PDF hosted at the Radboud Repository of the Radboud University
Nijmegen

The following full text is a publisher's version.

For additional information about this publication click this link.
http://hdl.handle.net/2066/142127

Please be advised that this information was generated on 2018-10-31 and may be subject to change.
A General Procedure for the Conversion of a Carbonyl Group into a Thione Group with Tetraphosphorus Decasulfide

J. W. SCHEEREN, P. H. J. OOMS, and R. J. F. NIVARD

Department of Organic Chemistry, Catholic University, Toernooiveld, Nijmegen, The Netherlands

SYNTHESIS 1973, 149–151
A New Synthesis of 1,2-Benzocyclohepta-1,3-diene

G. DAUPHIN, L. DAVID, P. DUPRAT, A. KERGMARD* and H. VIECHAMMS
Université de Clermont – BP 45 – 63170 – Aubière, France

The recent publication of a new synthesis of homophthalaldehyde1 (1) prompts us to report the synthesis of 1,2-benzocyclohepta-1,3-diene (3) using a method already described for the cyclization of heptatrienes2. o-Allylstyrene (2), obtained from homophthalaldehyde by a Wittig reaction, undergoes cyclization in isopropylamine in the presence of a small amount of suspended sodium to give 1,2-benzocyclohepta-1,3-diene (3) in 55% yield (based on o-allylstyrene). Benzocycloheptene (4) is obtained as a side product in 7% yield3.

The reaction described makes possible the synthesis of 3 from indene in 3 steps, whereas the usual method starting with cinnamaldehyde requires 4 steps and the method starting with benzosuberone (5) requires two steps.

\[
\begin{align*}
\text{CHO} & \quad \text{CHO} \\
1 & \quad 2 & \quad 3 \\
\text{4} & \quad \text{5} \\
\text{o-Allylstyrene (2):} & \\
\text{The compound is obtained by reaction of homophthalaldehyde (1) with methyltriphenylphosphonium bromide and sodium amide according to Ref6; yield: 50%; purity (G.L.C.): >99%.
}\end{align*}
\]

1H-N.M.R. (CDCl3): \( \delta = 3.4 \) (d, 2H, \( J = 6.0 \) Hz), 4.7-5.1 (m, 2H), 5.22 and 5.58 (dd, 2H, \( J = 11 \) Hz and \( J = 17 \) Hz), 5.7 (m, 1H), 6.95 (dd, 1H, \( J = 17 \) Hz and \( J = 11 \) Hz), 7.30 (m, 4H) ppm.

1,2-Benzocyclohepta-1,3-diene (3) and Benzocycloheptene (4):

A suspension of sodium (0.08 g, 0.003 g-atom) in a solution of cyclohexane/ethyl acetate (97/3) as eluent. The resultant mixture is extracted with ether, the organic extract is evaporated, and the residue subjected to chromatography on silica gel using cyclohexane/ethyl acetate (97/3) as eluent.

Compound 3; yield: 0.8 g (55%); purity (G.L.C.): >99%. The compound is obtained by reaction of homophthalaldehyde (1) with methyltriphenylphosphonium bromide and sodium amide according to Ref6; yield: 50%; purity (G.L.C.): >99%.

The compound is obtained by reaction of homophthalaldehyde (1) with methyltriphenylphosphonium bromide and sodium amide according to Ref6; yield: 50%; purity (G.L.C.): >99%.

U.V. (cyclohexane): \( \lambda_{\text{max}} = 253 \) nm (\( \epsilon = 12000 \)).

1H-N.M.R. (CDCl3): \( \delta = 1.95 \) (m, 2H), 2.35 (m, 2H), 2.85 (m, 2H), 5.83 (sextet, 1H, \( J = 12.5 \) Hz and \( J = 4.5 \) Hz), 6.40 (sextet, 1H, \( J = 12.5 \) Hz and \( J = 1.6 \) Hz), 7.05 (s, 4H) ppm. The spectrum is identical with that reported in Ref7 except for the misprint in that publication.

Compound 4; yield: 0.1 g (7%); purity (G.L.C.): >99%. The compound was identical with a sample obtained by Wolff-Kishner reduction of 5.

1H-N.M.R. (CDCl3): \( \delta = 1.7 \) (m, 6H), 2.7 (m, 4H), 6.9 (s, 4H) ppm.

Received: December 15, 1972

* To whom correspondence should be addressed.
### Table. Conversion of Carbonyl Compounds (1) into Thiono Compounds (3)

<table>
<thead>
<tr>
<th>R¹</th>
<th>R²</th>
<th>Reaction Conditions*</th>
<th>Molar Equivalents of P₂S₁₀</th>
<th>Molar Equivalents of NaHCO₃</th>
<th>Solvent</th>
<th>Concentration of 1 (%)</th>
<th>Isolation Procedure</th>
<th>Yield (%)</th>
<th>m. p. or b. p. (Lit. value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>30°, 3 hr 1.5</td>
<td>6</td>
<td>acetonitrile</td>
<td>10</td>
<td>B</td>
<td></td>
<td>65</td>
<td>m. p. 51-53° (m. p. 52-54°; b. p. 129-133°/0.06 torr)¹²</td>
</tr>
<tr>
<td>H₂C</td>
<td></td>
<td>30°, 3 hr 1.5</td>
<td>6</td>
<td>acetonitrile</td>
<td>10</td>
<td>A</td>
<td></td>
<td>80</td>
<td>m. p. 74-75° (m. p. 76°)¹³</td>
</tr>
<tr>
<td>H₂C</td>
<td></td>
<td>30°, 3 hr 1.5</td>
<td>6</td>
<td>acetonitrile</td>
<td>10</td>
<td>A</td>
<td></td>
<td>85</td>
<td>m. p. 105°</td>
</tr>
<tr>
<td>H₂C</td>
<td></td>
<td>30°, 3 hr 1.5</td>
<td>6</td>
<td>acetonitrile</td>
<td>10</td>
<td>A</td>
<td></td>
<td>85</td>
<td>m. p. 116-118° (m. p. 116°)¹³</td>
</tr>
<tr>
<td>H₂C</td>
<td>N</td>
<td>30°, 3 hr 1.5</td>
<td>6</td>
<td>THF</td>
<td>10</td>
<td>A</td>
<td></td>
<td>75</td>
<td>m. p. 156-158° (m. p. 157-158°)⁶</td>
</tr>
<tr>
<td>CHₙ</td>
<td></td>
<td>30°, 4 hr 1.0</td>
<td>4</td>
<td>diglyme</td>
<td>20</td>
<td>B</td>
<td></td>
<td>35</td>
<td>b. p. 78-82°/1 torr (b. p. 97-100°/12 torr)¹⁴</td>
</tr>
<tr>
<td>t-C₆H₅</td>
<td></td>
<td>30°, 4 hr 1.0</td>
<td>4</td>
<td>diglyme</td>
<td>20</td>
<td>B</td>
<td></td>
<td>55</td>
<td>b. p. 102°/0.6 torr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120°, 5 hr 1.5</td>
<td>6</td>
<td>diglyme</td>
<td>20</td>
<td>A</td>
<td></td>
<td>70</td>
<td>m. p. 143-145° (m. p. 145°)²</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td>30°, 5 hr 0.15</td>
<td>0.6</td>
<td>diglyme</td>
<td>50</td>
<td>D</td>
<td></td>
<td>(18)⁵</td>
<td>b. p. 86-87° (b. p. 86.5-87.5°)¹⁵</td>
</tr>
<tr>
<td>CHₙ</td>
<td></td>
<td>reflux, 24 hr 0.1</td>
<td>0.01</td>
<td>none</td>
<td>C</td>
<td>(14)⁶</td>
<td></td>
<td>b. p. 105° (b. p. 108-110°)¹⁶</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>80°, 24 hr 0.15</td>
<td>0.01</td>
<td>none</td>
<td>C</td>
<td>(25)⁷</td>
<td></td>
<td>b. p. 107-108°/15 torr (b. p. 112-115°/26 torr)¹⁷</td>
<td></td>
</tr>
<tr>
<td>CHₙ</td>
<td></td>
<td>reflux, 6 hr 1.0</td>
<td>4</td>
<td>diethyl ether (20)</td>
<td>C</td>
<td>50</td>
<td></td>
<td>b. p. 44°/16 torr (b. p. 61°/24 torr)¹⁸</td>
<td></td>
</tr>
<tr>
<td>CHₙ</td>
<td></td>
<td>reflux, 6 hr 1.0</td>
<td>4</td>
<td>diethyl ether (20)</td>
<td>C</td>
<td>60</td>
<td></td>
<td>b. p. 154°/14 torr (b. p. 155-160°/15 torr)¹²</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td></td>
<td>reflux, 5 hr 0.6</td>
<td>2</td>
<td>diethyl ether (20)</td>
<td>C</td>
<td>85</td>
<td></td>
<td>b. p. 108°/14 torr (b. p. 111-113°/10 torr)¹⁹</td>
<td></td>
</tr>
</tbody>
</table>

* After recrystallization from methanol.

b Conversion of starting compound (which was used in large excess).

* The amounts of carbonyl compounds used were 0.02 mol for benzophenones and xanthone and 0.1 mol for other compounds.
Sulfurization may be due to nucleophilic attack of these anions on the carbonyl C-atom followed by elimination of $O_2PS^-$ or $OPS^-$ (4), respectively, e.g.

$$\begin{align*}
R_1^1C=O + \underset{1}{SPS^2} & \rightarrow \underset{2}{[R_1^1(S-PS)S]} \\
R_2^2C=S + \underset{3}{OPS^2} & \rightarrow \underset{4}{R_2^2(S-OPS)S}
\end{align*}$$

If $R_1^1$ or $R_2^2$ is a good leaving group (as in acid chlorides), no thiono compound (3) is obtained$^{11}$, probably as a consequence of substitution of the leaving group. For aromatic ketones, the reaction rate is higher when $R_1^1$ or $R_2^2$ is electronegative, suggesting that nucleophilic attack of the negative oxygen on phosphorus in the addition product is rate-determining.

In general, the reaction rates are higher in acetonitrile than in the other solvents used (see Table), but the nitrile is not completely inert towards $P_4S_{10}$. During work-up under hydrolyzing conditions, thioacetamide is formed as a side product. With more reactive compounds such as carboxamides, even diethyl ether can be used as a solvent, although it does not give clear solutions with the sulfurizing agent. With esters, except formates, the best yields of thio derivatives are obtained when no solvent and only a catalytic amount of sodium hydroxide or hydrogen-carbonate is used. We have no explanation for these observations.

Conversion of Carbonyl Compounds into Thiono Compounds; General Procedure:

All sulfurization reactions were performed by dissolving the carbonyl compound in a suitable solvent, adding the solution of $P_4S_{10}$ in the same solvent, and adding solid sodium-hydrogen carbonate to the mixture under stirring and at such a rate as allowed by the evolution of carbon dioxide. Stirring was then continued for several hours. Experimental details are given in the Table. Isolation of the products was performed using several, slightly different procedures:

Isolation Procedure A: The reaction mixture was poured into water. The solid product which separated was isolated by filtration, washed several times with water, and dried at low pressure (0.5 torr) and = 50°.

Isolation Procedure B: Ether was added to the reaction mixture. The ethereal solution was washed several times with aqueous sodium-hydrogen carbonate (5%) and water, dried, and distilled at low pressure.

Isolation Procedure C: The reaction mixture was diluted with ether, filtered, and the filtrate distilled at low pressure.

Isolation Procedure D: Low-boiling reaction products were distilled from residual phosphorus compounds in the reaction mixture at low pressure and collected in a dry-ice trap. They were purified by redistillation.

Using these procedures, the products contained in some cases small amounts (up to 10%) of the starting compound. Pure samples (> 95%), however, could be obtained by redistillation or recrystallization. O-Ethyl thioacetate contained some S-ethyl thioacetate, which could not be separated by distillation. To obtain a pure sample, the S-ethyl thioacetate was converted into ethyl di-thioacetate via the sulfurization described. Separation of O-ethyl thioacetate and ethyl di-thioacetate was possible by distillation.

All products were identified and checked for purity by 1H-N.M.R. and in the case of aromatic ketones also by I.R. spectrometry. A comparison of the melting and boiling points found with values from the literature is given in the Table.

Received: October 19, 1972

---


Mixed Acylals; Synthesis of Alkylidene Carboxylic Formates

J. W. Scheeren and W. J. M. Tax

Department of Organic Chemistry, Catholic University, Toernooiveld, Nijmegen, The Netherlands
and R. Schuriger
Laboratory of Organic Chemistry, University of Leiden, The Netherlands

Since excellent synthetic procedures for the preparation$^{1,2}$ of pure mixed anhydrides of formic acid and other carboxylic acids are now available, it appeared worthwhile to investigate the reactivity of these anhydrides towards aldehydes, which might lead to a synthesis of the hitherto unknown mixed alkylidene dicarboxylates of formic acid and other carboxylic acids.
The relevant mixed anhydrides decompose readily at higher temperatures and in the presence of acids and bases. Thus, we performed our first experiments at 0° using iron(III) chloride as a catalyst; formaldehyde was introduced into ethereal solutions of mixed anhydrides. However, the yields of mixed acylals obtained under these conditions were very low due to polymerization of the aldehyde and decomposition (evolution of gas) of the anhydride. With acetaldehyde, the yields were better (up to 50%), but the reaction mixtures always contained substantial amounts of the ethylidene dicarboxylate with identical acid residues. In some cases, complete separation of this side product from the desired alkylidene carboxylate formate was difficult or even impossible. Ethylene diformate was never found, probably due to its low stability.

Because the use of pure mixed anhydrides did not prevent the formation of acylals with identical acid residues, we modified the procedure, replacing the mixed anhydride by a formic acid-carboxylic acid mixture. It is known that such mixtures contain the mixed anhydride as a consequence of equilibrium (1).

\[
R_2-\text{CHO} + R'-\text{COOH} \rightarrow R_2-\text{CH}-\text{O}-\text{CH}-R' + R'-\text{COOH}
\]

The best results were obtained when the anhydride and formic acid were used in excess (50% and 500%, respectively). If the molar ratio between aldehyde and anhydride is higher, a,a'-acyloxyethers, e.g.

\[
R\text{-CH-O-CH-} + \text{HCOOH} \rightarrow R\text{-CH-O-CH-} + \text{HCOOH}
\]

are found as side products.

Among the several possible catalysts tested (FeCl₃, H₂SO₄, P₂O₅, HCOONa, pyridine), phosphorus pentoxide appeared to be the most effective.

The alkylidene carboxylate formates (5) prepared by this procedure are listed in the Table. The compounds were identified and tested for purity by N.M.R. In all compounds, the \(H_a\) peak of

\[
R^2-\text{CH}_2-\text{O}-\text{CH}-R' + \text{HCOOH} \rightarrow R^2-\text{CH}-\text{O}-\text{CH}-R' + \text{HCOOH}
\]

was found between \(\delta = 6.5\) and \(6.9\) ppm (TMS as internal references).

In view of the strong acylating and preferential formylating ability of the formic acid - acetic anhydride system a tentative reaction scheme might be represented as follows.

The carboxylic anhydride is mixed with formic acid in a molar ratio of 1:5. After standing for 30 min at room temperature, an aldehyde (2/3 equivalents based on anhydride) and phosphorus pentoxide (0.5 g per mol of aldehyde) are added. The mixture becomes warm and a gas is evolved. After the mixture has been left for 3 hr at room temperature, formic acid is evaporated at reduced pressure (15 torr), ether is added, and the ethereal solution is extracted several times with aqueous sodium-hydrogen carbonate and finally with water. The solution is dried with sodium sulfate, ether is evaporated, and the residue is distilled using a Vigreux column (80 x 1.2 cm). Alkylidene acetate formates free from alkylidene diacetates can only be obtained by distillation of the crude products using a spinning-band column of at least 25 theoretical plates.

Preparation of Mixed Acylals; General Procedure:

(1) \(R^2-\text{CHO} + R'-\text{COOH} \rightarrow R^2-\text{CH}-\text{O}-\text{C}-R'\)

(2) \(R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH} \rightarrow R^2-\text{CH}-\text{O}-\text{C}-R'\)

(3) \(R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH} \rightarrow R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH}
\]

(4) \(R^2-\text{CH}-\text{O}-\text{C}-R' + R^2-\text{CHO} \rightarrow R^2-\text{CH}-\text{O}-\text{C}-R'\)

(5) \(R^2-\text{CH}-\text{O}-\text{C}-R' + R^2-\text{CHO} \rightarrow R^2-\text{CH}-\text{O}-\text{C}-R'\)

(6) \(R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH} \rightarrow R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH}
\]

(7) \(R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH} \rightarrow R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH}
\]

(8) \(R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH} \rightarrow R^2-\text{CH}-\text{O}-\text{C}-R' + \text{HCOOH}
\]