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# CARBOXYLIC ACIDS SUPPORTED ON SILICA: A SMOOTH ACYLATING AGENT FOR ALCOHOLS

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Abstract: An alternative procedure for the esterification of alcohols by short-chain carboxylic acids supported on silica is presented.

Acylation of alcohols is one of the most ubiquitous reactions in an organic laboratory.[1] The direct reaction of a carboxylic acid with the alcohol is generally avoided because of the equilibrium that is established between reagents and products, which requires the use of excess reagents or the elimination of water from the reaction mixture in order to lead the process to its completion. This can be achieved by physical means, such as an azeotropic distillation of the water formed, or by the addition of dehydrating agents, of which a variety has been reported.[2]

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These limitations make preferable the use of more reactive derivatives, such as the acid chloride or anhydride, instead of the carboxylic acid. [3] This means that, with the exception of the more common, commercially available acid derivatives, one is often confronted, for the general acylation of an alcohol, with the need of preparing beforehand the acyl chloride from the corresponding carboxylic acid

The use of reagents supported on a solid matrix is an area of permanent investigation in organic synthesis, with the development of convenient alternative methods for classical reactions under smoother conditions. Brominations [4], aromatic cyanations [5] or iodinations [6], nitrations [7], dehydrations [8,9] and Diels-Alder cyclizations [10], are just a few examples of processes which may be carried out with advantages by employing reagents adsorbed on a solid support. Acid or basic species may be adsorbed on silica or alumina, with the generation of more effective catalysts for a variety of organic processes [11-15].

In the present report we describe a simple alternative to the classical Schotten-Baumann esterification of alcohols with acyl chlorides, which obviates the need of derivatizing the carboxylic acid. This latter reagent, when previously adsorbed on silica gel, can be made to react irreversibly, at room temperature, with an alcohol to give the corresponding ester in high yield. The acid, with a few drops of concentrated sulfuric acid, is adsorbed onto the silica, and the solid mixture allowed to dry in the air to a free-flowing powder which may be stored for months in a closed vessel without decomposition or loss of activity. The acylation is simply performed by stirring the alcohol in the presence of the "solid" acid in chloroform at room temperature. Examples of this procedure with various alcohols and different carboxylic acids supported on silica are given in Table 1.

The method is restricted to short-chain aliphatic acids: attempts to react myristic acid supported on silica with a few alcohols failed, presumably because the adsorbed lipophilic acid drifted away from the solid support into the non-polar solvent. This observation, and the fact that the reactions were not reversible point to a process which takes place on the surface of the solid catalyst. The acid and the alcohol, both adsorbed on the surface of polar $SiO_2$,



Table 1- Ester formation from various alcohols and carboxylic acids supported on silica.

| Acid | Alcohol | Yield, % [a] |
|---|---|---|
| Acetic | 2-Phenylethanol | 84 |
| Acetic | 1-Phenylethanol | 88 |
| Acetic | 2-Octanol | 84 |
| Acetic | t-Butanol | 80 |
| Acetic | Menthol | 81 |
| Acetic | Benzylic | 90 |
| Propanoic | 1-Decanol | 83 |
| Butanoic | 2-Butanol | 76 |
| Butanoic | t-Butanol | 70 |
| Chloroacetic | 1-Butanol | 82 |
| Chloroacetic | iso-Butanol | 80 |
| Chloroacetic | 1-Decanol | 83 |
| Chloroacetic | Benzylic | 89 |
| Trichloroacetic | iso-Pentanol | 74 |
| Trichloroacetic | 1-Pentanol | 73 |
| Trichloroacetic | Benzylic | 89 |
| Trifluoroacetic | iso-Pentanol | 88 |
| Trifluoroacetic | 1-Pentanol | 91 |
| Trifluoroacetic | Benzylic | 91 |

(a) - After purification by flash chromatography.

give rise to the less polar ester, which returns to the non-polar chloroform phase. This and the probable retention of the water formed by the acidified silica, shift the equilibrium of the reaction steadily to the product formation, in an essentially irreversible process. The fact that the silica support is essential to the reaction is in agreement with this picture. Blank tests performed under similar conditions in the absence of acidified silica led to no esterification in chloroform at room temperature. Thus, no reaction was observed when acetic acid and 2-octanol were stirred in chloroform in the absence of silica, even when drops of concentrated sulphuric acid were added to the medium. Also, the use of silica gel without the addition of drops of $H_2SO_4$ failed to acetylate the above alcohol.

These acid-catalyzed esterifications probably take place via initial protonation of the alcohol and/or of the acid on the surface of the silica. The role of the latter is, at this stage, a matter of speculation. The acidity of the catalyst may be enhanced on its surface, by stabilization of intermediate protonated species; or it may simply bring together the polar reagents in an acidic environment, releasing irreversibly, to the dichloromethane solution, the non-polar product.

In conclusion, adsorption on silica renders a short-chain carboxylic acid a very convenient, smooth, easy-to-handle "solid" acylating agent. The reaction takes place as smoothly as other esterifications with more reactive acid derivatives. As an alternative procedure, the above method should prove useful whenever the esterification of an alcohol by a short-chain carboxylic acid is required, and the corresponding acyl chloride is not immediately available.

Experimental:

Ir spectra were recorded with a FT-IR 16 PC Perkin Elmer spectrometer, $^1$H nmr with a Brucker AC 200 MHz apparatus. Refractive indices were obtained with a Carl Zeiss Abbe refractometer.

General Procedure: The carboxylic acid (60 mmol) and 10 drops of concentrated $H_2SO_4$ were thoroughly mixed with silica gel ( Merck, 70-200 mesh, 6 g) and the solid mixture was then allowed to dry in the air to a free-flowing powder.



To a solution of the alcohol ( 13 mmol) in dichloromethane ( 100 mL) was then added the supported acylating mixture ( 6 g of the powder) and the suspension was stirred for 4 h at room temperature. The organic layer was then filtered, washed with a $NaHCO_3$ solution ( 0.1 M, 20 mL ), then with water, and dried over anhydrous sodium sulphate. Evaporation of the solvent yielded the crude ester which still contained, in some cases, little unreacted alcohol (5-10%), as shown by its $^1$H nmr spectrum in $CCl_4$. All products were purified by flash-chromatography (silica gel 60 H, Merck, elution with n-hexane) and their structures confirmed by their ir and $^1$H nmr spectra. In some cases, for the sake of comparison, authentic samples were prepared following reported procedures, or by reacting the alcohol and the acid in refluxing benzene with drops of concentrated $H_2SO_4$ in a Dean-Stark distillation apparatus. Thus, for example, a sample of 1-decyl chloroacetate was prepared by refluxing chloroacetic acid and 1-decanol in the presence of sulfuric acid for 7 h [16] .The product, bp 148-150 °C/ 10 mmHg , lit. [16] bp 146-147 °C / 9 mmHg, was identical by spectral comparison with the obtained compound, ir (film) $\nu_{max}$ 1750 cm $^{-1}$, $^1$H nmr ($CCl_4$, tetramethylsilane as internal standard ) $\delta$ 0.9 (distorted triplet, 3 H, $CH_3$ ), 1.2-1.4 ( m, 16 H, $(CH_2)_8$ ), 1.7 (distorted quintuplet, 2 H, $OCH_2$-$\underline{CH_2}$- ), 4.0 (s, 2 H, $CH_2Cl$), 4.2 (t, 2 H, J= 8 Hz, $OCH_2$).

The following esters, all colourless liquids, were further characterized by comparison of their boiling points or refractive indices with reported data from the literature:

2-phenylethyl acetate, $n_D^{20}$ 1.5182, lit. [17] $n_D^{20}$ 1.5171; 1-phenylethyl acetate, $n_D^{20}$ 1.4980, lit. [18] $n_D^{18}$ 1.5003; 2-octyl acetate, $n_D^{20}$ 1. 4121, lit. [17] $n_D^{20}$ 1.4146 ; t-butyl acetate , bp 95-97 °C, lit. [17] bp 97-98 °C ; menthyl acetate, bp 107-109 °C, lit. [17] bp 109 °C; benzyl acetate, $n_D^{20}$ 1.5254 , lit. [17] $n_D^{20}$ 1.5232 ; 1-decyl propanoate, $n_D^{20}$ 1.4273, lit. [19] $n_D^{20}$ 1.42696 ; 2-butyl butanoate, $n_D^{20}$ 1.4032, lit. [17] $n_D^{20}$ 1.4019; t-butyl butanoate, $n_D^{20}$ 1.4028, lit.[17] $n_D^{17.5}$ 1.4007 ; 1-butyl chloroacetate, bp 172-174 °C, lit.[20] 175 °C; iso-butyl chloroacetate, bp 166-168 °C, lit. [20] 170 °C benzyl chloroacetate, $n_D^{20}$

1.5411, lit. [17] $n_D^{20}$ 1.5426 ; iso-pentyl trichloroacetate, bp 212-215 °C, lit.[21] bp 217 °C; 1-pentyl trichloroacetate, bp 215-218 °C, lit. [17] bp 220-222 °C ; benzyl trichloroacetate , $n_D^{20}$ 1.5300, lit.[22] $n_D^{18.8}$ 1.5288 ; iso-pentyl trifluoroacetate, bp 117-119 °C, $n_D^{20}$ 1.3520, lit. [23] bp 119-120 °C , $n_D^{20}$ 1.3513 ; 1-pentyl trifluoroacetate, bp 123-125 °C, $n_D^{20}$ 1.3495, lit. [24] bp 122-124 °C, $n_D^{25}$ 1.3510; benzyl trifluoroacetate, bp 179-181°C, lit. [25] bp 178-179°C.

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