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Abstract

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SAPONIFICATION OF TETRAETHYL ACETALS OF β-DICARBONYL COMPOUNDS AND SOME WAYS OF USING THE COMPOUNDS FORMED

(Presented by Academician M. M. Shemyakin, January 16, 1960)

In our works (^{1},^{2}) we developed general methods for the synthesis of tetraethyl acetals of β-dicarbonyl compounds of the type $(C_2H_5O)_2CHCH R CH(OC_2H_5)_2$ and $RC(OC_2H_5)_2CH_2CH(OC_2H_5)_2$, and of tetraethyl acetals of ethoxydialdehydes of the type $(C_2H_5O)_2CHCHR[CH(OC_2H_5)CHR]_nCH(OC_2H_5)_2$, where $n = 1, 2, 3$. For further synthetic use of such tetraethyl acetals it was necessary to develop methods for converting them into the corresponding carbonyl compounds.

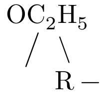
It turned out that saponification of tetraethyl acetals (I) with one equivalent of water (^{3}) in the presence of *p*-toluenesulfonic acid is a general method for the synthesis of β-formylvinyl ethers (II), further saponification of which leads to substituted malonic dialdehydes (III). These results agree with the recently published data of Isler (^{4}), who by this route obtained β-formyl-β-methylvinyl ethyl ether, which he successfully used for the synthesis of 15,15′-dehydro-β-apo-12′-carotinal and others. In the IR spectra of the β-formylvinyl ethers obtained by us there is absorption in the region of 1675 cm^{-1}, confirming their structure as α,β-unsaturated aldehydes. However, along with this, in the IR spectra of these compounds a weak absorption band at 1734 cm^{-1} was detected, indicating the presence in them of a small admixture of saturated aldehydes.

Saponification of tetraethyl acetals of β-ethoxyglutaric dialdehyde (IV) with one equivalent of water is accompanied by cyclization, and in this case the principal reaction products are 2,4,6-triethoxytetrahydropyrans (V). In the IR spectra of the triethoxytetrahydropyrans obtained in this way, absorption bands of CO groups are absent, which quite unambiguously confirms their structure. As was established earlier (^{2}), saponification of ethoxytetraethyl acetals of type (VI) with an excess of water gives, in good yield, only the corresponding ethoxydialdehydes (VII)

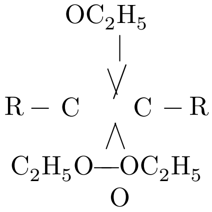
$$(C_2H_5O)_2CHCH(R)CH(OC_2H_5)_2 \xrightarrow{H_2O} C_2H_5OCH = C(R)CHO \rightarrow HOCCH(R)CHO$$

$$\text{(I)} \quad R = \text{H},\ \text{CH}_3,\ n\text{-C}_5\text{H}_{11} \qquad \text{(II)} \qquad \text{(III)}$$

$$(C_2H_5O)_2CHCH(R)CH(OC_2H_5)CH(R)CH(OC_2H_5)_2 \xrightarrow{H_2O}$$



$$\text{(IV)} \quad R = \text{H},\ \text{CH}_3$$



(V)

$$(C_2H_5O)_2CHCH(R)[CH(OC_2H_5)CH(R)]_nCH(OC_2H_5)_2 \xrightarrow{H_2O} HOCCH(R)[CH(OC_2H_5)CH(R)]_nCHO$$

$$\text{(VI)} \quad n = 1, 2, 3; \quad R = \text{H},\ \text{CH}_3 \qquad \text{(VII)}$$

$$RC(OC_2H_5)_2CH_2CH(OC_2H_5)_2 \xrightarrow{H_2O} RCOCH_2CH(OC_2H_5)_2 \qquad R = \text{CH}_3,\ \text{C}_2\text{H}_5,\ \text{C}_4\text{H}_9,\ \text{C}_6\text{H}_5$$

$$\text{(VIII)} \qquad \text{(IX)}$$

Saponification with one equivalent of water of tetraethyl acetal of acetosuccinic aldehyde and its substituted derivatives (VIII) proceeds in a peculiar manner; in this case only diethyl acetals of type (IX) are formed in good yields. All compounds thus obtained do not give the Fehling reaction and in the IR spectrum have an intense absorption band at 1717 cm^{-1}, characteristic of a free keto group, which confirms their structure.

For the purpose of synthetic use of the compounds described above, we studied some of their reactions at the aldehyde and ketone groups. It was found that dialdehydes of types (III) and (VII) readily react with carbethoxymethylenetriphenylphosphorane (X) under the conditions of the Wittig reaction, forming in high yields the corresponding diethyl esters of unsaturated dicarboxylic acids (XI) and (XII). Various β-formylvinyl esters are also capable of this reaction. For example, benzoate of β-formyl-β-methylvinyl ester (XIII), on interaction with phosphorane (X), gives 1-carbethoxy-4-methyl-5-benzyloxypentadiene-2,4 (XIV), from which the 2,4-dinitrophenylhydrazone of the corresponding aldehyde ester (XV) was obtained.

$$\mathrm{HOC{-}CHR{-}CHO} \xrightarrow[\text{(X)}]{(\mathrm{C_6H_5})_3\mathrm{P{=}CHCOOC_2H_5}} \mathrm{C_2H_5OOCCH{=}CHCHRCH{=}CHCOOC_2H_5}$$

$$\text{(III) } R = H,\ CH_3,\ n\text{-}C_5H_{11} \qquad\qquad \text{(XI)}$$

$$\mathrm{HOC{-}CHR[CH(OC_2H_5)CHR]_{nCHO}} \longrightarrow$$

$$\text{(XII) } R = H,\ CH_3,\ n = 1,\ 2,\ 3$$

$$\longrightarrow \mathrm{C_2H_5OOCCH{=}CHCHR[CH(OC_2H_5)CHR]_nCH{=}CHCOOC_2H_5}$$

$$\mathrm{C_6H_5COOCH{=}C(CH_3)CHO} \longrightarrow$$

$$\text{(XIII)}$$

$$\longrightarrow \mathrm{C_6H_5COOCH{=}C(CH_3)CH{=}CHCOOC_2H_5} \longrightarrow \mathrm{HOCCH(CH_3)CH{=}CHCOOC_2H_5}$$

$$\text{(XIV)} \qquad\qquad \text{(XV)}$$

β-Ketoacetals (IX) do not react with carbethoxymethylenetriphenylphosphorane. However, they readily enter into the acetylene synthesis reaction and, with lithium cyclohexen-1-ylacetylide, form in good yield acetylenic alcohols of type (XVI), saponification and dehydration of which gives unsaturated aldehydes (XVII).

$$\underset{\text{phenyl}}{\mathrm{C_6H_5}}\mathrm{{-}C{\equiv}CLi} + \mathrm{RCOCH_2CH(OC_2H_5)_2} \longrightarrow \underset{\text{phenyl}}{\mathrm{C_6H_5}}\mathrm{{-}C{\equiv}C{-}C(OH)(R){-}CH_2CH(OC_2H_5)_2} \xrightarrow{\mathrm{H_2}}$$

$$\text{(IX)} \qquad\qquad \text{(XVI)}$$

$$\longrightarrow \underset{\text{phenyl}}{\mathrm{C_6H_5}}\mathrm{{-}C{\equiv}C{-}C(R){=}CHCHO}$$

(XVII)

All the transformations studied above open broad possibilities for the synthesis of various polyene compounds related to natural ones, which is the subject of our forthcoming investigations.

Experimental Part

Hydrolysis of tetraethyl acetal of malonic dialdehyde. 44 g of tetraethyl acetal of malonic dialdehyde and 3.8 ml of a solution of *p*-toluenesulfonic acid containing 5.4 g of acid in 180 g of water were stirred with heating on a water bath until a homogeneous solution formed, and then for another hour. The mixture was cooled, 4 g of powd—

of powdered sodium bicarbonate, stirred for an hour, filtered, and distilled twice. This gave 11.8 g of β-formylvinyl ethyl ether with b.p. 77–81° at 14 mm, 54–55° at 5 mm, $n_D^{20.5}1.4472$.

Found, %:	C 59.40; 59.33;	H 8.74; 8.76
$C_5H_8O_2$. Calculated, %:	C 59.98;	H 8.05

The preparation changes readily on storage, which may account for the insufficiently accurate analytical data.

In an analogous manner the following were obtained: β-formyl-β-methylvinyl ethyl ether with b.p. 91–93° at 19 mm, $n_D^{21}1.4740$, $\lambda_{\max}$ (in alcohol) 252.5 mμ (ε 19100).

Found, %:	C 63.02; 63.21;	H 8.70; 8.56
$C_6H_{10}O_2$. Calculated, %:	C 63.13;	H 8.83

β-Formyl-β-amylvinyl ethyl ether with b.p. 126–129° at 13 mm, $n_D^{20}1.4729$, $\lambda_{\max}$ (in alcohol) 253 mμ (ε 14750).

Found, %:	C 70.35; 70.42;	H 10.60; 10.80
$C_{10}H_{18}O_2$. Calculated, %:	C 70.54;	H 10.66

Hydrolysis of tetraethyl acetal of acetoacetic aldehyde. This was carried out analogously to the above. From 70.3 g of tetraethyl acetal, 38.3 g of diethyl acetal of acetoacetic aldehyde was obtained with b.p. 73–74.5° at 9 mm, $n_D^{19}1.4215$.

Found, %:	C 59.84; 59.85;	H 9.69; 9.70
$C_8H_{16}O_3$. Calculated, %:	C 59.98;	H 10.07

Also obtained, in 70–75% yield, were: diethyl acetal of propionylacetic aldehyde with b.p. 93–96° at 17 mm, n_D^{20}1.4238.

Found, %:	C 61.89; 62.05;	H 10.13; 10.20
$C_9H_{18}O_3$. Calculated, %:	C 62.04;	H 10.41

Diethyl acetal of valerylacetic aldehyde with b.p. 89–91° at 4 mm, n_D^{22}1.4272.

Found, %:	C 65.64; 65.40;	H 10.60; 10.61
$C_{11}H_{22}O_3$. Calculated, %:	C 65.31;	H 10.96

Hydrolysis of tetraethyl acetal of β-ethoxyglutaric dialdehyde. Analogously to the preceding, from 13 g of tetraethyl acetal, 5.3 g of 2,4,6-triethoxytetrahydropyran was obtained with b.p. 112–115° at 10 mm, n_D^{21}1.4340.

Found, %:	C 60.53; 60.54;	H 10.29; 10.37
$C_{11}H_{22}O_4$. Calculated, %:	C 60.52;	H 10.16

Also obtained was 2,4,6-triethoxy-3-methyltetrahydropyran, yield 70%, b.p. 92–95° at 3 mm, n_D^{23}1.4368.

Found, %:	C 62.18; 62.21;	H 10.28; 10.32
$C_{12}H_{24}O_4$. Calculated, %:	C 62.04;	H 10.41

Preparation of 5-(cyclohexen-1′-yl)-3-methylpenten-2-yn-4-al. To an ethereal solution of cyclohexen-1-ylacetyl lithium (from 10.6 g of 1-ethynylcyclohexene and C_6H_5Li in ether), at 0° was added a solution of 16 g of diethyl acetal of acetoacetic aldehyde in 25 ml of ether; the mixture was stirred for an hour at 0°, for an hour at room temperature, and boiled for 4 hours. The mixture was treated with a saturated solution of ammonium chloride, and the ethereal layer was separated and dried with magnesium sulfate. On distillation, 10.9 g of 5-(cyclohexen-1′-yl)-3-hydroxy-3-methyl-1,1-diethoxypentyn-4 was isolated with b.p. 128–129° at 1 mm, n_D^{22}1.4871.

Found, %:	C 72.42; 72.50;	H 9.61; 9.87
$C_{16}H_{26}O_4$. Calculated, %:	C 72.14;	H 9.84

8.4 g of the product obtained was heated for 2.5 hr on a boiling water bath in a gentle stream of nitrogen with 35 ml of a solution of 11 g of sodium acetate in 7 ml of water and 110 ml of acetic acid. The mixture was poured onto ice and extracted with petroleum ether, and dried with magnesium sulfate. Distillation gave 3.1 g of 5-(cyclohexen-1′)-yl-3-methylpent-2-yn-4-al with b.p. 128–130° (bath) at $6 \cdot 10^{-4}$ mm, n_D^{18} 1.5797.

The aldehyde was characterized by the 2,4-dinitrophenylhydrazone, m.p. 161–161.5° (from alcohol), and the semicarbazone, m.p. 199–200° with decomposition, which agrees with the data given in the literature (^{5}).

Preparation of diethyl 3-methylpentadiene-1,4-dicarboxylate-1,5. A mixture of 3.36 g of methylmalonic dialdehyde and 20.34 g of carbethoxymethylenetriphenylphosphorane and 100 ml of benzene was boiled in a gentle stream of nitrogen for 4 hr. The benzene was distilled off; the residue was treated with petroleum ether, filtered, and by distillation 1.95 g of diethyl 3-methylpentadiene-1,4-dicarboxylate-1,5 was isolated, b.p. 151–154° at 4 mm, $n_D^{26.5}$ 1.4950.

Found, %:	C 63.63; 63.67;	H 7.99; 8.03
$C_{12}H_{18}O_4$. Calculated, %:	C 63.70;	H 8.02

On hydrogenation of 0.85 g of the ester in methanolic solution in the presence of platinum oxide, 172.1 ml of H_2 was absorbed (165.7 ml of H_2 calculated for two double bonds). Distillation gave 0.62 g of diethyl 3-methylpentanedicarboxylate-1,5 with b.p. 93–94° at 3 mm, $n_D^{22.5}$ 1.4402.

Found, %:	C 62.87; 62.71;	H 9.65; 9.79
$C_{12}H_{22}O_4$. Calculated, %:	C 62.56;	H 9.63

Preparation of 1,7-dicarbethoxy-4-ethoxy-3-methylheptadiene-1,6. The reaction was carried out analogously to that described above. From 3 g of α-methyl-β-ethoxyglutaric dialdehyde, 3.6 g of 1,7-dicarbethoxy-4-ethoxy-3-methylheptadiene-1,6 was obtained, with b.p. 166–168° at 2 mm, $n_D^{21.5}$ 1.4683.

Found, %:	C 64.11; 64.10;	H 8.92; 8.96
$C_{10}H_{26}O_5$. Calculated, %:	C 64.40;	H 8.78

Preparation of 1-carbethoxy-5-benzoyloxy-4-methylpentadiene-2,4. The reaction with the benzoate of β-formyl-β-methylvinyl ether was carried out analogously to that described above. 1-Carbethoxy-5-benzoyloxy-4-methylpentadiene-2,4 was obtained with m.p. 119–121.5° (from a mixture of ether with petroleum ether).

Found, %:	C 69.02; 69.10;	H 6.45; 6.50
$C_{15}H_{16}O_4$. Calculated, %:	C 69.21;	H 6.20

On treatment with an acidic solution of 2,4-dinitrophenylhydrazine, 2,4-dinitrophenylhydrazone is formed, m.p. 159-161.5° (from methanol).

Found, %:	N 17.16
$C_{14}H_{16}O_6N_4$. Calculated, %:	N 17.66

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Note: Figure translations are in progress. See original paper for figures.