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POLYMERS AS REAGENTS AND CATALYSTS. PART X. HALOGENATIONS OF ACETOPHENONE AND 1,3-DIKETONES WITH POLYMER-SUPPORTED REAGENTS[1]

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Summary

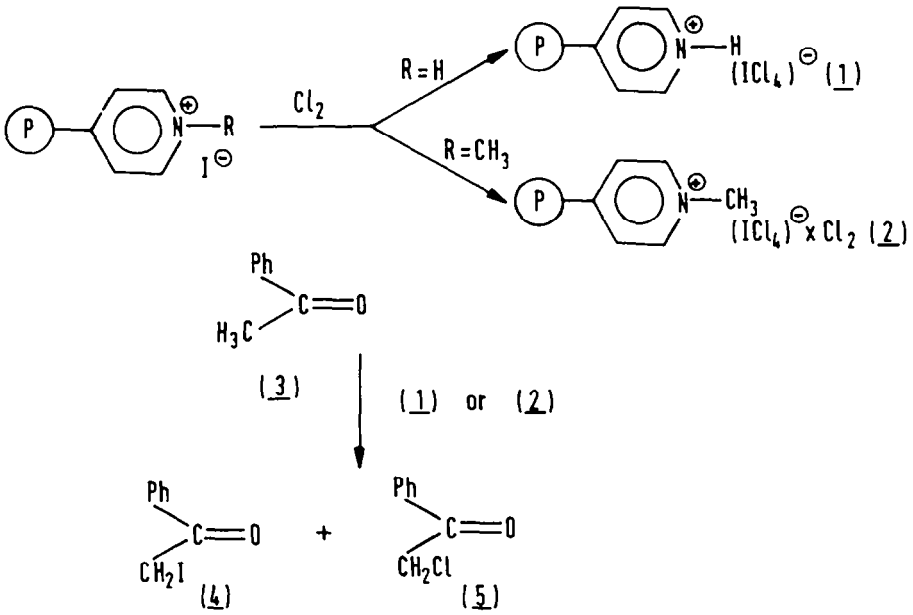
A crosslinked copolymer of styrene and 4-vinylpyridine (40-43% of monomer units) was reacted with hydrogen iodide to give a polymer containing pyridinium iodide residues. Reaction of this with chlorine in chloroform at 0° gave a polymer containing pyridinium tetrachloroiodate residues. In a similar manner but using methyl iodide in place of hydrogen iodide, crosslinked polymers containing N-methylpyridinium iodide and N-methylpyridinium tetrachloroiodate residues were prepared. The latter contained up to three chlorine molecules per iodine atom. Both reagents reacted with acetophenone, thus forming iodomethyl-phenyl ketone (4) and chloromethyl-phenyl ketone (5), the ratios depending on the reagent used and the reaction time. Chlorinations of 5,5-dimethyl cyclohexane-1,3-dione and indane-1,3-dione with polymer-supported reagent (2) resulted in the formation of geminal dichlorides in high yields.

Polymeric resins can be chemically transformed so that they can act as reagents or catalysts, and besides offering a simpler experimental technique, the chemical reactivity can also be changed when the reagent is attached to a polymer backbone |2|. Crosslinked polystyrene beads have found a wide range of use in organic chemistry for the preparation of reagents and catalysts, while crosslinked polyvinylpyridine or crosslinked copolymers with styrene and vinylpyridine have received much less attention, in spite of a known fact that pyridine has wide application in organic synthesis by itself or in conjuction with other reagents.

Katchalsky and coworkers have pointed out the important role of the polymeric backbone on the chemical reactivity observed in chlorination and bromination of alkyl substituted benzene derivatives with poly (N-chloromaleinimide) |3| and poly (N-bromomaleinimide)|4|. We have also recently demonstrated the effect of the polymer backbone on the chemical reactivity of aryliodo (III) dichloride when attached to crosslinked polystyrene |1|.

Tetrabutylammonium iodide reacted with chlorine [5] forming tetrabutylammonium tetrachloroiodate (III), while chlorination of the macroreticular anion exchange resin Amberlyst A-26 in the iodide form gave a polymer-supported reagent containing one chlorine molecule per iodine atom, which converts ketones and aldehydes to α-chloro derivatives with no evidence for the formation of iodo substituted products [6].

SCHEME



EFFECTS OF REAGENT AND REACTION TIME ON THE PRODUCT DISTRIBUTION [a]

REAGENT	AMOUNT OF REAGENT [g]	REACTION TIME [h]	CONVERSION OF (3) [%]	5/4
(1)	0.5	18	65	0.9
	1	4	81	0.7
(2)	0.3	18	42	7.4
	0.5	18	61	5.7
	0.5	30	67	7.4
	1	4	76	5.3
	1	18	97	18.4

a) T = 23°C ; Solvent – CH_2Cl_2 (10ml) ; 1 mmol of (3) ; product distribution determined by ^1H NMR.

Results and Discussion:

Being interested in the effect of the polymer backbone on the reactivity of polymer-supported reagents, we found it relevant to study the reaction of chlorine with a crosslinked styrene-4-vinyl(pyridinium iodide) copolymer and a crosslinked styrene-4-vinyl(N-methyl pyridinium iodide) copolymer which were prepared from a crosslinked styrene-4-vinylpyridine copolymer, containing 40-45% of pyridine rings with HI or methyl iodide. Chlorination of the crosslinked styrene-4-vinyl (pyridinium iodide) copolymer in chloroform at $0^{o}C$ gave reagent (1) containing 26.2% of iodine and 27% of chlorine, while similar chlorination of the crosslinked styrene-4-vinyl(N-methyl pyridinium iodide) copolymer resulted in reagent (2) containing 23.1% of iodine and 34.3% of chlorine, indicating a higher degree of incorporation of chlorine into polymer resins /four chlorine atoms per iodine atom for reagent 1 and six chlorine atoms per iodine atom for reagent 2/ than was observed by chlorination of Amberlyst A-26 |6|. The high degree of chlorine incorporation into styrene-4-vinyl(N-methyl pyridinium iodide) copolymer could be explained either by the formation of a chlorine complex with styrene-4-vinyl(N-methyl pyridinium tetrachloro iodate (III) copolymer or by formation of styrene-4-vinyl(N-methyl pyridinium hexachloro iodate (V)) copolymer, the second explanation being less probable since such coordination of an iodine atom in now known only with fluorine as halogen.

Reaction of polymer-supported reagent prepared by chlorination of Amberlyst A-26 in iodide form with acetophenone resulted in only a monochlorinated product in 66% yield |6|. 18-Hours reaction of 1 mmol of acetophenone with 0.5 g of (1) at room temperature gave a crude reaction mixture which, besides a signal at 2.49 ppm, corresponding to starting material, showed in its ^{1}H nmr spectrum two new signals at 4.35 ppm and 4.65 ppm. The signal at lower field corresponds to chlorinated product (5), while the signal at δ = 4.35 ppm is increased when the crude reaction mixture is mixed in acetone in the presence of KI. On the basis of spectroscopic data, it is evident that an iodinated product |7| was also formed by reaction with polymer-supported reagent (1). The use of greater amounts of reagent (1) increased the conversion of starting material, but also enlarged the formation of the iodinated product. The change in the nature of reagent has no significant effect on its reactivity towards acetophenone, but is reflected in the product distribution, and higher amounts of chlorinated product were observed in reactions with reagent 2 /Scheme/. Prolongation of reaction time with the same amount of reagent significantly increased the amount of chlorinated product, while the use of 1 g of reagent (2) gave a reaction mixture after 18 hours containing only 5% of iodinated product. The results presented in the Scheme suggest the initial formation of iodinated product, while the degree of further substitution of iodine with chlorine depends on the structure of the reagent and the reaction time.

Further, we studied halogenations of two 1,3-diketones 5,5-dimethyl cyclohexane-1,3-dione (6) and 1,3-indanedione (8), with polymer-supported reagent (2). An 18 hour reaction of 1 mmol of 6 and 1 g of 2 in dichloromethane gave a mixture containing mono and dichloro products and starting material, while increasing the amount of halogenating reagent 2 from 1 to 2 g led to complete conversion of star-

ting material, and 2,2-dichloro-5,5-dimethyl cyclohexane-1,3-dione (7) was isolated in high yield. Under similar conditions 1,3-indanedione was transformed into its dichloro derivative (9).

Experimental:

I.r. spectra were recorded using a Perkin-Elmer 727 B instrument and ^1H nmr spectra on JEOL JNM-PS-100 spectrometer with Me_4Si as internal reference. Mass spectra were taken on CEC 21-110 spectrometer. Gas liquid partition chromatography was carried out on a Varian Aerograph, Model 3700, and a CDS 111 integrator. Elemental analysis was performed in Microanalytisches Labor Pascher in Bonn.

Styrene-4-vinyl(pyridinium iodide)copolymer

1.5 g of styrene-4-vinyl pyridine copolymer |8| was suspended in 10 ml of 1,4-dioxane and 1.425 g of HI, and stirred at room temperature for 3 hours; the polymer beads were filtered off, washed twice with methanol /15 ml/, three times with chloroform /15 ml/, dried at room temperature for 18 hours and 2.4 g of product was isolated. 1 gram of air dried product was further dried at 63°C for 4 hours and 0.93 gram of product containing 36.7% of iodine was obtained. Functionalization of pyridine rings occured to more than 95%.

Reaction of styrene-4-vinyl(pyridine iodide)copolymer with Chlorine

1.5 g of styrene-4-vinyl(pyridinium iodide)copolymer was suspended in 15 ml of chloroform and under stirring at 0°C, chlorine was introduced until a yellow colour persisted; the reaction mixture was stirred for 1 hour at 0°C and for an additional 2 hours at room temperature, the insoluble product was filtered off, washed three times with chloroform /20 ml/, dried at room temperature for 18 hours and 2.1 g of product was isolated. 1 g of air dried product was dried at 63°C for 4 hours, and 0.93 g of polymer-supported halogenating reagent (1), containing 26.2% of iodine and 27% of chlorine, was obtained.

Chlorination of styrene-4-vinyl(N-methyl pyridinium iodide)copolymer

1.5 g of styrene-4-vinyl(N-methyl pyridinium iodide)copolymer |8| was suspended in 15 ml of chloroform and under stirring at 0°C, chlorine was introduced until a yellow colour persisted; the reaction mixture was stirred for 1 hour at 0°C and for an additional 2 hours at room temperature, the insoluble product was filtered off, washed three times with chloroform /20 ml/, dried at room temperature for 18 hours, and 2.35 g of product was isolated. 1 g of air dried product was dried at 63°C for 4 hours, and 0.965 g of polymer-supported halogenating reagent (2), constaining 23.1% of iodine and 34.8% of chlorine was obtained.

Halogenations of Acetophenone (3)

Various amounts of polymer-supported halogenating reagents 1 and 2 /amounts are stated in the Scheme/ were suspended in 10 ml of CH_2Cl_2 at room temperature for 1 hour, 1 mmol of acetophenone was added, the reaction mixture was stirred at room

temperature for various times, insoluble polymer beads were filtered off, washed twice with CH_2Cl_2 /10 ml/, the solvent was evaporated in vacuo and the crude reaction mixture was analysed by ^1H nmr spectroscopy. The effect of the reagent used, the ratio of the amount of reagent to acetophenone and the reaction time on the course of the reaction is presented in the Scheme. Products were identified on the basis of a comparison of spectroscopic data with the literature ones and their comparison with independently synthesized compounds |6,7|.

2,2-Dichloro-5,5-dimethyl cyclohexane-1,3-dione (7)

2 g of polymer-supported reagent 2 was suspended in 10 ml of CH_2Cl_2, stirred at room temperature for 1 hour, and one mmol of 5,5-dimethyl cyclohexane-1,3-dione was added. The reaction mixture was stirred for 18 hours at room temperature, insoluble polymer beads were filtered off, washed twice with CH_2Cl_2 /5 ml/, the solvent was evaporated in vacuo and 0.195 g of crude product was isolated. The ^1H nmr spectrum of the crude product shows complete conversion of starting 1,3-diketone to geminal dichloro derivative (7), which was further crystallized from CH_3OH and 0.148 g /71%/ of 2,2-dichloro-5,5-dimethyl cyclohexane-1,3-dione was obtained: mp = 110-111°C, mp_{lit}[9] = 113°C; ^1H nmr spectrum: δ_{CH_2} = 3 ppm, δ_{CH_3} = 1.0 ppm.

2,2-Dichloroindane-1,3-dione (9)

2 g of polymer-supported halogenating reagent 2 was suspended in 10 ml of CH_2Cl_2, stirred at room temperature for 1 hour, and 1 mmol of indane-1,3-dione was added. The reaction mixture was stirred for 18 hours at room temperature, insoluble polymer beads were filtered off, washed twice with CH_2Cl_2 /5 ml/, the solvent was evaporated in vacuo and 0.205 g of crude product was isolated. The ^1H nmr spectrum of the crude product shows complete conversion of starting 1,3-diketone to geminal dichloro derivative (9), which was further crystallized from petrolether and 0.16 g /74%/ of 2,2-dichloroindan-1,3-dione was obtained: mp = 122-123°C, mp_{lit}[10] = 124-125°C, ^1H nmr spectrum: δ_H = 8.1 ppm.

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