THE ROLE OF POLYMER CATALYST STRUCTURE ON CONVERSION OF ALCOHOLS AND AMINES TO ESTERS AND AMIDES

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The effect of the polymer catalyst structure, containing units of basic character, i.e. crosslinked co-poly/styrene-4-vinylpyridine/ and crosslinked polystyrene bearing n-butylamine, piperidine, and piperazine units, was investigated in the conversion of phenol or aniline with acetanhydride or acetyl chloride to phenylacetate or acetanilide. The role of the structure of the alcohol, acid chloride, or anhydride, on the formation of esters in the presence of polymer supported catalyst was tested using poly/styrene-4-vinylpyridine/.

Chemical modification of polymer resins offers an interesting possibility for the preparation of new reagents, catalysts, separation media, etc. [1-5] It is known that the reactivity of reagents or catalysts strongly depends on the structure of the polymer backbone (polarity, crosslinking, etc.), the structure of the organic residue introduced into the polymer backbone, solvent (polarity - swelling of polymer resins), and the structure of organic molecules, being usually more important than in the case of the corresponding homogeneous reactions; the effects of all the abovementioned variables have been recently reviewed. [6] Introduction of functional groups containing a nitrogen atom into the polymer backbone received great attention because of the well known fact that substituted amines, pyridine, and substituted pyridines are often used as catalysts in the preparation of esters, amides, etc. In recent years, polymer-bound dimethylaminopyridine [7-13] was extensively studied, Frechet and coworkers [14] have extensively studied the relationship between the local reaction medium and catalyst efficiency, while Patchornik and coworkers [15] have designed a new "mediator methodology" for the synthesis of peptides. Recently, trifluoroacetylation of amines and amino acids by a polymer-supported trifluoroacetylation agent was reported. [16]

The important role of the polymer-bound catalyst structure on the conversion of organic molecules stimulated us to study the effect of polymer catalyst on the conversion of several alcohols to esters, and aniline to acetanilide. In our recent study on site-site interactions of the polymer matrix [17] studied on chloromethylated crosslinked polystyrene, we have reported that nucleophilic displacement of chlorine by an amine is also accompanied by additional crosslinking. For the present studies, crosslinked co-poly/styrene-4-vinylpyridine/(1a) [18], and crosslinked polystyrene, bearing the basic units piperidine (1b) [17], n-butylamine (1c) [17], and piperazine (1d) [17] were chosen. In the chemical transformation of organic molecules the question of the swelling of resins versus the polarity of the solvent arises, and for this reason we measured the swelling capacity of catalyst 1 in various solvents and for further studies we decided to perform reactions in benzene (some of the reactions were also run in cyclohexane, but no significant effect was observed in the case of conversion of some alcohols to acetates with acetanhydride).

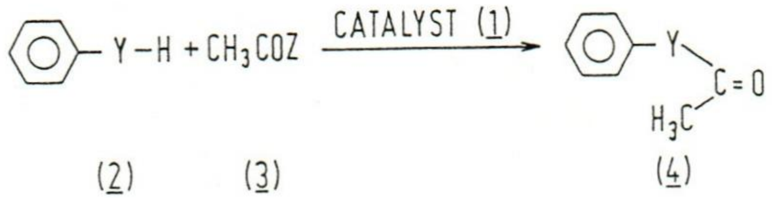
THE EFFECT OF CATALYST STRUCTURE ON DEGREE OF SWELLING IN VARIOUS SOLVENTS

SOLVENT	1a	1b	1c	1d
hexane	1.1	1.8	1.5	1.4
cyclohexane	1.1	1.7	1.6	1.3
1,4-dioxane	2.7	2.3	2.3	2.0
benzene	2.7	2.7	2.4	2.3
chloroform	4.0	2.8	2.7	2.6
DMF	2.4	1.4	1.9	1.8
acetonitrile	1.5	1.1	1.4	1.4

First we studied the effect of the catalyst (1, Scheme 1) on the conversion of phenol (2a) and aniline (2b) with acetanhydride (3a) and acetyl chloride (3b) to phenylacetate (4a) or acetanilide (4b). As evident from Scheme 1, the presence of catalyst enhanced the conversion of phenol with acetanhydride, while the corresponding reaction with aniline gave acetanilide in the absence of catalyst, while introduction of insoluble catalyst (1c, 1d) diminished the conversion. The effect of the polymer resin on conversion of acetanilide with acetyl chloride is also presented in Scheme 1.

Further, we studied the effect of the structure of the alcohol and the structure of the acid chloride and anhydride on the formation of esters. In Scheme 2, the effect of the amount of catalyst, and the structure of the organic molecule is presented. As in previous cases, different effects of the polymeric catalyst on the conversion of alcohols to esters were observed. After the reaction, the insoluble catalyst was filtered off and regenerated, and could be reused several times without appreciable loss of capacity. Several alcohols were converted into esters in the presence of co-poly/styrene-4-vinylpyridine/ on the 20 mmol scale and in high yields.

SCHEME 1

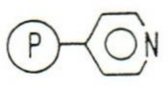


2a : Y = O 3a : Z = $OCOCH_3$

2b : Y = NH 3b : Z = Cl

CATALYST:

1a:



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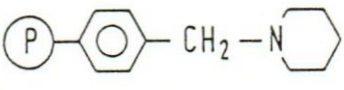
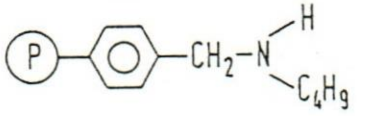
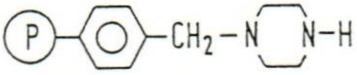


1c:



1d:



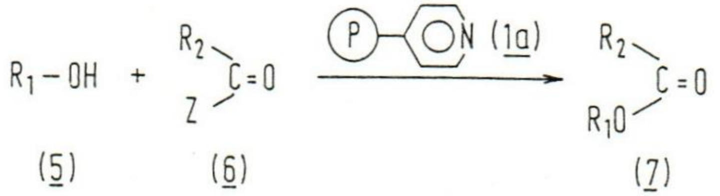
THE EFFECT OF THE STRUCTURE OF THE CATALYST (1), ORGANIC MOLECULE (2), AND ACYLATING AGENT (3) ON THE FORMATION OF PHENYLACETATE (4a) OR ACETANILIDE (4b)

	2 : Y = O[a/]		2 : Y = NH[b/]	
	3a : Z = $OCOCH_3$		3a : Z = $OCOCH_3$	3b : Z = Cl
CATALYST	A	B	B	B
1a	93%	100%	100%	71%
1b	68%	97%	100%	100%
1c	45%	86%	55%	71%
1d	40%	80%	82%	58%
NONE	16%		100%	70%

a/ 1 mmol of phenol, 1 mmol of 3a, 5 ml of benzene, 24-hours reaction at room temperature; amount of 1 A: 0.1 mmol, and B: 1 mmol of basic units

b/ 1 mmol of aniline, 1.1 mmol of 3a or 3b, 5 ml of benzene, 5 minutes at 16°C; amount of 1 B: 1 mmol of basic units

SCHEME 2



5a : $R_1 = n-C_6H_{13}$

5b : $R_1 = c-C_6H_{11}$

5c : $R_1 = -CH_2C_6H_5$

5d : $R_1 = -C_6H_5$

5e : $R_1 = \beta-C_{10}H_7$

6a : $R_2 = C_6H_5$, $Z = Cl$

6b : $R_2 = CH_3$, $Z = Cl$

6c : $R_2 = CH_3$, $Z = OCOCH_3$

6d : $R_2 = CF_3$, $Z = OCOCF_3$

THE EFFECT OF THE STRUCTURE OF ALCOHOL (5), ACID CHLORIDE (6a, 6b), OR ANHYDRIDE (6c, 6d), AND THE AMOUNT OF CATALYST (1a) ON THE FORMATION OF ESTERS (7)[a/]

	6a $R_2 = C_6H_5$ $Z = Cl$			6b $R_2 = CH_3$ $Z = Cl$			6c $R_2 = CH_3$ $Z = OCOCH_3$			6d $R_2 = CF_3$ $Z = OCOCF_3$	
5	A	B	C	A	B	C	A	B	C	A	C
$n-C_6H_{13}$	17%	26%	84%	96%	95%	92%	8%	29%	89%	100%	100%
$c-C_6H_{11}$	8%	13%	81%	91%	94%	92%	1%	16%	37%	100%	90%
$-CH_2C_6H_5$	14%	17%	99%	92%	94%	98%	6%	59%	96%	100%	91%
$-C_6H_5$	8%	26%	97%	40%	43%	97%	16%	93%	100%	79%	94%
$-C_{10}H_7$	12%	18%	95%	15%	34%	96%	8%	83%	100%	85%	94%

[a/] 1 mmol of 5, 1.1 mmol of 6, 5 ml of benzene; 1a A: none, B: 0.1 mmol, and C: 1 mmol of pyridine units; conversion of alcohol after 24-hours stirring at room temperature.

EXPERIMENTAL SECTION

Chloromethylated polystyrene was prepared by functionalization of crosslinked polystyrene (2% DVB), using chloromethyl methyl ether and boron trifluoride and further transformed with amines to catalyst 1b (molar ratio of CH_2Cl:n-butylamine 1:3, %N: 2.8) [17], 1c (molar ratio CH_2Cl:n-butylamine 1:3, %N:2) [17], 1d (molar ratio CH_2Cl:piperazine 1:3, %N:4.0) [17], indicating that resins 1c and 1d are crosslinked during nucleophilic substitution up to 30%. Crosslinked (2% of divinylbenzene) copoly/styrene-4-vinylpyridine/ (%N: 5.1; % of pyridine rings: 39) was prepared according to the literature [18]. All reagents and solvents were purified before use.

Determination of Degree of Swelling

To 1 ml of dry catalyst 1 in a graduated cylinder, 5-10 ml ofsolvent was added and left to swell for 24 hours at room temperature and the final volume of the swollen resin was measured.

Conversion of Alcohols to Esters

An amount of polymeric resin containing 1 mmol of basic units (1a: 274 mg; 1b: 505 mg; 1c: 700 mg; 1d: 700 mg) was placed into the reaction vessel, 5 ml of benzene were added and the reaction mixture stirred at room temperature for 2 hours, 1.1 mmol of reagent 3 or 6 was subsequently added, and after 5 minutes 1 mmol of alcohol 5 was added and the reaction mixture stirred at room temperature for 24 hours. The conversion of starting alcohol was determined by glc. Products were isolated after usual work-up procedure, i.e. polymer resins were filtered off, benzene evaporated in vacuo and crude products crystallized or distilled. Spectroscopic data of products were in agreement with those of the independently prepared compounds.

Conversion of Aniline to Acetanilide

An amount of polymeric resin containing 1 mmol of basic units (1a: 274 mg; 1b: 505 mg; 1c: 700 mg; 1d: 700 mg) was placed into the reaction vessel, 5 ml of benzene were added and the reaction mixture stirred at room temperature for 2 hours, 1.1 mmol of reagent 3a or 3b was subsequently added, and after 5 minutes 1 mmol of aniline was added and the reaction mixture stirred at 16°C for 5 minutes. The conversion of starting aniline was determined by glc. Products were isolated by the usual work-upprocedure.

Typical Synthetic Procedure: 2-Naphthylacetate

8.8 g of co-poly/styrene-4-vinylpyridine/ (1a) was swollen in 160 ml of benzene at room temperature for 2 hours, under stirring 1.9 g of acetanhydride was subsequently added and stirred for 5 minutes; 2.3 g of 2-naphthol was added and the reaction mixture stirred at 16°C for 5 hours. The polymer resin was filtered off, washed with benzene, the solvent removed in vacuo, and 2.9 g of solid 2-naphthylacetate was isolated. Crystallization from ethanol yielded 2.5 g (84%) of pure product.

Regeneration of Resins

Insoluble catalyst 1 was washed with benzene and methanol, and then stirred for 15 hours in 1 M NaOH in a methanol/water mixture (1:1). Resins were filtered off and washed with water and a methanol/water mixture until neutral. No appreciable change in the reactivity was observed after five cycles.

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