Caled for C₈H₁₄: C, 87.20; H, 12.80. Found: C, 87.33; H, 12.67.

trans, trans-3, 4-Dimethyl-2, 4 hexadiene (4) was prepared by dehydration of the pinacol (dl-meso mixture) over aluminum oxide at 250°. The following data are on material separated by glpc: bp 104° (760 mm);¹¹ uv max (cyclopentane) 205 m μ (ϵ 2000); ir (neat) 3040, 2980-2900, 2850, 1650 (w), 1620 (w), 1440, 1360, 1310, 1080, 1030, 890 (m), and 830-810 cm⁻¹; nmr (DCCl₃) δ 5.28 (quartet, 2, J = 6.5 Hz, C=CHCH₃), 1.72 (s, 6, =C(CH₃)C), 1.47 (d, 6, J = 6.5 Hz, C=CHCH₃); mass spectrum (70 eV) m/e (rel intensity) 110 (100), 95 (100), 81 (14), 79 (11), 77 (13), 67 (51).

Anal. Calcd for C₈H₁₄: C, 87.20; H, 12.80. Found: C, 87.40; H, 12.78.

cis-2-Ethyl-3-methyl-1,3-pentadiene (5) was best prepared by procedure using phenyl isocyanate. The following data are on material separated by glpc: bp 127° (760 mm);¹¹ ir (neat) 3090, 2970-2900, 2880, 1640 (m), 1620 (s), 1470, 1390, 1080, 1010, 880 (s), 830, 800, 730, and 695 cm⁻¹; nmr (DCCl₈) δ 5.63 (quartet, 1, J = 7 Hz, C=CHCH₃), 4.90 (s, 1, =CH₂), 4.78 (s, 1, =CH₂), 2.25 (quartet, 2, J = 7 Hz, CH₂CH₃), 1.75 (s, 3, =C(CH₃)C), 1.68 (d, 3, J = 7 Hz, C=CHCH₃), 1.03 (t, 3, J = 7 Hz, CH₂CH₃); mass spectrum (70 eV) m/e (rel intensity) 110 (57), 95 (100), 81 (41), 79 (17), 77 (17), 68 (14), 67 (46), 65 (10).

Anal. Caled for C₈H₁₄: C, 87.20; H, 12.80. Found: C, 87.32; H, 12.60.

trans-2-Ethyl-3-methyl-1,3-pentadiene (6) was prepared by the procedure using iodine in propionic anhydride. The following data are on materials separated by glpc: bp 108° (760 mm);¹¹ ir (neat) 3075, 2970-2900, 2860, 1630 (s), 1445, 1360, 1080, 1030, 890 (s), 865, and 820 cm⁻¹; nmr (DCCl₃) δ 5.32 (quartet, 1, J = 7 Hz, C=CHCH₃), 4.95 (s, 1, =CH₂), 4.68 (s, 1, =CH₂), 2.13 (quartet, 2, J = 8 Hz, CH₂CH₃), 1.75 (s, 3, =C(CH₃)C), 1.60 (d, 3, J = 7 Hz, C=CHCH₈), 0.98 (t, 3, J = 8 Hz, CH₂-CH₃); mass spectrum (70 eV) m/e (rel intensity) 110 (63), 95 (100), 81 (32), 79 (17), 77 (10), 68 (15), 67 (56), 65 (9).

Anal. Calcd for C₈H₁₄: C, 87.20; H, 12.80. Found: C, 87.23, H, 12.78.

2,3-Diethyl-1,3-butadiene (7) was best prepared by the procedure using phenyl isocyanate. The following data are on material separated by glpc: bp 119° (760 mm);¹¹ ir (neat) 3080, 2980-2900, 2870, 1790 (w), 1630 (w), 1600 (s), 1460, 1390, 1365, 1070, and 890 cm⁻¹ (s); nmr (CHCl₃) δ 5.07 (s, 2, =:CH₂), 4.93 (s, 2, =:CH₂), 2.28 (quartet, 4, J = 7 Hz, CH₂CH₃), 1.07 (t, 6, J = 7 Hz, CH₂CH₃).

Anal. Calcd for C₈H₁₄: C, 87.20; H, 12.80. Found: C, 87.39; H, 12.57.

Maleic anhydride adducts were prepared by Criegee's method.² The diene (0.5 g), 0.44 g of maleic anhydride (purified by recrystallization from chloroform), and 0.5 or 2 ml (for 2 and 3, respectively) of benzene were heated in a sealed tube in a steam bath for 8 or 17 hr (for 2 and 3, respectively). 2 had mp 111-112° (lit.² 113-114°); 3 had mp 70-71° (lit.² 68-69°).

Sulfones.—The diene mixture (10 ml), bp 104-135°, which had been prepared by the iodine in the propionic anhydride procedure was cooled in Dry Ice and mixed with 10 ml of liquid sulfur dioxide. The mixture was stored in a cold room at -17° and samples were analyzed periodically by glpc. The glpc data were obtained using a Carbowax-1000 column at 50° with the injection port at 105°. After 10 days, the reaction appeared to have proceeded as far as it was going to go; after 30 days the results were essentially the same. The amounts of the diene that reacted

⁽⁹⁾ W. Reeve and M. Karickhoff, J. Amer. Chem. Soc., 78, 6053 (1956).
(10) L. W. Newton and E. R. Coburn in "Organic Syntheses," Collect.
Vol. III, Wiley, New York, N. Y., 1955, p 313.

⁽¹¹⁾ Microbolling point by Siwoloboff's method in F. Schneider, "Qualitative Organic Microanalysis," Wiley, New York, N. Y., 1946, p 93.

follow (compound, per cent in original mixture, per cent unreacted hydrocarbon in final hydrocarbon mixture): 2, 35, 0; 3, 38, 5; 4, 1, 80; 5, 13, 0; 6, 3, 15; 7, 3, 0. **Registry No.**—*meso*-1, 32388-93-5; *dl*-1, 32388-94-6; 2, 18265-39-9; 3, 2417-88-1; 4, 21293-01-6; 5, 32388-98-0; 6, 32388-99-1; 7, 16356-05-1.

Reaction of Ethynyl Compounds with Lactones

Haruo Ogura,* Hiroshi Takahashi, and Tsuneo Itoh

School of Pharmaceutical Sciences, Kitasato University, Shirogane, Minato-ku, Tokyo 108, Japan

Received May 20, 1971

Acetylenic lactols, 3-butyl-3,3'-dihydroxy-1,5-diphenylpenta-1,4-diyne, 6-hydroxy-1-phenylheptan-3-one, 1-(2-substituted ethynyl)- β -L-gulofuranose, and 1-(2-substituted ethynyl)- α -D-ribofuranose, were synthesized via the lithium derivative of ethynyl compounds. The reaction mechanism involving the lactone carbonyl is similar to the reaction of aldehyde or ketone with the ethynyllithium compound.

The nucleoside antibiotics, showdomycin¹ (1), pyrazomycin² (2), and formycin^{3.4} (3), are carbon-linked nucleosides. The carbon-linked nucleosides are interesting compounds with potent biological activity, and the synthetic studies on these compounds have been reported by Sorm, *et al.*,⁵ and by Goodman, *et al.*⁶



Tronchet and Perret' reported the synthesis of an analog of pyrazomycin (2), $3-\beta$ -D-erythrofuranosyl-1*p*-nitrophenylpyrazole. On the other hand, Asbun and Binkley⁸ synthesized 5-substituted pyrimidine nucleosides from the reaction of diisopropylidene aldehydopentose with 2,4-dibenzyloxy-5-lithiopyrimidine.

The present paper concerns attempted reaction of ethynyl compounds with lactones and sugar lactones, which was expected as a model experiment for the preparation of the carbon-linked nucleoside.⁹ γ -Valerolactone (4) (Scheme I) was treated with the

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Grignard compound of phenylacetylene to obtain 3-butyl-3,3'-dihydroxy-1,5-diphenylpenta-1,4-diyne (5). This is similar to the reaction of γ -butyrolactone and phenylmagnesium bromide.¹⁰ Butyllithium was used in place of the Grignard compound of γ -butyrolactone (4) to form 6-hydroxy-1phenylhepta-1-yn-3-one (6), which was confirmed as its *p*-nitrophenylhydrazone (7) through examination of ir, nmr, and mass spectra.

By application of this method to sugar lactones, it has been possible to obtain acetylenic lactols. Treatment of 5-O-(tetrahydropyran-2-yl)-2,3-O-isopropylidene-D-ribonolactone (9) with butyllithium and phenylacetylene in ether failed to afford phenylacetylenic lactol. On the other hand, reaction of 2,3-Oisopropylidene-D-ribonolactone (8) or 2,3-O-isopropylidene-5-O-acetyl-D-ribonolactone (10) with lithium acetylenic compounds gave 1-(2-substituted ethynyl)-2,3-O-isopropylidene-D-ribofuranose (11a,b) in 30% yield (Scheme II). The ir spectra of these compounds (11a,b) show hydroxyl bands at 3380 and 3280 cm⁻¹ and acetylenic band at 2180-2190 cm⁻¹, and no lactonic band at around 1780 cm⁻¹.

In case of L-gulonolactone, 2,3:5,6-di-O-isopropylidene derivative (12) was treated with various lithium acetylenic compounds to obtain 1-substituted 2,3:5,6di-O-isopropylidene-L-gulofuranose (13a-g) in a reasonable yield (40-50%) (Scheme III). The ir spectra of these compounds (13a-g) showed a hydroxyl band at around 3300-3400 cm⁻¹ and an acetylenic band at 2160-2180 cm⁻¹, and the mass spectra of these compounds showed molecular ion (M⁺) peaks.

The nmr spectra of these compounds (13a-g) showed a broad singlet due to C₁-hydroxyl group at around δ

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