

Acyl Iodides in Organic Synthesis: V. Reactions with Carboxylic Acid Esters

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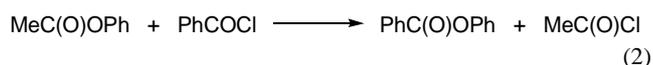
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Abstract—Acyl iodides react with alkyl, alkenyl, and aralkyl esters derived from saturated, unsaturated, and aromatic mono- and dicarboxylic acids in the absence of a catalyst. The reaction involves cleavage of the OR bond and formation of organic iodide RI (including $\text{CH}_2=\text{CHI}$) and one or two symmetric carboxylic acid anhydrides. Phenyl acetate reacts with benzoyl iodide to give acetyl iodide and phenyl benzoate as a result of cleavage of the $(\text{O}=\text{C})\text{O}$ bond. The reaction of diethyl fumarate with acetyl iodide is accompanied by *cis*–*trans* isomerization to afford maleic anhydride. In the reactions of acetyl iodide with diethyl oxalate and diethyl malonate, CO and CO_2 and CO_2 and polyketene are formed, respectively, in addition to ethyl iodide and acetic anhydride. Ethyl esters of strong organic acids, e.g., ethyl trihaloacetates, failed to react with acyl iodides under analogous conditions.

While studying the chemical potential of acyl iodides as reagents and synthons, we previously reported on their reactions with alcohols [1, 2], acyclic and cyclic ethers [3], and carboxylic acids [4]. The present communication describes the reactions of acyl iodides with esters derived from saturated, unsaturated, and aromatic mono- and dicarboxylic acids, namely acetic, trifluoroacetic, trichloroacetic, acrylic, benzoic, oxalic, malonic, fumaric, and phthalic.

We have no published data on reactions of aliphatic acyl chlorides with esters. Aroyl chlorides are known [5] to react with esters only in the presence of Lewis acids, and the reaction takes two pathways. For example, the reaction of benzoyl chloride with ethyl benzoate involves cleavage of the O–Et bond [reaction (1)], while in the reaction of the same compound with phenyl acetate, the $(\text{O}=\text{C})\text{O}$ bond is cleaved [reaction (2)].



We carried out reactions of acyl iodides with alkyl, alkenyl, and aralkyl carboxylates by heating the reactants at 60–90°C for 1–8 h in the absence of solvent and catalyst. The reactions occurred according

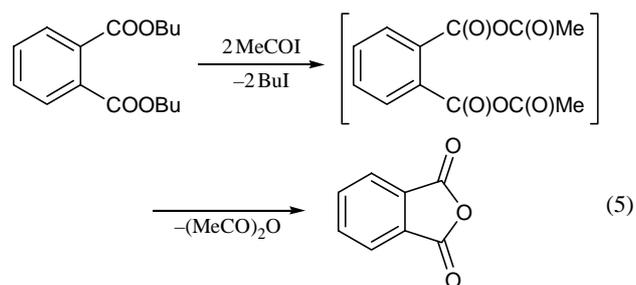
to general equation (3) and led to formation of the corresponding alkyl iodides and carboxylic acid anhydrides as a result of cleavage of the ester O–R² bond.



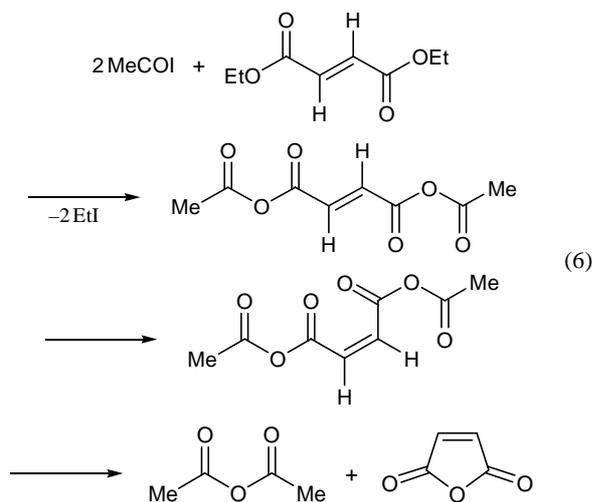
In particular, acetyl iodide reacted with acetic acid esters MeC(O)OR^2 ($\text{R}^2 = \text{Me, Et, CH}_2\text{Ph, CH}=\text{CH}_2$) to give acetic anhydride and the corresponding iodide (including $\text{CH}_2=\text{CHI}$). Likewise, in the reaction of benzoyl iodide with ethyl benzoate, benzoic anhydride and ethyl iodide were obtained [scheme (4)].



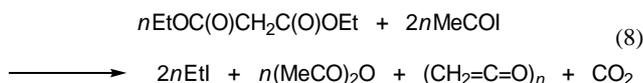
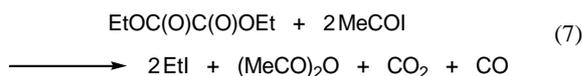
Acetyl iodide reacted with dibutyl phthalate to afford butyl iodide, acetic anhydride, and phthalic anhydride [scheme (5)]. The latter products were



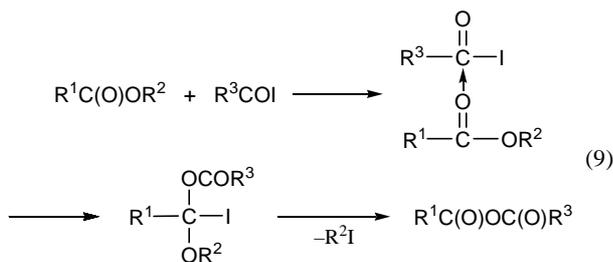
formed via disproportionation of mixed acetic phthalic anhydride. It is known that such disproportionation is typical of mixed anhydrides derived from weak carboxylic acids. Interestingly, the reaction of acetyl iodide with diethyl fumarate was accompanied by *cis-trans* isomerization, leading to ethyl iodide, acetic anhydride, and maleic anhydride [scheme (6)].



The major products of the reactions of acetyl iodide with diethyl oxalate and diethyl malonate were ethyl iodide and acetic anhydride. No expected cyclic anhydrides were formed, obviously because of their thermodynamic instability. From diethyl oxalate, carbon(II) oxide and carbon(IV) oxide were obtained [reaction (7)], whereas diethyl malonate gave rise to polyketene and carbon(IV) oxide [reaction (8)].

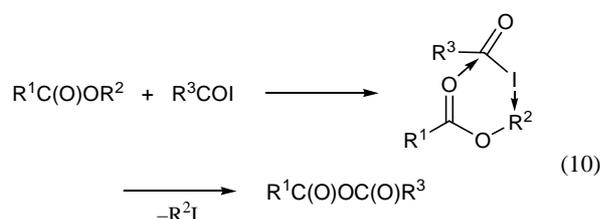


Presumably, all the above reactions involve initial electrophilic addition of acyl iodide (or acyl cation) to the ester carbonyl oxygen atom; next follow rupture of the C=O bond and addition of iodide ion to the



carbonyl carbon atom. The final reaction stage is geminal decomposition of the $-(\text{R}^2\text{O})-\text{C}(\text{OAc})-\text{I}$ moiety [scheme (9)]. It is known that nucleophilic center in esters is the carbonyl rather than ester oxygen atom [6].

Protolysis of esters in reactions with water, alcohols, and acids follows an analogous scheme [7]. Up to now, only one example of addition of acyl iodides to a carbonyl group has been reported; it is the reaction of benzoyl iodide with benzaldehyde [8]. Also we cannot rule out that the process occurs through an activated six-membered cyclic complex, as shown in scheme (10).



Unlike the above reactions, phenyl acetate failed to react with acetyl iodide according to scheme (1): no phenyl iodide was detected in the reaction mixture, and the initial reactants were recovered completely. However, the possibility for exchange process cannot be excluded [reaction (11)]. For example, the reaction of phenyl acetate with benzoyl iodide afforded acetyl iodide and phenyl benzoate via cleavage of the $(\text{O}=\text{C})-\text{O}$ bond [scheme (12)].



This is not surprising, for the ester O-Ph bond is much stronger than the neighboring $(\text{O}=\text{C})-\text{O}$ bond. Likewise, in the reaction of acetyl iodide with ethoxybenzene, only the O-Et bond is cleaved [3]. It should be noted that acetyl iodide reacts with vinyl acetate to give vinyl iodide and acetic anhydride as a result of cleavage of the $\text{O}-\text{C}_{\text{sp}^2}$ bond. A similar reaction between acetyl iodide and ethyl vinyl ether was observed by us previously [3]; it led to formation of vinyl iodide and ethyl acetate.

Ethyl trifluoroacetate and ethyl trichloroacetate did not react with acetyl iodide under analogous conditions. Presumably, the reason is the reduced nucleophilicity of the carbonyl oxygen atom in these esters. The carbonyl vibration frequencies $\nu(\text{C}=\text{O})$ in

the IR spectra of RCOOEt where R = Me, Cl₃C, and F₃C are equal to 1735, 1760, and 1780 cm⁻¹, respectively. This means that the order of the C=O bond increases while the electron density on the carbonyl oxygen atom decreases in going from acetic acid esters to its halogenated analogs.

EXPERIMENTAL

Reactions of carboxylic acid esters R²OC(O)R¹ (R¹ = Me, Et, CH=CH₂, CH₂Ph; R² = Me, CH=CH₂) with acetyl iodide (general procedure). A mixture of equimolar amounts of acetyl iodide and the corresponding ester was heated for 1–3 h at the boiling point. The products, organic iodide and acetic anhydride (as well as acrylic anhydride in the reactions with acrylic acid ester) were isolated by distillation under atmospheric or reduced pressure.

Reaction of acetyl iodide with methyl acetate. A mixture of 5.31 g (0.031 mol) of acetyl iodide and 2.3 g (0.031 mol) of methyl acetate was heated for 1 h at the boiling point. Distillation of the mixture gave 1.51 g (34%) of methyl iodide, bp 40–41°C, $n_D^{19} = 1.5316$, and 2.15 g (68%) of acetic anhydride, bp 140°C, $n_D^{19} = 1.3885$.

Reaction of acetyl iodide with phenyl acetate. A mixture of 5.31 g (0.031 mol) of acetyl iodide and 5.87 g (0.031 mol) of phenyl acetate in 20 ml of methylene chloride was heated for 10 h under reflux. Only the initial reactants were identified in the mixture.

Reaction of acetyl iodide with diethyl oxalate. A mixture of 10.62 g (0.062 mol) of acetyl iodide and 4.56 g (0.031 mol) of diethyl oxalate was heated for 2 h at 90°C; the reaction was accompanied by evolution of CO and CO₂, which were identified qualitatively. Distillation of the mixture gave 4.2 g (44%) of ethyl iodide and 2.92 g (47%) of acetic anhydride whose physical constants were consistent with published data.

Reaction of acetyl iodide with diethyl malonate. A mixture of 10.62 g (0.062 mol) of acetyl iodide and 5.88 g (0.031 mol) of diethyl malonate was heated for 5 h at 90°C. Distillation gave 7.98 g (82%) of ethyl iodide and 2.99 g (94%) of acetic anhydride. Carbon dioxide evolved during the process was identified by reaction with aqueous Ca(OH)₂. The crystalline residue was washed with acetone to remove iodine; we thus isolated 0.96 g of polyketene which does not melt and is insoluble in common organic solvents. IR spectrum, ν , cm⁻¹: 2920 s (C–H), 1732 s (C=O), 1656 m (C=C).

Reaction of acetyl iodide with diethyl fumarate.

A mixture of 10.62 g (0.062 mol) of acetyl iodide and 5.4 g (0.031 mol) of diethyl fumarate was heated for 6 h at 90°C. Distillation gave 2.1 g (31%) of ethyl iodide and 1.92 g (28%) of acetic anhydride; by sublimation of the residue we isolated 1.53 g (52%) of maleic anhydride with mp 52°C.

Reaction of acetyl iodide with dibutyl phthalate.

A mixture of 10.32 g (0.062 mol) of acetyl iodide and 6.31 g (0.031 mol) of dibutyl phthalate was heated for 8 h at 80°C. Vacuum distillation of the mixture gave a fraction with bp 45–50°C (18 mm); according to the GLC data, it was a mixture of butyl iodide (47%) and acetic anhydride (53%). The solid residue was recrystallized to isolate 2.95 g (66%) of phthalic anhydride with mp 136°C.

Reaction of benzoyl iodide with phenyl acetate.

A solution of 10.01 g (0.043 mol) of benzoyl iodide and 5.87 g (0.043 mol) of phenyl acetate in 20 ml of methylene chloride was heated for 3 h under reflux. Distillation gave 2.51 g (34%) of acetyl iodide, and by subsequent vacuum distillation we isolated 1.55 g (18%) of phenyl benzoate with mp 70°C.

Reaction of benzoyl iodide with ethyl benzoate.

A mixture of 10.01 g (0.043 mol) of benzoyl iodide and 6.47 g (0.043 mol) of ethyl benzoate was heated for 3.5 h at the boiling point. Distillation gave 4.52 g (91%) of ethyl iodide. By sublimation of the solid residue we isolated 2.12 g (22%) of benzoic anhydride with mp 42°C.

The physical constants of the isolated products were in agreement with published data [9].

REFERENCES

- Voronkov, M.G., Trukhina, A.A., and Vlasova, N.N., *Russ. J. Org. Chem.*, 2002, vol. 38, p. 1576.
- Shagun, V.A. and Voronkov, M.G., *Russ. J. Org. Chem.*, 2003, vol. 39, p. 331.
- Voronkov, M.G., Trukhina, A.A., and Vlasova, N.N., *Russ. J. Org. Chem.*, 2002, vol. 38, 1579.
- Voronkov, M.G., Belousova, L.I., Trukhina, A.A., and Vlasova, N.N., *Russ. J. Org. Chem.*, 2003, vol. 39, p. 1702.
- Sonntag, N.O., *Chem. Rev.*, 1953, vol. 52, p. 237.
- Gur'yanova, E.N., Gol'dshtein, I.G., and Romm, I.P., *Donorno-aktseptornaya svyaz'* (Donor–Acceptor Bond), Moscow: Khimiya, 1973, p. 344.
- Bender, M.J., *J. Am. Chem. Soc.*, 1951, vol. 73, p. 1626.
- Staudinger, H. and Authes, E., *Chem. Ber.*, 1913, vol. 46, p. 1423.
- Spravochnik khimika* (Chemist's Handbook), Nikol'skii, B.P., Ed., Moscow: Khimiya, 1963, vol. 2, p. 398.