Direct Esterification of Sodium cis-9,10-Epiminooctadecanoate[1]

A. BILYK, A. EISNER and G. MAERKER, Eastern Regional Research Laboratory,[2] Philadelphia, Pennsylvania 19118

ABSTRACT

Compounds containing the aziridine ring are known to have a tendency toward polymerization in the presence of mineral acids. Moreover, with aziridine derivatives of fatty acids, ring opening reactions are possible as a result of nucleophilic attack by generated carboxylic acids groups. It was found that high yields (86-89%) of methyl cis-9,10-epiminooctadecanoate, with a minimum of attendant byproducts could be obtained by heating the corresponding sodium soap with methanol in the presence of certain acid catalysts under carefully controlled conditions. Temperature, duration of the heating period, and catalyst concentration were the variables studied for each catalyst. The catalysts evaluated were: boron trifluoride etherate, methanesulfonic acid, sulfuric acid, fluoboric acid and p-toluenesulfonic acid. Of these, for most laboratory preparations, p-toluenesulfonic acid is the catalyst of choice.

INTRODUCTION

Among the recent contributions from this laboratory are several papers concerning the preparation and properties of long chain fatty acid derivatives containing internal aziridine rings (1-7). In one of these studies (7), it was shown that some epiminostearate derivatives, such as soaps, have potential utility as lubricant components. However, until recently, a similar evaluation of epiminostearate esters was not possible due to difficulties involved in their preparation by conventional acid catalysis. Simple aziridines, e.g., ethyleneimine, readily undergo polymerization in the presence of acid catalysts. The rate of the reaction varies with the temperature, concentration of the ethyleneimine and the nature and amount of the catalyst (8-10). One contributing factor to the difficulty of ester preparation is the instability of the free epimino carboxylic acid. The internal aziridine ring has been shown to be susceptible to scission by nucleophilic attack of carboxylic acids (1,3,4,11). Foglia et al. (4) demonstrated that it was possible to circumvent this difficulty by effecting an esterification by the reaction of the epimino soap with boron trifluoride etherate in methanol. These authors emphasized the need for careful control of reaction conditions to prevent the Lewis acid-catalyzed ring opening of the aziridine ring and attendant byproduct formation.

The present investigation is an extension of this approach. Its purpose was to evaluate a series of acids as catalysts for the direct esterification of epimino soaps and, with each catalyst, determine the effect of changes in reaction variables on ester and byproduct formation.

EXPERIMENTAL PROCEDURES

Materials

Sodium cis-9,10-epiminooctadecanoate was prepared via the addition of iodine isocyanate to methyl oleate by procedures described previously (4,7). It had an estimated purity of 98-99% by titration (12).

Methods

The following, in which methanesulfonic acid was used as the catalyst, is typical of the esterification procedures employed. To a solution of methanesulfonic acid (3.84 g, 0.04 mole) in methanol (384 ml) was added 3.19 g (0.01 mole) of sodium cis-9,10-epiminooctadecanoate. The mixture was refluxed for 5 min on the steam bath (the period of ebullition must be rigorously observed) and then concentrated in vacuo at room temperature to a volume of ca. 20 ml on a rotary evaporator. The resultant slurry was shaken with 5% aqueous sodium hydroxide and the mixture extracted with benzene (4 x 50 ml). The combined extracts, after washing with water (3 x 100 ml), were dried over anhydrous magnesium sulfate and then evaporated to dryness in vacuo. The residue (3.05 g, purity 88.4%, yield 98.4%) was recrystallized from hexane to give the analytically pure sample, mp 50-51 C lit. (4) mp 50-51 C. 2-Ethylhexyl cis-9,10-epiminooctadecanoate was prepared by alcoholysis of the methyl ester. To a solution of 0.07 g (0.003 mole) of sodium metal in 6.50 g (0.05 mole) of 2-ethylhexyl alcohol was added 1.56 g (0.005 mole) of methyl cis-9,10-epiminooctadecanoate. The mixture was heated at 85-95 C, with stirring, for 2 hr. The reaction was carried out in a N_2 atmosphere. The mixture was transferred to a separatory funnel; 50 ml of water was added and then extracted with chloroform (3 x 10 ml). The extract was washed with water and then dried over anhydrous $MgSO_4$. The dried extract was evaporated and the excess alcohol removed by vacuum distillation. The residue 1.76 g, 86.3% yield had an estimated purity of 90% by gas liquid chromatography (GLC). This was improved to 97.8% purity

---

TABLE I

Optimum Conditions for Esterification of Sodium
cis-9, 10-Epiminooctadecanoate by Acid Catalysts

Catalyst	Soap-catalyst, moles	Catalyst concentration %[a]	Time, min	Yield,[b] %
$BF_3 \cdot O(C_2H_5)_2$	1:5	10	5	89.1
CH_3SO_3H	1:4	1	5	87.0
H_2SO_4	1:2	1	15	88.1
$HClO_4$	1:4	1	5	87.4
HBF_4	1:4	3	5	87.2
$p-CH_3C_6H_4SO_3H$	1:2	4	15	86.4

[a]Weight to volume per cent.
[b]Calculated on basis of 100% purity.

(GLC) by chromatography using a Florisil column and hexane as eluent.
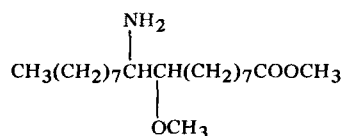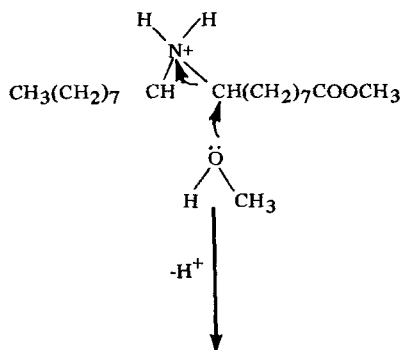
Analytical Procedures

Determinations of purity of the methyl ester product were made by means of a modified Jay titration procedure developed at this laboratory (12). All of the esterification runs were monitored by thin layer chromatography (TLC). Byproducts were isolated on preparative TLC plates and identified by means of elemental, IR and mass spectral analyses. The purity values obtained by direct titration compared well with estimates of purity obtained by TLC or GLC.

RESULTS AND DISCUSSION

In Table I are listed the yield data obtained with a variety of acid catalysts. Phosphoric acid was also tried as a catalyst, but the yield of ester obtained with this acid was negligible. Also included in the table are the optimum conditions for each reaction variable investigated. The concentrations of catalyst shown are in terms of weight to volume per cent.

The esterification of the epimino soap must be carried out under carefully controlled conditions in order to minimize the opening of the aziridine ring and subsequent formation of byproducts. Among the isolable byproducts identified were: methyl 9(10)-amino-10 (9)-methoxyoctadecanoate, trace amounts of methyl stearate and oleate, and what are believed to be, as indicated by elemental and mass spectral analyses, methyl 9(10)-amino-10(9)-hydroxyoctadecanoate and methyl 9(10) hydroxy- 10(9)-methoxyoctadecanoate. The trace amounts of methyl oleate and stearate may have resulted from side reactions, but more probably they were inherited from the starting olefin (methyl oleate) which was used for making the epimino soap via INCO addition. The amount and composition of the nitrogen-containing byproducts varied with changes in esterification conditions.

The epimino ring is reported to be stable under basic conditions, and the ring remains intact on treatment with reagents such as potassium hydroxide or sodium azide (11). However such stability is noticeably absent under acidic conditions, and a variety of products have been obtained resulting from the scission of the epimino ring. These include β-aminoalcohols, β-aminoesters and their isomeric β-hydroxyamides, Δ-2 oxazolines and β-aminoethers. The last type product represented by methyl 9(10)-amino-10(9)-methoxyoctadecanoate was obtained in varying amounts, depending upon conditions, as a byproduct of the esterification. Conceivably this material is formed by the protonation of the aziridine nitrogen followed by nucleophilic attack by methanol as shown in the following:

$$\text{CH}_3(\text{CH}_2)_7 \quad \overset{\text{H}\diagup \text{H}}{\underset{\diagup\diagdown}{\overset{\text{N}^+}{\diagdown}}} \quad \text{CH(CH}_2)_7\text{COOCH}_3$$

$$\overset{\diagup\diagdown}{\underset{\text{H}\quad\text{CH}_3}{\overset{\ddot{\text{O}}}{}}}$$

$$\downarrow -\text{H}^+$$

$$\overset{\text{NH}_2}{\underset{}{|}}$$
$$\text{CH}_3(\text{CH}_2)_7\text{CHCH(CH}_2)_7\text{COOCH}_3$$
$$\underset{\text{OCH}_3}{|}$$

For the reaction to take the desired course, at least two moles of acid per mole of soap are required. One mole of acid is required to liberate the free acid and the other to tie up the basic nitrogen. However this may not be the optimum amount. With methanesulfonic acid, for example, this ratio of acid to soap leaves a considerable amount of unreacted soap in the reaction mixture. Best results were obtained with twice the theoretical amount of acid indicated.

The concentration of the catalyst in the reaction mixture is as important a variable as the actual quantity used. Too high a concentration of the catalyst increases the amount of byproducts and gives rise to indications of polymeric substances. Particularly significant is the effect of heating time on the yield of ester obtained. Exposure to prolonged periods of heat contributes to ring-opening reactions, giving rise to the formation of byproducts, especially the amino ether.

The results obtained show that the esterification can be accomplished simply and effectively with inexpensive catalysts. All of the catalysts examined appear to have comparable effectiveness; the yields of ester obtained were almost equal to that obtained with boron trifluoride etherate. For most laboratory preparations and from the standpoint of ease of handling, minimum byproduct formation and ease of purification p-toluenesulfonic acid would be the catalyst of choice. In making large quantities of ester where cost of the catalyst is a factor, sulfuric acid would probably be more suitable.

A procedure for making the 2-ethylhexyl ester was described in the experimental section. All of our trials for making this ester by the direct esterification procedure were unsuccessful. It is believed that the lack of success was due to the insolubility of the soap in the reaction medium. Alcoholysis of the methyl ester is accomplished quite readily. The purification of 2-ethylhexyl cis-9,10-epiminooctadecanoate is not feasible by conventional crystallization techniques, but the compound was readily purified by chromatography.

REFERENCES

1. Maerker, G., E.T. Haeberer and T.A. Foglia, Chem. Ind. 1968:1524.
2. Foglia, T.A., E.T. Haeberer and G. Maerker, JAOCS 47:27 (1970).
3. Maerker, G., E.T. Haeberer, E.T. Donahue and T.A. Foglia, J. Heterocyclic Chem. 7:563 (1970).
4. Foglia, T.A., G. Maerker and G.R. Smith, JAOCS 47:384 (1970).
5. Foglia, T.A., L.M. Gregory and G. Maerker, J. Org. Chem. 35:3779 (1970).
6. Foglia, T.A., L.M. Gregory, G. Maerker and S.F. Osman, Ibid. 36:1068 (1971).
7. Eisner, A., T. Perlstein, G. Maerker and L. Stallings, JAOCS 48:811 (1971).
8. Kern, W., and E. Brenneisen, J. Prakt. Chem. 159:193 (1941).
9. Jones, G.D., in "The Chemistry of Cationic Polymerization," Edited by P.H. Pleach, MacMillan, New York 1963, p. 521.
10. Jones, G.D., A. Langsjoen, M.M.C. Neumann and J. Zomlefer, J. Org. Chem. 9:125 (1944).
11. McGhie, J.F., and B.T. Warren, Chem. Ind. 1968:253.
12. Maerker, G., E.T. Haeberer, L.M. Gregory and T.A. Foglia, Anal. Chem. 41:1698 (1969).