salt must allow for the complete absence of color in all the half-salts observed so far.

EXPERIMENTAL

Acylamido phenols. All formulations and acetylations were performed as described by Smith, *et al.*[8] for the formation of 4-formamido-2,3,5-trimethylphenol from the aminophenol. It was desirable, however, to employ boiling water or a water–formic acid mixture as a recrystallization solvent, after prior treatment of the crude reaction product with charcoal.

4-Formamido phenol melted at 137.5–139° (from water).

4-Formamido-2,6-xylenol melted at 159–160° (from water).

4-Formamido-3,5-xylenol melted at 233° (from water).

5-Ethyl-4-formamido-m-cresol melted at 185–186° (from formic acid-water).

3,5-Diethyl-4-formamido phenol melted at 208–209° (from formic acid–water).

4-Formamido-2,3,5-trimethylphenol melted at 215° (from water).

4-Formamido-2,3,5,6-tetramethylphenol melted at 298° dec. (from formic acid–water).

4-Acetamido-3,5-xylenol was obtained as the monohydrate from water; m.p., 179–180.5°, with sintering at 90°. The anhydrous form may be obtained by dehydration with boiling benzene and recrystallization from ether-pentane.

4-Formamido-3,5-xylenol tetrabutylammonium 4-formamido-3,5-xylenate. Preparation in nonaqueous medium. A solution of 1.0 g. of 4-formamido-3,5-xylenol in a minimum amount of methyl isobutyl ketone was titrated to its normal endpoint with a full equivalent of 0.2*M* tetrabutylammonium hydroxide[2a] in isopropyl alcohol methanol (5:1 V/V). To this solution of the normal salt was then added an additional 1.0 g. of the parent phenol in a minimum amount of solvent. The mixture was stirred for 2 hr. during which time the half-salt was deposited as a white, crystalline solid. It was removed by filtration and washed sparingly with methyl isobutyl ketone. Recrystallization from acetonitrile yielded 2.5 g. (72%) of a fine, white microcrystalline product; m.p. 189° dec.

Anal. Calcd. for $C_{34}H_{57}N_3O_4$: C, 71.41%; H, 10.05%; N, 7.35%; neut. equiv. ($HClO_4$) 571. Found: C, 71.08%; H, 9.96%; N, 7.28%; neut. equiv. 560.

Preparation in aqueous medium. To a solution of 4-formamido-3,5-xylenol in three times its weight of dimethylformamide there was added exactly 0.5 equivalent to a 1*M* solution of tetrabutylammonium hydroxide in water (Southwestern Analytical Chemical Co.). Crystallization of the half-salt started immediately and was essentially complete in 10 min. Filtration and recrystallization yielded a product identical with that formed in preparation in nonaqueous medium, above.

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(7) This does not exclude a dimeric form for the free phenol, as a normal —OH group would still be expected for the unbonded form, and the bonded —OH may well lie outside of the narrow, transparent region available in methylene chloride.

Unfortunately, neither the free phenol nor the half-salt was sufficiently soluble in carbon tetrachloride or carbon disulfide to permit their use as solvents.

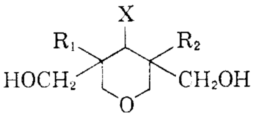
(8) L. I. Smith, H. H. Hoehn, and A. G. Whitney, *J. Am. Chem. Soc.*, **62**, 1867 (1940).

The Preparation of Tetrahydro-3,3,5,5-tetrakis(hydroxymethyl)pyran

THOMAS J. PROSSER

Received April 29, 1960

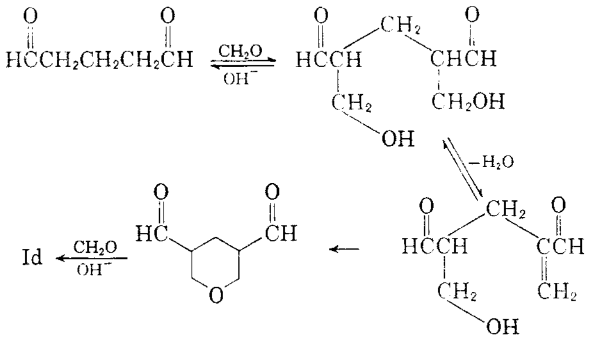
Limited evidence found in the literature indicates that the base catalyzed, exhaustive hydroxymethylation of ketones in which the carbonyl group is flanked by methylene groups gives rise to substituted tetrahydropyran-4-ols. Thus, the reaction of acetone and formaldehyde gives anhydroenneaheptitol (Ia),[1] whereas methyl ethyl ketone and diethyl ketone are reported to give tetrahydro-3,3,5-tris(hydroxymethyl)-5-methylpyran-4-ol (Ib) and tetrahydro-3,5-bis(hydroxymethyl)-3,5-dimethylpyran-4-ol (Ic), respectively.[2]



I

a) $R_1 = R_2 = CH_2OH$; X = OH
b) $R_1 = CH_2OH$; $R_2 = CH_3$; X = OH
c) $R_1 = R_2 = CH_3$; X = OH
d) $R_1 = R_2 = CH_2OH$; X = H

It has now been found that a similar reaction takes place in a 1,3-bis(methylene) system activated by terminal aldehyde groups rather than by a central ketone function. The exhaustive hydroxymethylation of glutaraldehyde gives the previously unreported tetrahydro-3,3,5,5-tetrakis(hydroxymethyl)pyran (Id). A general reaction mechanism would seem to apply to all of the above cases. The following scheme is proposed for the glutaraldehyde-formaldehyde reaction and is analogous to that suggested for the formation of dipentaerythritol in the preparation of pentaerythritol from acetaldehyde and formaldehyde.[3]



The tetraacetate, dibenzylidene acetal, and diisopropylidene ketal derivatives of Id were prepared.

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(1) M. Apel and B. Tollens, *Ber.*, **27**, 1089 (1894), *Ann.*, **289**, 46 (1896); C. Mannich and W. Brose, *Ber.*, **55**, 3155 (1922).

(2) I. R. Roach, H. Wittcoff, and S. E. Miller, *J. Am. Chem. Soc.*, **69**, 2651 (1947).

(3) S. Wawzonek and D. A. Rees, *J. Am. Chem. Soc.*, **70**, 2433 (1948).

EXPERIMENTAL[4]

Tetrahydro-3,3,5,5-tetrakis(hydroxymethyl)pyran (Id). To 236 g. (3.30 moles) of 42% aqueous formaldehyde solution adjusted to *p*H 11.0 by addition of 50% sodium hydroxide solution was added 200 g. (0.50 mole) of 25% aqueous glutaraldehyde (Union Carbide Chemicals Co.) at 40–45° over a 1-hr. period. Thereafter, the temperature of the mixture was held at 50, 60, and 70° for 4, 3, and 2 hr., respectively. A *p*H of 11.0 was maintained throughout by intermittent addition of base. Theoretical base consumption was observed following the complete heating period. Deionization of the total crude reaction solution by passage through columns of Dowex 50 and Dowex 1 exchange resin, in that order, gave 60.6 g. of crystalline to semicrystalline product in the initial portions of effluent. Further rinsing gave an additional 10.3 g. of oily by-product considered to represent lower condensation products. The major portion of the latter material was absorbed by the exchange resin and not recovered. The main product contained 55.5% Id (32.6% yield) as determined by quantitative isolation of its dibenzylidene derivative. Preparation of an analytical sample of Id by water recrystallization gave a white crystalline solid; m.p. 176.5°.

Anal. Calcd. for $C_9H_{18}O_5$: C, 52.41; H, 8.80; OH, 32.99; mol. wt., 206.23. Found: C, 52.64, 52.51; H, 8.80, 8.96; OH (acetylation), 32.3, 31.9; mol. wt. (cryoscopic in ethanol), 206, 206.

Derivatives of tetrahydro-3,3,5,5-tetrakis(hydroxymethyl)-pyran (Id). (1) *Tetraacetate.* A mixture of 10 g. (0.049 mole) of Id, 40 g. (0.39 mole) of acetic anhydride, and 4 ml. of glacial acetic acid was heated under reflux for 1 hr., allowed to stand overnight, and then poured into 100 ml. of water. The crystalline, white solid which separated amounted to 7.8 g. (43% yield), m.p. 91–95°, recrystallized from *n*-hexane, 94°.

Anal. Calcd. for $C_{17}H_{26}O_9$: C, 54.54; H, 7.00; mol. wt., 374.38; Sapon. No., 599.48. Found: C, 54.81, 55.00; H, 7.09, 7.17; mol. wt. (Rast), 386, 381; Sapon. No., 604.

(2) *Dibenzylidene acetal.* A mixture of 5.0 g. (0.024 mole) of impure Id, 25 ml. of water, 25 ml. of methanol, and 5 ml. of concd. hydrochloric acid was reacted with 10 ml. of benzaldehyde for 45 min. at steam bath temperature. There was obtained 8.14 g. (89% yield) of crude, white solid which upon recrystallization from butyl acetate melted at 232–234°.

Anal. Calcd. for $C_{23}H_{26}O_5$: C, 72.22; H, 6.85; mol. wt., 382.43. Found: C, 72.37, 72.47; H, 7.01, 7.02; mol. wt. (Rast), 388, 403.

Tests with pure Id showed the dibenzylidene reaction to be quantitative and applicable to the determination of Id in mixtures, or compounds hydrolyzed under the reaction conditions.

(3) *Diisopropylidene ketal.* A mixture of 10 g. (0.048 mole) of Id, 150 ml. of acetone, 5 drops of concd. sulfuric acid, and 15 g. of 2,2-dimethoxypropane (Dow Chemical Co.) was heated under reflux overnight. Concentration of the reaction mixture gave 11.6 g. (91.4% yield) of white crystals. Recrystallization from acetone gave a melting point of 201–205°.

Anal. Calcd. for $C_{15}H_{26}O_5$: C, 62.91; H, 9.15. Found: C, 63.27, 63.25; H, 9.39, 9.29.

The Id content of the recrystallized product was determined by conversion to its dibenzylidene derivative: calcd., 72.02; found, 71.2. Various samples of Id diisopropylidene ketal melted over a range of 153–206°, suggesting the presence of allotropic crystalline forms.

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[4] All melting points are uncorrected.

Reaction of Trimethylacetoxysilane with Tetraisopropoxytitanium[1]

J. B. RUST, H. H. TAKIMOTO, AND G. C. DENAULT[2]

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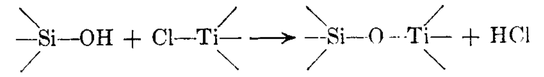
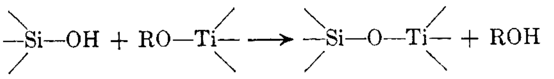
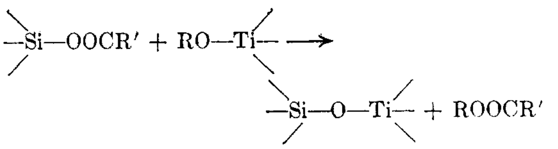
The preparations of organotitanium derivatives containing the silicon-oxygen-titanium linkage have been reported by several investigators.[3–9] These compounds have been prepared by any one of the following methods:


(1)


(2)


(3)

Although these three methods have been utilized in the synthesis of the tetrasubstituted triorganosiloxy titanium derivatives, only Danforth[8] has reported the preparation of monomeric, partially substituted trimethylsiloxy titanium esters. He studied the reaction of trimethylsilanol with tetraisopropoxytitanium. The reaction was reported to proceed as follows:

$$n(CH_3)_3SiOH + Ti(OC_3H_7)_4 \longrightarrow [(CH_3)_3SiO]_nTi(OC_3H_7)_{4-n} + nC_3H_7OH \quad (4)$$

where *n* is 1, 2, or 4. The extent of the substitution may be controlled by the stoichiometry of the reactants used.

The condensation reaction of trimethylacetoxysilane with tetrabutoxytitanium as reported by Andrianov and Ganina[10] results not in the desired tetrakis(trimethylsiloxy)titanium but rather in

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[1] This work was supported in part by the Office of Naval Research under Contract No. Nonr 2540(00).

[2] Hughes Research Laboratories, A Division of Hughes Aircraft Company, Malibu, Calif.

[3] W. D. English and L. H. Sommer, *J. Am. Chem. Soc.*, **77**, 170 (1955).

[4] V. A. Zeitler and C. A. Brown, *J. Am. Chem. Soc.*, **79**, 4616 (1957).

[5] D. N. Dolgov and N. F. Orlov, *Izvest. Akad. Nauk. S.S.S.R., Otdel. Khim Nauk*, 1395 (1957). *Doklady Akad. Nauk S.S.S.R.*, **117**, 617 (1957).

[6] K. A. Andrianov, A. A. Zhdanov, N. A. Kurasheva, and V. G. Dulova, *Doklady Akad. Nauk. S.S.S.R.*, **112**, 1050 (1957).

[7] D. C. Bradley and I. M. Thomas, *Chem. and Ind.*, **17** (1958).

[8] J. D. Danforth, *J. Am. Chem. Soc.*, **80**, 2585 (1958).

[9] H. H. Takimoto and G. C. Denault, *Reactions of Acetoxysilanes with Tetraisopropyl Titanate*, Pacific Southwest Regional Meeting of the American Chemical Society, Redlands, Calif., October 1958.

[10] K. A. Andrianov and T. N. Ganina, *Z. Obschei Khimii S.S.S.R.*, **29**, 605 (1959).