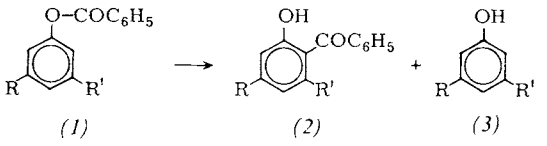


(1) (2) (3)

Table 1. Fries rearrangement of phenyl benzoates *(1)* with catalytic amounts of trifluoromethanesulfonic acid.

Starting material	R	R'	Products [%] [a] *(1)*	*(2)* [b]	*(3)*	decomp. products
(1a)	H	H	48	39	5	8
(1b)	H	NO_2	100	—	—	—
(1c)	H	CH_3	40	49	11	—
(1d)	H	CH_3O	7	78	—	15
(1e)	CH_3	CH_3	100	—	—	—

[a] Average yields from several parallel runs, determined by glc (Varian 1200).
[b] *p*-Hydroxyaryl ketones are formed in less than 2% yield, if at all.

New Aspects of the Fries Rearrangement[1]

By *Franz Effenberger*, *Herbert Klenk*, and *Peter Ludwig Reiter*[*]

Dedicated to Professor Karl Winnacker on the occasion of his 70th birthday

Even in the most recent literature, the Fries rearrangement of phenolic esters *(1)* not substituted in the arene nucleus (R = R' = H) is held to be an irreversible process yielding *o*- and/or *p*-hydroxyaryl ketones (acylphenols)[2]. *Rosenmund* and *Schnurr*[3] as well as *Miguel et al.*[4] have reported a reversal of the Fries rearrangement for 4-acyl-3-alkylphenols whereas *Cullinane* and *Edwards*[5] maintain that the Fries rearrangement is irreversible in this case too.

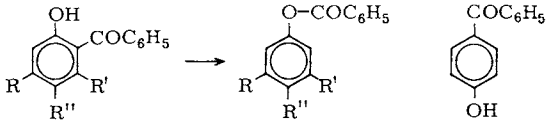
Formerly we had found that aromatic compounds can be acylated by acyl chlorides or carboxylic anhydrides under the influence of catalytic amounts of trifluoromethanesulfonic acid (TFMS)[6]. Since *C*-acylation of phenols is of great practical importance, we have investigated whether the Fries rearrangement which is usually carried out with molar amounts of $AlCl_3$ could also be achieved with TFMS-catalysis.

If solutions of phenyl benzoates *(1)* in anhydrous tetrachloroethane are heated with *ca.* 2 mol-% TFMS for 24 h at 170 °C in sealed tubes, the reaction mixture contains *o*-hydroxyaryl ketones *(2)*, phenols *(3)*, and decomposition products besides starting material (Table 1).

Reactions run on a preparative scale (*e.g.* 0.1 mol *(1a)*, 0.02 ml TFMS in 100 ml anhydrous tetrachloroethane) give yields identical within the error limit with those in Table 1. Phenolic esters of aliphatic carboxylic acids also undergo Fries rearrangement with TFMS.

Electron donors in position 3 of the phenolic ester favor the TFMS-catalyzed rearrangement as the results in Table 1 indicate: starting from *(1d)*, *(2d)* was obtained in 78% yield while *(1b)* remained unchanged under the reaction conditions. Surprisingly, *(1e)* did not rearrange even though the two methyl groups at C-3 and C-5 should enhance acylation of the arene nucleus. This finding can be rationalized in terms of reversibility of the Fries rearrangement.

In order to test this hypothesis, we have heated several *o*-hydroxyaryl ketones with TFMS under the conditions given above. These experiments (Table 2) clearly show the Fries rearrangement to be indeed reversible.



(2) (1) (4)

Table 2. Retro Fries rearrangement of *o*-hydroxyaryl ketones *(2)* with catalytic amounts of TFMS.

Starting material	R	R'	R''	Products [%] [a] *(2)*	*(1)*	decomp. products
(2a)	H	H	H	75	25	—
(2e)	CH_3	CH_3	H	—	90	10
(2f)	H	H	CH_3	47	53	—
(4)				*(4)*, 23 *(2a)*, 9	*(1a)*, 40	28

[a] See note [a] in Table 1.

There is qualitative agreement between the isomer distribution for the Fries and the retro Fries rearrangement (Table 1 *vs.* Table 2); this is not sufficient, however, to establish a truly reversible equilibrium (which should be attained from either direction) so that further investigations are necessary.

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The mechanisms proposed so far for the Fries rearrangement must now be critically reviewed since they do not take account of the reversibility of the reaction which has been established beyond doubt by the results reported here, especially since we have found the retro rearrangement also with typical Friedel-Crafts catalysts such as $FeCl_3$.

Our inference from the experimental data given is that for the acid-catalyzed Fries rearrangement product formation is subject to thermodynamic control in many cases. Since phenolic esters and hydroxyaryl ketones seem to have about the same energy they are present side by side in solution. Steric hindrance due to buttressing of two *o*-substituents as in *(2e)* shifts the isomer distribution in favor of the sterically unhindered ester (Table 2). We observe almost exclusive *o*-rearrangement which is another argument in favor of the thermodynamic control mechanism since the *o*-hydroxyaryl ketones are stabilized by intramolecular hydrogen bonding which is impossible in the *p*-isomers.

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