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The Preparation of Cyclic Glycerol Acetals by Transacetalation[1]

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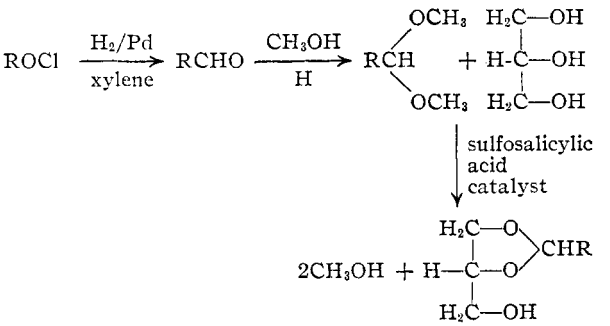
A method is described for the preparation of five-membered acetals by an exchange between primary alcohols in acetal linkage and polyhydroxy alcohols such as glycerol or higher boiling primary or secondary alcohols. Evidence is presented to show that only the 1,2-cyclic glycerol acetals are obtained by this transacetalation reaction. An exchange between primary alcohols in ketone acetal linkage and glycerol occurred showing that transketalation also occurs under the same conditions as required for transacetalation. Further modification of the reaction conditions using the benzylidene glycerol acetals as models led to the isolation of three isomeric forms of benzylidene glycerol acetal consisting of a 1,2- and two 1,3-isomers. The equilibrium constant for the interconversion of the 1,2- and the 1,3-benzylidene glycerol acetals in the presence of acid was determined. Starting with the 1,2-isomer, K_{eq} was found to be 0.114; with the 1,3-isomer, a K_{eq} of 0.119 was obtained. The equilibrium favored the dioxolane structure.

Present methods for preparing glycerol acetals by direct condensation with aldehydes lead to the formation of mixtures of the 1,2- and 1,3-isomers.[2] Furthermore, the preparation of higher aliphatic homologs of cyclic glycerol acetals results in low yields partly because of the polymerization of the free aldehydes used.[3,4] To overcome these difficulties we have synthesized cyclic acetals by an exchange of primary alcohols in acetal linkage with glycerol. The low yields usually associated with the use of free aldehydes can be avoided by using the dimethyl or diethyl acetal of long-chain fatty aldehydes which can be prepared in good yields.[5]

Bachman[6] was the first to demonstrate that an exchange between alcohols in acetal linkage and primary alcohols would take place when he heated, in sealed tubes, various primary alcohols with dimethyl acetal. Later, Delepine,[7] but without sealed tubes, used the same procedure with various primary, secondary and tertiary alcohols and phenols. McElvain and Curry,[8] using small amounts of sulfuric acid as a catalyst, have extended this reaction to the formation of a number of halocyclic acetals and ketene acetals with ethylene and trimethylene glycol. We have been unable to find an application of this reaction to the important trihydric alcohol, glycerol.

The synthesis of cyclic glycerol acetals by exchange of alcohols in acetal linkage with glycerol would be expected to yield a mixture of the 1,2- and 1,3-cyclic isomers. In view of the greater reactivity of the primary as compared to the secondary hydroxyl group the 1,3-derivative might be expected to be favored. However, when the transacetalation was carried out under controlled conditions in accordance with the scheme shown, the 1,2-isomer was obtained exclusively.

The R group may be an aliphatic chain, a substituted aliphatic chain or an aromatic radical. In addition to glycerol the reaction takes place with the propanediols and high boiling primary and secondary aliphatic alcohols.



In all cases where glycerol acetals were synthesized by this procedure, only the 1,2-cyclic acetals were obtained. For the purpose of investigating the structure of the cyclic glycerol acetals, derivatives of the 1,2-octadecylideneglycerol acetal (2-heptadecyl-4-hydroxymethyl-1,3-dioxolane)[9] were prepared and the acetal group removed by acid hydrolysis in the cold. This procedure led to the formation of α-monomyristin, whose melting point compared favorably with that reported in the literature.[10]

Next, the 1,2-benzylideneglycerol acetal (2-phenyl-4-hydroxymethyl-1,3-dioxolane) was prepared by transacetalation and compared with the 1,2-benzylideneglycerol acetal obtained by azeotropic distillation. Although azeotropic distillation leads to the formation of both the 1,2- and the 1,3-cyclic glycerol acetals, the product obtained by transacetalation was identical with the 1,2-benzylideneglycerol acetal isolated from the reaction mixture following azeotropic distillation. In addition, the 3-benzoyl derivatives (2-phenyl-4-benzoxymethyl-1,3-dioxolane) obtained from the 1,2-benzylideneglycerol acetals synthesized by both transacetalation and azeotropic distillation were

(1) This work was supported by a grant from the Life Insurance Medical Research Fund.

(2) H. Hill and H. Hibbert, THIS JOURNAL, **45**, 3117 (1923); **50**, 2235 (1928).

(3) M. Anchel and H. Waelsch, *J. Biol. Chem.*, **152**, 501 (1944).

(4) H. R. LeSueur, *J. Chem. Soc.*, **87**, 1888 (1905).

(5) F. Leopold and H. Büttner, *Z. physiol. Chem.*, **291**, 178 (1952).

(6) A. Bachman, *Liebig's Ann. Chem.*, **218**, 44 (1883).

(7) M. M. Delepine, *Soc. chim. de Paris*, **1**, 574 (1901).

(8) S. M. McElvain and M. J. Curry, THIS JOURNAL, **70**, 3781 (1948).

(9) In the older chemical and biological literature and for that matter recently in Vol. I, pp. 167–170, of Deuel's comprehensive three volume "The Lipids," Interscience Publ., Inc., New York, N. Y., 1951, the nomenclature included outside the parentheses in this paper has been traditionally used by both chemists and biologists. The present paper is one in a series concerned with the chemistry and metabolism of cyclic acetal phosphatides, believed by some investigators to be derived during isolation procedures from tissue plasmalogens. Since the general subject is of interest to both chemists and biologists, there is included within parentheses the more rational nomenclature based on the parent heterocyclic 1,3-dioxolane and dioxane ring structures and as used by McElvain and Curry.[8]

(10) M. Bergman and L. Carter, *Z. physiol. Chem.*, **191**, 211 (1930).

TABLE I

COMPOUNDS PREPARED BY THE TRANSACETALATION PROCEDURE

Compound	Yield, %	M.p., °C.	B.p., °C.	Mm.	$n^{30}D$	Formula	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
2-Heptadecyl-4-hydroxymethyl-1,3-dioxolane	95	56–57				$C_{21}H_{42}O_3$	73.39	72.93	12.35	12.11
2-Tridecyl-4-hydroxymethyl-1,3-dioxolane	93	37–38				$C_{17}H_{34}O_3$	71.33	72.00	12.00	12.00
2-Phenyl-4-hydroxymethyl-1,3-dioxolane	88		142–145	5	1.5388	$C_{10}H_{12}O_3$	66.66	66.70	6.67	6.72
2-Phenethyl-4-hydroxymethyl-1,3-dioxolane	79		129–130	3	1.5300	$C_{11}H_{14}O_3$	68.06	68.53	7.21	7.49
2-[2,6-Dimethyl-2,6-heptene]-4-hydroxymethyl-1,3-dioxolane	66		132–134	3	1.4660	$C_{13}H_{22}O_3$	69.02	68.58	9.73	10.06
2-Dichloromethyl-4-hydroxymethyl-1,3-dioxolane[a]	88		109–110	4	1.4882	$C_5H_8O_3Cl_2$	32.22	32.17	4.30	4.37
2-Methyl-4-hydroxymethyl-1,3-dioxolane	82		65–66	3	1.4405[b]					
2-Phenyl-4-methyl-1,3-dioxolane	60		83–85	4	1.5089[c]					
2-Phenyl-1,3-dioxane	60		98–99	4						
Ethyl, *n*-octyl acetal of benzaldehyde	70		142–143	4	1.4740[c]					
Ethyl, octanol-2 acetal of benzaldehyde	60		129–132	4	1.4730[c]					
2-Dimethyl-4-hydroxymethyl-1,3-dioxolane	86		80–81	11	1.4339[b]					

[a] Calcd.: Cl, 37.64. Found: Cl, 38.00. [b] Temp. 25°. [c] Temp. 27°.

identical. The 2-benzoyl-1,3-benzylideneglycerol acetal (2-phenyl-5-benzoxy-1,3-dioxane) obtained from the 1,3-benzylideneglycerol acetal (2-phenyl-5-hydroxy-1,3-dioxane) isolated from the reaction mixture in the azeotropic distillation procedure had different physical properties as compared with the benzoyl derivative of the 1,2-benzylideneglycerol acetal.

Based on the findings with regard to the derivatives prepared, it is evident that the transacetalation procedure when used in the synthesis of glycerol acetals gives rise to only the 1,2-cyclic glycerol acetals, thus leaving the third hydroxyl group of glycerol free for the preparation of many derivatives of glycerol, some of which, such as the acetal phospholipids, may be of biological importance. In addition, the acetal group blocking positions 1 and 2 of such glycerol derivatives may be removed easily by acid hydrolysis in the cold, thus offering another method for the preparation of α-mono derivatives of glycerol.

By analogy, it was felt that possibly the synthesis of cyclic ketone acetals could be accomplished by the procedure used for the synthesis of the 1,2-glycerol acetals. Accordingly, acetone diethyl acetal was allowed to react with glycerol under the conditions described below. An exchange between primary alcohols in ketone acetal linkage and glycerol occurred. The 1,2-isopropylideneglycerol (2,2-dimethyl-4-hydroxymethyl-1,3-dioxolane) was isolated in good yield from the reaction mixture, thus showing that transketalation also occurs under the same conditions required for transacetalation.

Although only the 1,2-glycerol acetals were obtained by the procedure, it was thought that by varying the details of the preparation it might be possible to obtain the 1,3-isomer or a mixture of the 1,2- and the 1,3-isomers. This postulate is supported by the fact that other methods for the synthesis of glycerol acetals lead to the formation of mixtures of the 1,2- and 1,3-glycerol acetals.[2,11]

Accordingly, benzylideneglycerol acetals were synthesized by the transacetalation procedure with the following modification. Instead of neutralizing the acid catalyst and isolating the product immediately upon completion of the reaction, the reaction mixture was allowed to stand overnight. After such treatment, three isomers of the benzylideneglycerol acetals were obtained, one with a melting point of 84°, another with a melting point of 64–65°, and a third with a boiling point of 135–137° (3 mm.).

The isomer boiling at 135–137° was identical with the 1,2-benzylideneglycerol acetal (2-phenyl-4-hydroxymethyl-1,3-dioxolane) prepared as described above. This was shown by the preparation of the 3-benzoyl-1,2-benzylidene derivative (2-phenyl-4-benzoxymethyl-1,3-dioxolane) with subsequent cleavage of the acetal linkage to yield α-glycerol benzoate. The isomer melting at 84° was found to be the 1,3-benzylideneglycerol acetal (2-phenyl-5-hydroxy-1,3-dioxane) by preparation of the benzoate whose melting point was identical with that of the benzoate of 1,3-benzylideneglycerol acetal (2-phenyl-5-benzoxy-1,3-dioxane) prepared by azeotropic distillation. It was first thought that the isomer melting at 64–65° might be the solid 1,2-benzylideneglycerol acetal reported by Irvin.[12] The benzoate of this lower melting isomer was prepared and its melting point found to be different from those of the other two isomers isolated. Cleavage of the acetal linkage by catalytic hydrogenation under conditions where no migration of the acyl group could occur led to the recovery of 2-benzoylglycerol which was identical with the benzoylglycerol prepared from the 1,3-benzylideneglycerol acetal.

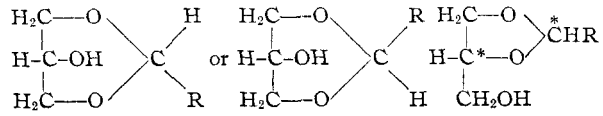
These findings show that the three isomers isolated from the reaction mixture described below consisted of a 1,2-benzylideneglycerol acetal and two 1,3-benzylideneglycerol acetals. These three isomers, along with the solid 1,2-benzylideneglycerol acetal reported by Irvin,[12] indicate that there are at least two isomers of each of the benzylideneglycerol acetals and in the case of the 1,2-derivative possibly four. Examination of the structure of the two benzylideneglycerol acetals shows that the 1,3-benzylidene isomer has the possibility of *cis–trans* isomerism about the carbon atom in the 2-position of the dioxane ring in relation to the secondary hydroxyl group on the carbon atom in the 4-position.

In the case of the 1,2-benzylideneglycerol acetal the structure is such that there are two asymmetric carbon atoms in the compound, one at the 2-position and one at the 4-position of the dioxolane

(11) W. H. Davis, I. M. Heilbron and W. E. Jones, *J. Chem. Soc.*, **266**, 1232 (1934).

(12) J. C. Irvin, L. MacDonald and C. Soutar, *ibid.*, **107**, 337 (1915).

ring, which should thus give rise to two pairs of *dl*-isomers.



Since the conversion of the 1,2-benzylideneglycerol acetal to the 1,3-isomer was accomplished by allowing the 1,2-derivative to stand in the presence of catalytic amounts of acid it was felt that the mixture of isomers obtained represented an equilibrium condition. If this should be the case, an equilibrium constant could be obtained for this system. Therefore, an investigation of the equilibrium conditions for this reaction was made. For the purpose of determining the concentrations of the 1,2- and the 1,3-benzylideneglycerol acetals in ethanol solutions, the ultraviolet absorption spectra of these compounds were made (Figs. 1, 2 and 3). Examination of these spectra reveals

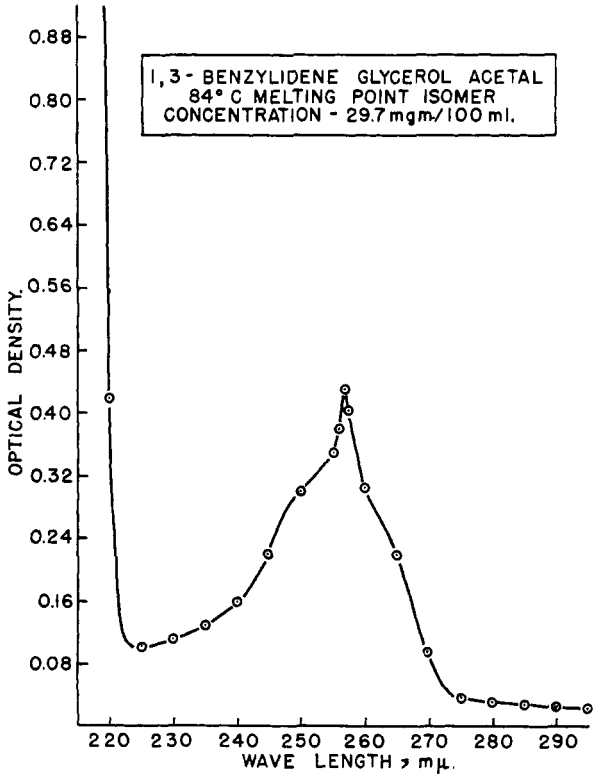


Fig. 1.

a considerable amount of overlap. However, the curves for the 1,2- and the 1,3-benzylideneglycerol acetals show a difference in optical density and a difference in the slope of the curves at wave lengths of 270 and 275 mμ. Under these conditions a mixture of two compounds when present can be resolved by setting up two simultaneous equations as described later. This condition holds true if each of the substances in the mixture obeys Beer's law over the range of concentrations used. Both the 1,2- and the 1,3-benzylidene-

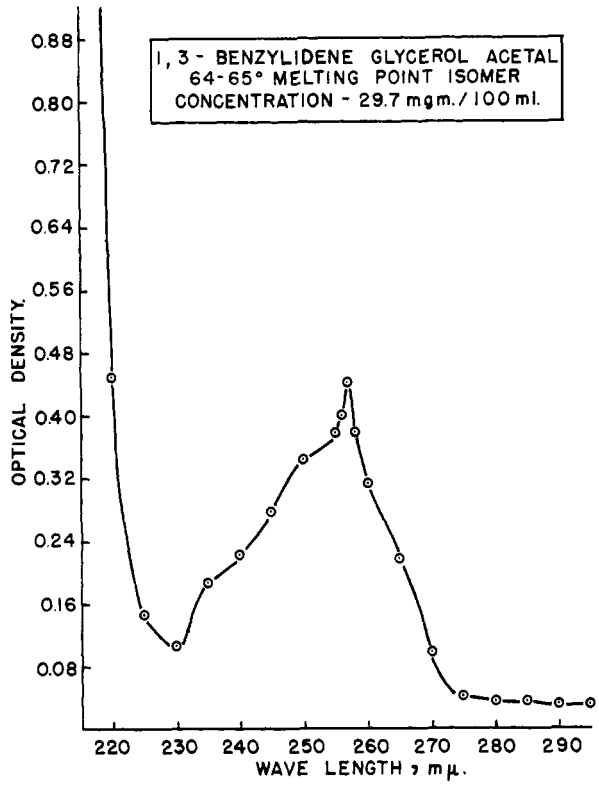


Fig. 2.

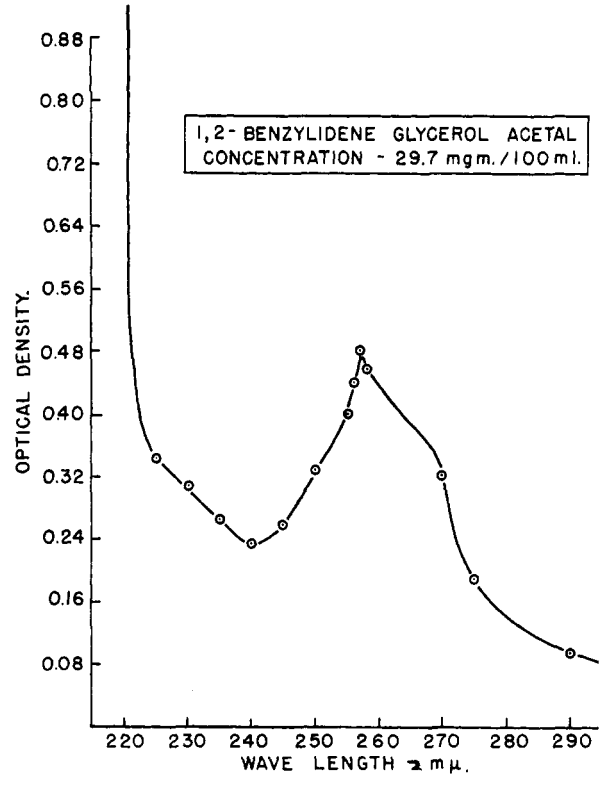


Fig. 3.

glycerol acetals conformed with Beer's law at both wave lengths over the range of concentrations used.

For the evaluation of the equilibrium constant several determinations were made starting with

each of the benzylideneglycerol acetals. Starting with the 1,2-isomer K_{eq} was found to be 0.114, whereas starting with the 1,3-isomer a K_{eq} value of 0.119 was obtained. These results clearly demonstrate that in the presence of catalytic amounts of acid a slow equilibrium exists between the 1,2- and 1,3-benzylideneglycerol acetals.

Experimental

Preparation of the Dimethyl Acetals.—The reduction of the acid chlorides was accomplished by the method of Rosenmund.[13] As an example of the experimental procedure the synthesis of palmital dimethyl acetal is described. Fifteen grams of palmitoyl chloride was suspended with 3 g. of 5% palladium–barium sulfate catalyst in 75 ml. of anhydrous xylene. The reaction mixture was heated on an oil-bath at 140°, and the reduction of the acid chloride was accomplished by passing a strong stream of hydrogen into the reaction mixture while vigorous stirring was maintained. After 30 minutes, the reaction was stopped and the catalyst was removed by centrifugation. Allowing the reduction to run for appreciably longer times led to diminished yields of aldehyde presumably due to polymerization.

A modification of the procedure of Leopold and Büttner[5] was used for the preparation of the dimethyl acetals. The xylene solution of the aldehydes obtained by reduction of the acid chloride was added immediately to 200 ml. of anhydrous methanol containing 100 mg. of sulfosalicylic acid. This mixture was refluxed under anhydrous conditions for 3 hours on a water-bath. Then 500 ml. of 0.5 *M* methanolic sodium hydroxide was added and the refluxing continued for 2 more hours to saponify any unreacted acid chloride. Next, the palmital dimethyl acetal was extracted by shaking the reaction mixture with three 250-ml. portions of petroleum ether (b.p. 40–60°), and the petroleum ether extracts were combined. The petroleum ether and most of the xylene were removed under reduced pressure. The resulting light yellow product was purified by distillation under reduced pressure; yield 88%, b.p. for the dimethyl acetal of hexadecanal was 144–146° (2 mm.), $n^{25}D$ 1.4362.

The following dimethyl acetals were prepared by analogous procedures: octadecanal dimethyl acetal with a yield of 88%, b.p. 168–170° (3 mm.), $n^{25}D$ 1.4410; tetradecanal dimethyl acetal with a yield of 90%, b. p. 134–136° (4 mm.), $n^{25}D$ 1.4342; dodecanal dimethyl acetal with a yield of 86%, b.p. 132–134° (5 mm.), $n^{25}D$ 1.4310.

Preparation of Cyclic Glycerol Acetals.—The preparation of 1,2-hexadecylideneglycerol acetal (2-pentadecyl-4-hydroxymethyl-1,3-dioxolane) is given as an example of the procedure. In a three-necked flask equipped with a stirrer, a thermometer and a distilling head for the collection of the alcohol evolved were placed 18 g. of glycerol, 30 g. of hexadecanal dimethyl acetal and 50 mg. of sulfosalicylic acid. The reaction mixture was heated with vigorous stirring on an oil-bath. When the temperature of the reaction mixture reached 140°, methanol began to evolve and the temperature of the reaction mixture was increased gradually to 170°. At this point, the theoretical quantity of methanol had been recovered. The reaction mixture was heated at this temperature for 15 additional minutes to ensure completeness of reaction. After allowing to cool to room temperature, 50 ml. of 0.5 *M* sodium hydroxide was added and the ether extract was dried over anhydrous potassium carbonate. The ether was removed under reduced pressure, and the resulting oil solidified at room temperature. Recrystallization from methanol gave a yield for 1,2-hexadecylidene glycerol acetal of 93%, m.p. 47–48°.[14]

Anal. Calcd. for $C_{19}H_{38}O_3$: C, 72.56; H, 12.18. Found: C, 72.43; H, 12.12.

Preparation of α-Monomyristin.—*In a 250-ml. glass-stoppered flask* were placed 3 g. of 1,2-octadecylideneglycerol acetal, 5 ml. of pyridine and 10 ml. of chloroform. The flask was then immersed in an ice-bath. To the contents of the flask was added in a dropwise manner 2.5 g. of tetradecanoyl chloride dissolved in 5 ml. of chloroform. The mixture was allowed to stand overnight at room temperature. The reaction mixture was extracted with 25 ml. of ether, and the ether solution washed in succession with distilled water, 10% sodium bicarbonate solution, and then again with distilled water. After drying the ether solution over anhydrous sodium sulfate, the ether was removed at the water-pump, and the residue was redissolved in 25 ml. of ether. The flask was immersed in an ice-salt-bath and 15 ml. of concentrated hydrochloric acid was added dropwise. Upon standing for 30 minutes, 100 ml. of ice-water was added, and the product was filtered. The residue was recrystallized from a mixture of ether and petroleum ether (1:1) and give a 75% yield, m.p. 65–66°. This melting point compared favorably with that reported in the literature for α-monomyristin.[10]

Preparation of 1,2- and 1,3-Benzylideneglycerol Acetals (2-Phenyl-4-hydroxymethyl-1,3-dioxolane and 2-Phenyl-5-hydroxy-1,3-dioxane) by Azeotropic Distillation.—Pure benzaldehyde (160 g.), 150 g. of glycerol, 200 ml. of benzene and 1 g. of sulfosalicylic acid were heated in a carbon dioxide atmosphere with vigorous stirring for 6 hours. The reaction mixture was cooled, a few drops of phenolphthalein indicator was added followed by 100 ml. of 0.1 *M* sodium hydroxide. This mixture was then extracted with 350 ml. of ether, and the ether extract treated with a neutral, saturated solution of sodium bisulfite. The ether layer was separated, washed with distilled water and dried over anhydrous potassium carbonate. The ether was removed at the water-pump, and the residue dissolved in an equal volume of petroleum ether (b.p. 40–60°) and stored at −15° overnight. The crystals of the 1,3-benzylideneglycerol acetal which formed were filtered in the cold and recrystallized from a mixture of benzene and petroleum ether; yield 23%, m.p. 83–84°.

The filtrate obtained above was then evaporated and the oily 1,2-benzylideneglycerol acetal which remained after the solvent was removed was distilled at reduced pressure; yield 70%, b.p. 146–148° (4 mm.), $n^{30}D$ 1.5350.

Preparation of the 3-Benzoyl-1,2-benzylideneglycerol Acetal (2-Phenyl-4-benzoxymethyl-1,3-dioxolane).—Ten grams of the 1,2-benzylideneglycerol acetal obtained by transacetalation or by azeotropic distillation was dissolved in 40 g. of anhydrous pyridine in a glass-stoppered flask, and 9.24 g. of benzoyl chloride was added in a dropwise manner. After allowing the reaction mixture to stand for 30 minutes, 200 ml. of ice-water was added to remove most of the pyridine. The water phase was then decanted, and the residue taken up in ether. Upon removal of the ether at the water-pump, a thick viscous oil remained. This oil was purified by distillation under reduced pressure, b.p. 212–215° (7 mm.), $n^{25}D$ 1.5540.

The 2-benzoyl-1,3-benzylideneglycerol acetal was prepared in an analogous manner. Recrystallization of the solid residue from ethanol gave a product with a m.p. 103°, lit.[2] m.p. 103°.

Preparation of the Mixture of the 1,2- and 1,3-Benzylideneglycerol Acetals by Transacetalation.—The benzylideneglycerol acetals were prepared by the transacetalation reaction described above with the following modification. Upon complete evolution of the alcohol which appeared to occur in two stages, the reaction mixture was allowed to stand overnight, instead of isolating the product immediately. The mixture was then treated with 100 ml. of 0.5 *M* sodium hydroxide and extracted with 100 ml. of ether. The ether extract was washed with distilled water and dried over anhydrous potassium carbonate and the ether removed under reduced pressure. The yield of crude product was 97%. This product was dissolved in a mixture of petroleum ether (b.p. 40–60°) and benzene (1:1) and stored overnight at −24°. Crystals were obtained which were collected and washed once with a cold mixture of petroleum ether and benzene (1:1). Recrystallization from a mixture of petroleum ether and benzene (5:3) gave an 8% yield of short feathery crystals, m.p. 84°, fraction I.

The solvent from the filtrate was evaporated and the oily residue distilled under reduced pressure, b.p. 165–166° (11 mm.). This product was dissolved in a mixture of petroleum ether and benzene (1:1), placed in the deep freeze at −24° for 6 hours and then allowed to stand overnight in the cold room at 5–10°. Another crop of crystals was obtained which was collected on a filter in the cold. Recrystallization from petroleum ether–benzene (1:1) gave a 4% yield, m.p. 64–65°, fraction II.

After removal of the solvent from the filtrate obtained from fraction II, the oily residue was distilled under reduced pressure, yield 82%, b.p. 135–137° (3 mm.), $n^{30}D$

(13) K. W. Rosenmund, *Ber.*, **51**, 585 (1918).

(14) All melting points are uncorrected.

1.5350, fraction III. The constants obtained and reported for fraction III are identical with those for the 1,2-benzylideneglycerol acetal prepared above.

The benzoates of all three fractions were prepared by the procedures described above. The benzoate of fraction I had a melting point of 103° which is identical with that reported in the literature for the benzoate of 1,3-benzylideneglycerol acetal.[2,11] The benzoate of fraction II had a melting point of 83–84°. The benzoate of fraction III distilled at 212–215° (7 mm.), $n^{30}D$ 1.5540. These latter constants are identical with those for the 3-benzoyl-1,2-benzylideneglycerol acetal obtained above.

Preparation of β-Glycerol Benzoate from the Benzoates of Benzylideneglycerol Acetals of Fractions I and II.[10]—Seven grams of the benzylideneglycerol acetal benzoate derivatives from fraction I or II was suspended in 100 ml. of absolute ethanol with 1.0 g. of A-100 palladium catalyst.[15] The acetal group was removed by catalytic hydrogenation at 60 p.s.i.g. After 3 hours the hydrogenation was complete, and the catalyst was removed by filtration. The volume of the alcoholic filtrate was reduced by evaporation. Upon cooling the concentrate to a temperature of 0–5°, crystals were obtained which were removed by filtration. Recrystallization of the solid residue from benzene gave a yield of β-glycerol benzoate of 94%, m.p. 70–71°, lit.[10] m.p. 70–71°.

Preparation of α-Glycerol Benzoate from the Benzylidene Benzoate of Fraction III.—Ten grams of the benzoate of fraction III was mixed with 50 ml. of 0.1 *N* hydrochloric acid and stirred vigorously on a water-bath at a temperature of 60°. After 2 hours the solution was cooled, neutralized with sodium hydroxide, saturated with sodium chloride and extracted with ether. The ether extract was dried over anhydrous sodium sulfate, and the ether was removed at the water-pump. The oily residue was placed in a vacuum desiccator over concentrated sulfuric acid and dried overnight. The residue was then placed in the deep freeze at −20° where it solidified. Recrystallization from ether–petroleum ether (1:1) gave a 95% yield, m.p. 35–36°.

Ultraviolet Absorption Spectra of the Benzylideneglycerol Acetals.—The ultraviolet absorption spectra of the 1,2-benzylideneglycerol acetal and of the two 1,3-benzylidene glycerol acetals were taken over the range of wave lengths of from 220 to 290 mμ using a concentration of 29.7 mg. of each substance per 100 ml. of ethanol as a solvent. These spectra (Figs. 1, 2, and 3) were obtained with the Beckman model DU spectrophotometer using a 1.00-cm. quartz cuvette.

Next, a series of solutions of the benzylidene glycerol acetals was prepared covering the range of concentrations from 0.000 to 0.509 g./100 ml. solvent, and the conformity of these substances to Beer's law at the two wave lengths 270 and 275 mμ was determined: for the 1,2-benzylideneglycerol acetal, E_{270} = 48.2, E_{275} = 6.57; for the 1,3-benzylideneglycerol acetal, E_{270} = 40.3, E_{275} = 8.77.

Determination of K_{eq} for the Interconversion of Benzylideneglycerol Acetals.—Eighteen grams each of the 1,2- and 1,3-benzylideneglycerol acetals were heated separately with 100 mg. of sulfosalicylic acid on an oil-bath at a temperature of 165° for one hour. The reaction mixture then was allowed to remain overnight at room temperature. The two benzylidene mixtures were shaken with 50 ml. of 0.5 *M* sodium hydroxide, and then extracted with ether. The ether solutions were washed with distilled water and dried over anhydrous potassium carbonate. After removal of the ether at the water-pump, the oily residues were distilled, b.p. for each mixture 143–145° (3 mm.), $n^{30}D$ 1.5335. Each of the products was then dissolved in ethanol and made up to volume in a 100-ml. volumetric flask, and the optical densities of the solutions were measured at wave lengths of 270 and 275 mμ using the 1.0-cm. quartz cuvette in the Beckman model DU spectrophotometer.

From the determined value of the extinction coefficient for the 1,2- and the 1,3-benzylidene glycerol acetals at the two wave lengths shown, the concentration of each of the two substances was calculated by use of the simultaneous equations:

$$\text{O.D.}_{mix} \text{ at } 270\ m\mu = E_1C_1L + E_2C_2L$$

$$\text{O.D.}_{mix} \text{ at } 275\ m\mu = E_3C_1L + E_4C_2L$$

Where O.D._{mix} is the optical density of the mixture at the wave length indicated, E_1 and E_3 are the extinction coefficients of the 1,2-benzylideneglycerol acetals at 270 and 275 mμ, respectively, C_1 is the concentration of the 1,2-isomer, L is the length of the light path through the solution, E_2 and E_4 are the extinction coefficients of the 1,3-benzylideneglycerol acetal at 270 and 275 mμ, respectively, and C_2 is the concentration of the 1,3-isomer. Representative data from this experiment are shown in Table II. From these data,

TABLE II

EQUILIBRIUM DATA FOR THE INTERCONVERSION OF BENZYLIDENEGLYCEROL ACETALS

Starting material	Wave length, mμ	Optical density of mixture	Concentration × 10^3 *M* 1,2-Isomer	1,3-Isomer
1,2-Isomer	270	0.4430	8.386	0.958
1,2-Isomer	275	.0635		
1,3-Isomer	270	.4940	9.310	1.116
1,3-Isomer	275	.0710		

K_{eq} for the following reaction may be calculated

1,2-benzylideneglycerol acetal ⇌ 1,3-benzylideneglycerol acetal

$$K_{eq} = C_{1,3}\text{-isomer}/C_{1,2}\text{-isomer}$$

Starting with the 1,2-benzylidene glycerol acetal, K_{eq} = 0.114; starting with the 1,3-benzylidene glycerol acetal K_{eq} = 0.119.

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(15) Obtained from Dr. Walter H. Hartung, School of Pharmacy, The Medical College of Virginia. The catalyst was prepared from anhydrous sodium acetate and Norite and contained 100 mg. of $PdCl_2$/g. Norite.