### Experimental

**Synthesis of the Mixed Ethyl-Glycerol Acetal.**—In a three-necked flask equipped with a stirrer, a thermometer, and a condenser for the collection of alcohol were placed 55 g. of glycerol, 35 g. of diethyl acetal, and 50 mg. of sulfosalicylic acid. The reaction mixture was heated on an oil bath and ethanol began to evolve at 94°. The first step in the evolution of ethanol was complete at 104°; yield of ethanol was 102% as calculated for the mixed acetal. The reaction was stopped at this point by chilling in an ice bath. After chilling, the reaction mixture was extracted three times with 125-ml. portions of ether. The combined extracts were washed with 50 ml. of a 0.1 *N* sodium hydroxide and then with distilled water and dried over anhydrous potassium carbonate. The ether was removed under reduced pressure leaving a yellowish oil which had an odor distinctly different from that of diethyl acetal, acetaldehyde or 1,2-ethylideneglycerol. This oil was further purified by fractional distillation at 3 mm. Two fractions were obtained: Fraction I, b.p. 53–55° (3 mm.); $n^{25}D$ 1.4395; yield was 21% as calculated for the mixed ethyl-glycerol acetal. Fraction II, b.p. 65–66° (3 mm.); $n^{25}D$ 1.4405 (These constants are identical with those reported earlier for 1,2-ethylideneglycerol acetal.[3]); yield was 3.1% as calculated for 1,2-ethylideneglycerol acetal.

**Preparation of 1-2-Dimyristin from the Mixed Ethyl-Glycerol Acetal.**—In a glass-stoppered Erlenmeyer flask were placed 9.6 g. of the product from fraction I, 12 ml. of pyridine, and 10 ml. of purified chloroform. This mixture was chilled thoroughly in an ice bath. To the chilled mixture were added in a dropwise manner 29 g. of myristoyl chloride. A crop of white crystals appeared and the solution became yellow in color. After the reaction was completed, 150 ml. of ether was added and a voluminous precipitate appeared which went back into solution upon addition of 150 ml. of ice–water. The ether layer was removed, washed with 10% sodium bicarbonate, then with ice–water, and dried over anhydrous sodium sulfate. The solvent was removed under reduced pressure leaving a waxy solid. Yield of crude material was 99% as calculated for the dimyristoyl derivative of the mixed acetal.

The acetal group was removed by acid hydrolysis. The crude material was dissolved in 40 ml. of ether and 40 ml. of concentrated hydrochloric acid was added in a dropwise manner to the constantly shaken ether solution cooled in an ice–salt mixture. After the addition of acid was complete, the ether layer was separated and washed repeatedly with 100-ml. portions of ice–water. After each wash a troublesome emulsion occurred. Each water wash was extracted with three 100-ml. portions of ether, these extracts being added to the original ether solution. The combined ether fractions were dried over anhydrous sodium sulfate and placed in the cold room at 5° overnight, where a small amount of white precipitate formed. The ether solution was concentrated to a volume of 50–75 ml. by evaporation and the precipitate filtered on a Büchner funnel. The precipitate was shown to be mostly the soap of myristic acid, although repeated crystallization from ethanol at 5° produced a few milligrams of a white crystalline material melting at 71–72°. This melting point compared favorably with that reported for β-monomyristin.[7]

The ether filtrate from the above procedure was evaporated to dryness under reduced pressure. The residue obtained was dissolved in 50 ml. of acetone, and 50 ml. of water was added. This mixture was placed in the cold room overnight at 5° where a light yellow precipitate formed. This precipitate was recrystallized repeatedly from acetone until a white crystalline material melting sharply at 59° was obtained and which showed no change in melting point upon subsequent recrystallizations. This melting point corresponded exactly with that reported for 1,2-dimyristin.[7]

**Investigation of Conditions for Ring Closure in the Synthesis of 1,2-Glycerol Acetals.**—The synthesis of 1,2-benzylideneglycerol acetal from 0.1 *M* diethyl acetal of benzaldehyde and 0.1 *M* glycerol was carried out by the procedure previously described[3] with the following modification. After evolution of one-half of the theoretical quantity of alcohol, the reaction was stopped and the product extracted with ether and base in the usual manner. The ether was removed under reduced pressure and the oil which remained was heated to temperatures of 110–135° where evolution of the second half of the alcohol occurred. Distillation of the reaction mixture gave an 80% yield, b.p. 130–131° (3 mm.); $n^{30}D$ 1.5350. These constants compare with those reported earlier for 1,2-benzylideneglycerol acetal.

(4) A. Bachman, *Liebig's Ann.*, **218**, 44 (1883).
(5) M. M. Delepine, *Bull. soc. chim. Paris*, (3) **25**, 574 (1901); *Chem. Zentr.*, **72**, II, 185 (1901).
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(7) Lutton, E. S., *J. Am. Oil Chem. Soc.*, **27**, 276 (1950).

## Reaction of Chloral Hydrate with Aliphatic Amines in Water

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It has been shown by Blicke and Lu that chloral hydrate reacted with N-methyl-α-methylhomopiperonylamine or piperidine to form the N-formyl derivative in almost quantitative yield.[1] More detailed investigation with a number of amines showed that formylation with the aid of chloral in chloroform under anhydrous conditions is an excellent general procedure for the acylation of a strong organic base.

The purpose of this work was to establish whether the formylation could be performed in water (equation 1) at the same time differentiating between formamide synthesis through chloral hydrolysis followed by ammonium formate dehydration (equation 2).

$$RNH_2 + CCl_3CH(OH)_2 \xrightarrow{H_2O} RNHCHO + CHCl_3 \quad (1)$$

$$\downarrow H_2O$$

$$[R\overset{+}{N}H_3\ HCOO^-] + CHCl_3 \longrightarrow RNHCHO + H_2O \quad (2)$$

Four aliphatic amines representing various degrees of steric hindrance and one aliphatic diamine were studied (Table I).

TABLE I

REACTION OF AMINES WITH CHLORAL HYDRATE

$$RNHR' + CCl_3CH(OH)_2 \longrightarrow RNR'CHO + [RNH_2R'\ HCOO^-]$$

| R | R′ | Yield, % RNR′CHO | Yield, % [RNH₂R′HCOO⁻] |
|---|---|---|---|
| *n*-C₄H₉— | H | 78.5 | ... |
| *t*-C₄H₉— | H | 6.0 | 92.0 |
| Cyclohexyl— | H | 72.5 | 2.1 |
| (CH₃)₂N(CH₂)₃— | H | 73.5 | 8.3[a] |
| C₂H₅— | C₂H₅ | 41.5 | 19.7[b] |

[a] Isolated as an N,N-Dimethylpropanediammonium formate–formic acid (3:1) azeotrope. [b] Isolated as a diethylammonium-formate–formic acid (3:2) azeotrope.

Hydrolysis to an ammonium formate was evident with *t*-butylamine and to a much lesser extent with all the other amines except the *n*-butyl analog. Ammonium formate dehydration was eliminated as a major route to formamides in this investigation on the basis of a comparison of conditions employed and those required for dehydration. The conditions for dehydration were determined previously in the course of distilling mixtures containing excess amine and 89% formic acid. The appropriate ammonium formates were isolated as solids, binary azeotropes with formic

(1) F. F. Blicke and C.-J. Lu, *J. Am. Chem. Soc.*, **74**, 3933 (1952).

acid, or ternary azeotropes with formic acid and formamides depending on the particular amine.[2] Appreciable dehydration to formamide required atmospheric distillation over 100°. In contrast, the chloral hydrate reactions were performed at room temperature and the formamides were isolated by extraction with chloroform followed by vacuum distillation.

The hydrolysis of chloral occurs presumably by a mechanism such as that given by Gustafson and Johanson[3]; either hydroxide ion or amine could serve as the base. There is no obvious relationship between amine basicity and degree of either formylation or hydrolysis. However, steric hindrance appears to play an important role. Appreciable hydrolysis only with *t*-butylamine implies that approach of the amine nitrogen to the carbonyl carbon is hindered to such an extent that no formylation was detected. Except for such hindered compounds the reaction of chloral hydrate with amines in water is an acceptable procedure for the preparation of formamides.

### Experimental

**General Procedure for the Reaction of Chloral Hydrate with Aliphatic Amines in Water.**—To a magnetically stirred solution (200 ml.) of the appropriate amine (0.5 mole) in water was added an aqueous solution (150 ml.) of chloral hydrate (82.5 g., 0.5 mole). A liquid or solid separated and the temperature rose to not higher than 45°. The mixture was allowed to stir overnight at room temperature. In all cases two liquid layers remained. The aqueous layer was extracted with chloroform. The chloroform extracts were combined with the organic layer and vacuum distillation gave the appropriate formamide. The aqueous portion was evaporated on a rotating evaporator at 50° under water-aspirator vacuum to give either a solid ammonium formate or a liquid residue. The liquid was distilled to give an ammonium formate azeotrope with formic acid. The various formamides, ammonium formates, and ammonium formate azeotropes were characterized by comparison with authentic samples. Elemental analyses, indices of refraction, infrared absorption curves, boiling points, and melting points were used for this purpose.

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(2) E. J. Poziomek and Mary D. Pankau, unpublished results.
(3) C. Gustafson and M. Johanson, *Acta Chem. Scand.*, **2**, 42 (1948).

## Complexes of Sugars with Molybdate

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In the course of an investigation of the biological function of molybdenum, complexes of sugars with this metal in aqueous solution have been studied.

Bourne, Hutson, and Weigl have reported the results of paper ionophoresis studies of sugars in acidified molybdate solution.[2] These authors concluded from their results that pyranose sugars possessing three hydroxyl groups in a *cis-cis*-1 (ax), 2 (eq), 3 (ax), arrangement (chair form) complex with molybdate.

(1) Abstracted from the M.S. thesis of S. Kiang, Utah State University, 1962.
(2) E. J. Bourne, D. H. Hutson, and H. Weigl, *J. Chem. Soc.*, 4252 (1960).

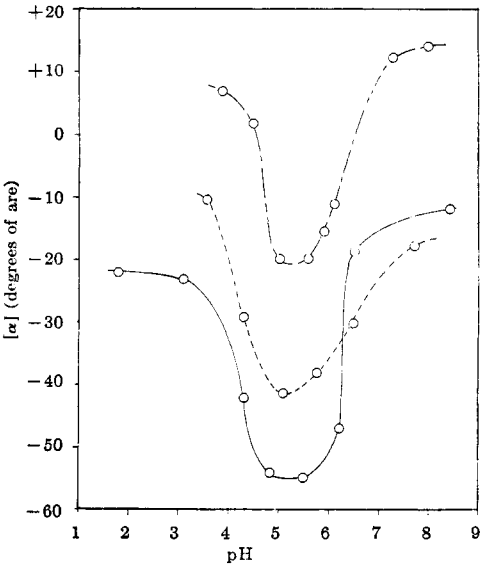


Fig. 1.—Effect of pH on specific rotation ([α]) of sugar–molybdate complexes.
Ratio of sugar to molybdate, 1:1; temp., 25.0 ± 0.5° C.
— — — — D-mannose
---------- D-ribose
—·— D-lyxose

Polarimetric studies of these complexes have verified these conclusions. It was found that when molybdate was added to a solution of a sugar with the correct structure at a pH near 5 a large change in optical rotation due to complex formation occurred, while little or no change occurred with sugars not having this structure. Table I gives the results with various sugars. It can be seen that only those having the necessary 1 (ax), 2 (eq), 3 (ax) arrangement complex. The absence of one of the necessary hydroxyls prevents complexing, as with 2-deoxy-D-ribose and α-methyl-D-mannopyranoside.

TABLE I

| Sugars that complex | Sugars that do not complex |
|---|---|
| D-Mannose | D-Glucose |
| D-Lyxose | D-Galactose |
| D-Ribose | D-Arabinose |
| | D-Xylose |
| | 2-Deoxy-D-ribose |
| | α-Methyl-D-mannopyranoside |

Fig. 1 indicates that the optimum pH for complex formation is about 5.5 and most studies were done in this region.

Continuous variations plots (Fig. 2) show that the ratio of molybdenum:sugar in the complexes is 1:1 in all cases. The plots also show that the complexes are relatively weak. This was confirmed by measuring the optical rotation of a solution of D-mannose in the presence of increasing molybdate concentration. It was found that the optical rotation of the solution did not become constant until a tenfold excess of molybdate had been added.

It is interesting to note that the sign of the rotation for mannose changes upon complex formation. This is undoubtedly due to the fact that the equilibrium mixture of D-mannose consists predominantly of the α-iso-