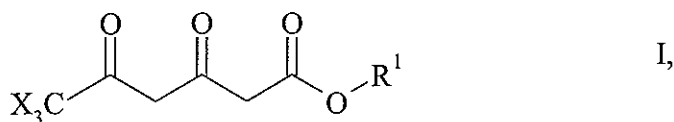


Method for the production of 6,6,6-trihalo-3,5-dioxohexanoic acid esters

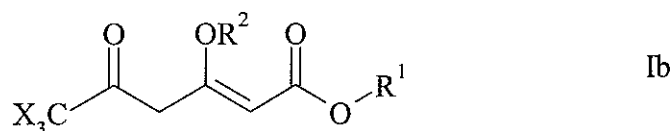
The invention relates to a method for preparing 6,6,6-trihalo-3,5-dioxohexanoic esters of the formula



and the enols and *E* and *Z* isomers thereof

or

the enol ethers thereof, of the formula



and the enols and *E* and *Z* isomers thereof

in which the substituents X are each independently of one another fluorine, chlorine or bromine, and in which R^1 is in each case alkyl, cycloalkyl, aryl or aralkyl, and R^2 is alkyl, cycloalkyl, allyl or benzyl, starting from pyranones of the formula



in which X has the abovementioned meaning.

Ethyl 6,6,6-trihalo-3,5-dioxohexanoates of the formula I are employed for example for the production of herbicides and agrochemicals (JP-A-06-049039).

Known methods for synthesizing substituted tricarbonyl compounds having a 3,5-dioxohexanoic ester basic structure start for example from ethyl acetoacetate, which is condensed with ethyl benzoate in THF in the presence of KH/BuLi (WO-A-94/11361), or with a highly substituted 3-oxopentanamide in THF in the presence of NaH/BuLi (WO-A-02/055519).

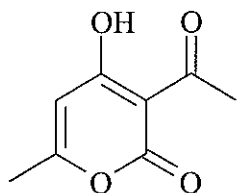
A method for preparing *tert*-butyl 6,6,6-trifluoro-3,5-dioxohexanoate from 2,2,2-trifluoroethyl

trifluoroacetate and *tert*-butyl acetoacetate is disclosed in WO-A-02/02547.

A further alternative variant for preparing substituted tricarbonyl compounds proceeds by ring opening of a pyranone such as, for example, of dehydracetic acid, which is converted by means of $\text{Mg}(\text{OMe})_2$ in methanol into methyl 3,5-dioxohexanoate (Batelaan, J.G., *Synthetic Commun.* 1976, 6, 81–83).

These known methods have the disadvantage that costly reagents such as BuLi are used.

Solladié, et al., *Tetrahedron: Asymmetry* 1996, 7, 2371–2379, disclosed that ring opening of dehydracetic acid of the formula

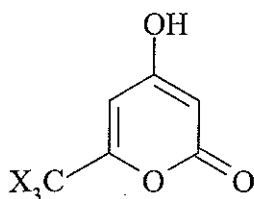


to give the tricarbonyl compound is possible, but leads to elimination of the acetyl substituent previously introduced during the synthesis. However, a loss of mass has disadvantageous effects on the profitability of a method in industrial process management.

It was therefore an object of the present invention to provide a simple method for preparing alkyl 6,6,6-trihalo-3,5-dioxohexanoates and the enols and enol ethers thereof, which can utilize easily obtainable pyrones as starting compounds.

This object is achieved according to the invention by the method claimed in claim 1.

It has been found that compounds of the formula



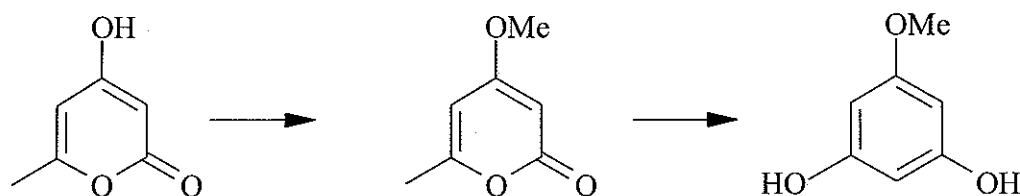
II,

in which the substituents X are each independently of one another fluorine, chlorine or bromine, provide, after conversion of the hydroxyl group into an ether group and subsequent opening of the pyran ring with a metal alcoholate, depending on the further reaction

conditions, compounds of the formula I or the enol ethers thereof of the formula Ib in good yield.

The present method is distinguished by no loss of mass occurring during the ring opening, and the number of carbon atoms present in the basic structure being maintained.

The method of the invention is surprising because it is known that 4-hydroxypyran-2-one cannot be converted into the open-chain tricarbonyl compound by reaction with sodium methanolate but, on the contrary, as shown in the reaction equation below is firstly methylated on the hydroxyl group and then the pyranone ether is converted into a phloroglucinol derivative (Effenberger, F. et al., *Chem. Ber.* **1984**, *117*, 3270–3279).



It was thus not possible to expect the ring opening resulting in the method of the invention.

Tetsuro S. et al. disclose the formation of 6-tribromo-4-methoxypyran-2-one as unwanted byproduct of a bromination reaction of 4-methoxy-6-methylpyran-2-one with *N*-bromo-succinimide (NBS) in a yield of only 5%.

The starting compounds of the formula II of the method of the invention can easily be obtained. Thus, for example, 4-hydroxy-6-trifluoromethylpyran-2-one can be prepared by reacting trifluoroacetic acid with ketene.

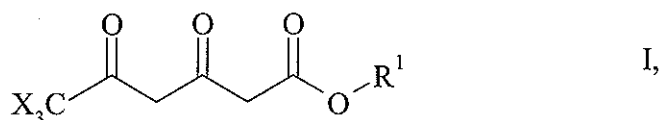
Alkyl means here and hereinafter in particular an optionally halogen-substituted, linear or optionally branched group having 1 to 8 carbon atoms, such as, for example, methyl, ethyl, propyl, isopropyl, *n*-butyl, isobutyl, *sec*-butyl, *tert*-butyl, pentyl, hexyl, heptyl, octyl.

Cycloalkyl means here and hereinafter in particular a cyclic group having 3 to 8 carbon atoms, such as, for example, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl.

Aryl means here and hereinafter in particular an optionally alkyl- and or halogen-substituted aromatic group having 6 or 8 carbon atoms, such as, for example, phenyl, *p*-tolyl or naphthyl.

Aralkyl means here and hereinafter in particular an alkyl group substituted by an aryl group, such as, for example, phenylethyl, where the alkyl group comprises 1 to 4 carbon atoms, and the aryl group is an optionally halogen-substituted, aromatic or heteroaromatic group having 4 to 8 carbon atoms, such as, for example, phenyl, naphthyl, 2- or 3-furanyl, 2- or 3-thiophenyl or 2-, 3- or 4-pyridinyl.

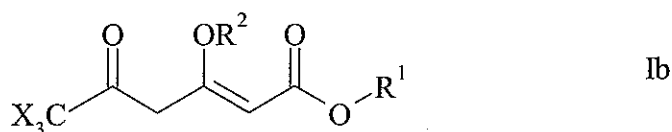
In the method of the invention for preparing compounds of the formula



and the enols and *E* and *Z* isomers thereof

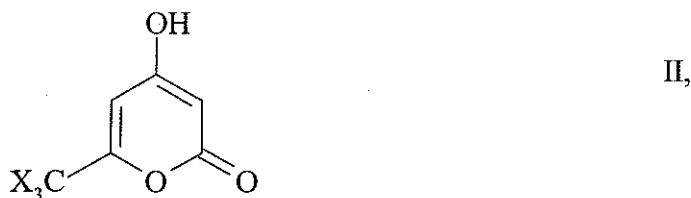
or

the enol ethers thereof of the formula

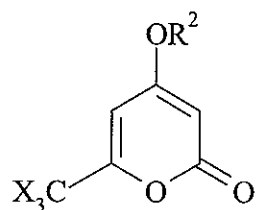


and the enols and *E* and *Z* isomers thereof

in which the substituents X are each independently of one another fluorine, chlorine or bromine, and in which R^1 is in each case alkyl, cycloalkyl, aryl or aralkyl, and R^2 is alkyl, cycloalkyl, allyl or benzyl, compounds of the formula



in which X has the aforementioned meaning, are converted by reacting the hydroxyl group with a compound of the formula $(\text{R}^2\text{O})_2\text{SO}_2$ or with a compound of the formula $\text{Y}-\text{R}^2$ in which Y is tosyl, chlorine, bromine or iodine, and in which R^2 in each case has the abovementioned meaning, into a compound of the formula



III,

in which R^2 and X have the stated meanings, and the pyranone ring of the reaction product is subsequently opened by reaction with a metal alcoholate of the formula $R^1O^- \frac{1}{n} M^{n+}$ in which R^1 has the abovementioned meaning, and M^{n+} is an alkali metal or alkaline earth metal cation and $n=1$ or 2, depending on the further reaction conditions, to give compounds of the formula I or Ib.

Suitable reagents for the preparation according to the invention of compounds of the formula III are for example dimethyl sulfate, diethyl sulfate, methyl iodide, ethyl bromide, methyl tosylate, ethyl tosylate, phenyl tosylate, allyl chloride, allyl bromide, benzyl chloride or benzyl bromide.

M^{n+} in the metal alcoholates of the formula $R^1O^- \frac{1}{n} M^{n+}$ is preferably Li^+ , Na^+ , K^+ , Mg^{2+} or Ca^{2+} .

If a strong acid is added ($pH < 1$) to the reaction mixture of compounds of the formula III after addition of the metal alcoholate, and the mixture is reacted further, compounds of the formula I and enols thereof can be obtained. In this method, the radical R^2 is eliminated. If a weak acid, or no acid at all, is added to the reaction mixture of compounds of the formula III after addition of the metal alcoholate, and the mixture is reacted further, enol ethers of the formula Ib and enols thereof can be obtained. In this variant of the method, the radical R^2 is retained.

The enol ethers of the formula Ib can likewise be converted into compounds of the formula I and enols thereof in poor yields after addition of strong acids and under strongly acidic conditions with elimination of the radical R^2 .

Strong acids mean in the method of the invention for example HCl, HBr, HI, H_2SO_4 , trifluoroacetic acid or solid acids such as, for example, acidic zeolites such as H-ZSM-5 or

In a preferred embodiment, compounds of the formula III are converted into compounds of the formula I in which X is fluorine and R¹ is C₁₋₈-alkyl, with elimination of the radical R². In a further preferred embodiment, R¹ is C₁₋₄-alkyl. In a particularly preferred embodiment, R¹ is methyl.

$$\text{X}_3\text{C}-\overset{\text{O}}{\parallel}\text{C}-\text{CH}_2-\text{CH}=\overset{\text{OH}}{\parallel}\text{C}-\overset{\text{O}}{\parallel}\text{C}-\text{O}-\text{R}^1 \quad \text{Ia'}$$

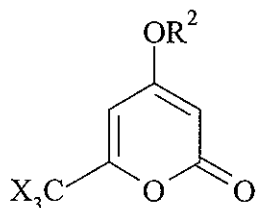
(*E* and *Z* isomers)

$$\begin{array}{c} \text{OH} \quad \text{O} \quad \text{O} \\ | \quad || \quad || \\ \text{X}_3\text{C}-\text{C}=\text{C}-\text{C}-\text{CH}_2-\text{C}-\text{O}-\text{R}^1 \\ (E \text{ and } Z \text{ isomers}) \end{array} \quad \text{Ia''}$$

The enols of compounds of the formula I differ from one another by the enolized carbonyl group and the location and orientation of the resulting double bond(s). The carbonyl groups at C³ and/or C⁵ may be enolized. Thus, it is possible that there are one or two isolated double bonds between carbon atoms C²/C³, C³/C⁴, C⁴/C⁵ or conjugated double bonds between C²/C³ and C⁴/C⁵, and each of the double bonds may additionally be in the *E* or *Z* configuration. The

enols are usually in the form of mixtures of a plurality of forms.

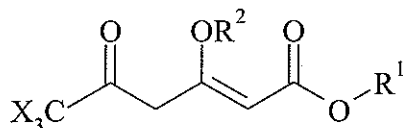
The invention likewise encompasses compounds of the formula



III

in which X is in each case independently of one another F, Cl or Br, and in which R² is alkyl, cycloalkyl, allyl or benzyl, with the exception of the compound in which X is bromine and R² is methyl.

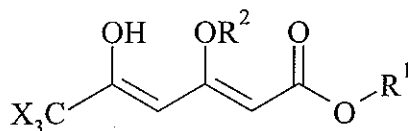
Likewise encompassed by the invention are enol ethers of the formula



Ib', and

(*E* and *Z* isomers)

and enols thereof, such as, for example



Ib'',

(*E* and *Z* isomers)

in which X is in each case independently of one another F, Cl or Br, and in which R¹ is alkyl, cycloalkyl, aryl or aralkyl, and in which R² is alkyl, cycloalkyl, allyl or benzyl. The compounds of the formula Ib may, just like the compounds of the formula I described above, be in the form of *E* and/or *Z* isomers. Depending on the external conditions, however, only the carbonyl group at C⁵ may be enolized. The number and location of the resulting double bonds at C²/C³ and/or C⁴/C⁵ correspond to the *E* and *Z* isomers of the enols of the compounds of the formula I.

Alkyl 3,3,3-trihalo-3,5-dioxohexanoates can be prepared by the method described above from 4-methoxy-6-trihalomethylpyran-2-ones. Preferably, methyl 6,6,6-trifluoro-3,5-dioxohexanoate is prepared from 4-methoxy-6-trifluoromethylpyran-2-one.

Examples

The following examples illustrate the procedure for the method of the invention without this being regarded as a restriction.

Example 1

4-Methoxy-6-trifluoromethylpyran-2-one (III; R^2 = methyl, X = fluorine)

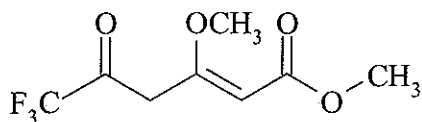
Sodium carbonate (1.35 g, 13 mmol) and dimethyl sulfate (2.17 g, 17 mmol) were added to a solution of 4-hydroxy-6-trifluoromethylpyran-2-one (3.0 g, 17 mmol) in acetone (50 mL).

The mixture was heated under reflux for 3 hours and, after cooling, filtered. Concentration of the filtrate resulted in 2.9 g of crude product as a brown oil. It was possible to obtain 4-methoxy-6-trifluoromethylpyran-2-one (2.74 g, 14 mmol, 83%) as colorless needles with a melting point of 61°C by crystallization from hexane.

^1H NMR (400 MHz, $\text{DMSO}-d_6$) δ : 7.01 (d, J = 1.6 Hz, 1H), 5.98 (d, J = 1.6 Hz, 1H), 3.7 (s, 3H).

Example 2

Methyl 6,6,6-trifluoro-2-methoxy-5-oxo-2-hexenoate (Ib; $R^1 = R^2$ = methyl, X = fluorine)



and the enols and *E* and *Z* isomers thereof

A solution of 4-methoxy-6-trifluoromethylpyran-2-one (2.7 g, 14 mmol) in a methanolic magnesium methanolate solution (8.5% $\text{Mg}(\text{OMe})_2$, 8.36 g, 8 mmol) was heated under reflux for 16 hours. The solution was concentrated and taken up in water and ethyl acetate, and the organic phase was brought to pH 5 by adding dilute hydrochloric acid. The organic phase was separated off, dried and concentrated. 1.5 g of crude product were obtained as a yellow oil. Kugelrohr distillation at 0.04 mbar and about 160°C afforded methyl 6,6,6-trifluoro-3-methoxy-5-oxo-2-hexenoate (1.50 g, 6.6 mmol, 48%) as a pale yellow oil.

Data for the main compound:

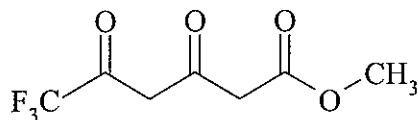
^1H NMR (400 MHz, $\text{DMSO}-d_6$) δ (resonance lines of the enol form Ib, without *E/Z* determination): 6.05 (s, 1H), 3.9 (s, 3H), 3.82 (s, 2H), 3.62 (s, 3H).

^{19}F -NMR (386 MHz, $\text{DMSO}-d_6$) δ : -76.8.

MS: 227 $[M+H]^+$.

Example 3

Methyl 6,6,6-trifluoro-3,5-dioxohexanoate (I; R^1 = methyl, X = fluorine)



and the enols and *E* and *Z* isomers thereof

A solution of 4-methoxy-6-trifluoromethylpyran-2-one (10 g, 52 mmol) in a methanolic magnesium methanolate solution (8.5% $Mg(OMe)_2$, 62.8 g, 61 mmol) was heated under reflux for 2 hours. Concentrated aqueous HCl (25.5 g, 250 mmol) was added to the reaction solution, and the mixture was heated under reflux for a further 2 hours, then cooled and concentrated in vacuo to about 20% of the initial volume. The residue was mixed with 10 mL each of methylene chloride and water. The organic phase was separated off, washed with water, dried over sodium sulfate and concentrated. Kugelrohr distillation at 0.04 mbar and about 160°C afforded methyl 6,6,6-trifluoro-3,5-dioxohexanoate (2.8 g, 13 mmol, 26%) as a pale yellow oil.

Data for the main compound:

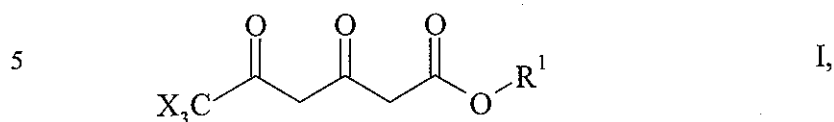
1H NMR (400 MHz, $DMSO-d_6$) δ (resonance lines of the enol form Ia', without *E/Z* determination): 6.0 (br, 2H), 3.8 (s, 2H), 3.65 (s, 3H).

^{13}C -NMR (100 MHz, $DMSO-d_6$) δ (resonance lines of the enol form Ia', without *E/Z* determination): 181.6 (s), 167.7 (s), 116.9 (q, $^1J_{C-F}$ 286 Hz), 95.9 (t), 52.0 (q), 49.7 (t), C-3 not identifiable.

MS: 212 (M^+).

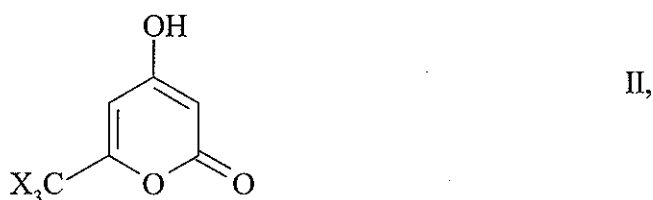
Claims:

1. A method for preparing compounds of the formula

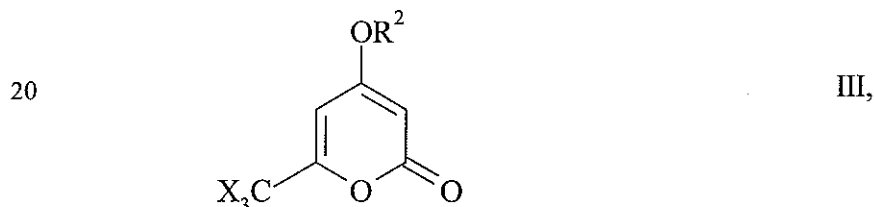


and the enols and *E* and *Z* isomers thereof

in which X is in each case independently of one another fluorine, chlorine or bromine,
and in which R¹ is alkyl, cycloalkyl, aryl or aralkyl, characterized in that a compound of
10 the formula

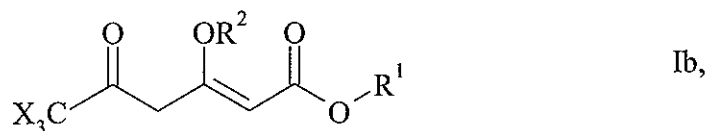


- 15 in which X has the stated meaning, is initially converted by reacting of the hydroxyl
group with a compound of the formula (R²O)₂SO₂ or with a compound of the formula
Y-R² in which Y is tosyl, chlorine, bromine or iodine, and in which R² is in each case
alkyl, cycloalkyl, allyl or benzyl into a compound of the formula

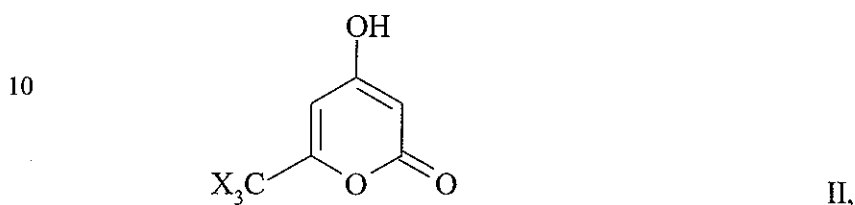


- in which R² and X each has the abovementioned meaning, and the latter is then
converted by reaction with a metal alcoholate of the formula R¹O⁻ $\frac{1}{n}$ Mⁿ⁺ in which R¹ is
25 alkyl, cycloalkyl, aryl or aralkyl and Mⁿ⁺ is an alkali metal or alkaline earth metal cation
and n = 1 or 2, and further treatment with a strong acid, into compounds of the formula I
and/or enols thereof.

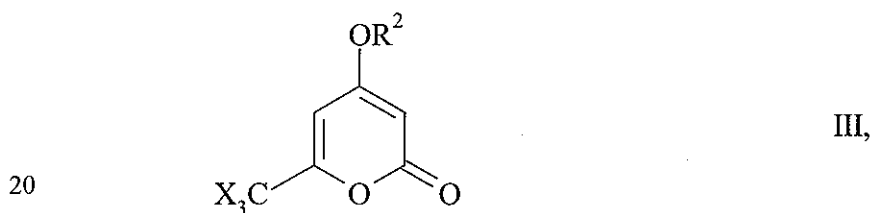
2. A method for preparing enol ethers of the formula



- 5 and the enols thereof and in each case the *E* and *Z* isomers thereof,
in which X is in each case independently of one another F, Cl or Br, and in which R^1 is
alkyl, cycloalkyl, aryl or aralkyl, and R^2 is alkyl, cycloalkyl, allyl or benzyl,
characterized in that a compound of the formula

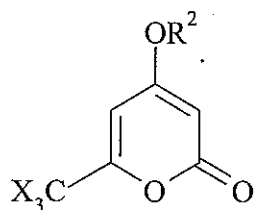


- in which X has the stated meaning, is initially converted by reaction of the hydroxyl
group with a compound of the formula $(\text{R}^2\text{O})_2\text{SO}_2$ or with a compound of the formula
15 $\text{Y}-\text{R}^2$ in which Y is tosyl, chlorine, bromine or iodine, and in which R^2 in each case has
the abovementioned meaning, into a compound of the formula



- in which R^2 and X each has the abovementioned meaning, and the latter is then
converted by reaction with a metal alcoholate of the formula $\text{R}^1\text{O}^- \frac{1}{n} \text{M}^{n+}$ in which R^1 is
alkyl, cycloalkyl, aryl or aralkyl and M^{n+} is an alkali metal or alkaline earth metal cation
25 and $n = 1$ or 2 , and optionally further treatment with a weak acid into enol ethers of the
formula Ib and/or enols thereof.

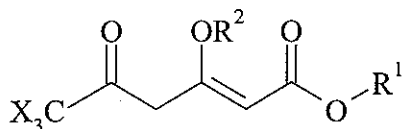
3. Compounds of the formula



III,

in which X is in each case independently of one another F, Cl or Br, and in which R² is alkyl, cycloalkyl, allyl or benzyl, with the exception of the compound in which X is bromine and R² is methyl.

4. Compounds of the formula



Ib,

and the enols and *E* and *Z* isomers thereof

in which X is in each case independently of one another fluorine, chlorine or bromine, and in which R¹ is alkyl, cycloalkyl, aryl or aralkyl, and in which R² is alkyl, cycloalkyl, allyl or benzyl.