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BIS(TRIPHENYLPHOSPHINE) COPPER(I) TETRAHYDROBORATE IN THE REDUCTION OF ACID CHLORIDES TO ALDEHYDES

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Acid chlorides in the presence of two moles of triphenylphosphine are reduced to aldehydes in good yields by bis(triphenylphosphine) copper(I) tetrahydroborate, $(Ph_3P)_2CuBH_4$ (table 1). The reaction is generally complete in 30 min at room temperature. Under the conditions of the reaction, aldehydes are only slowly reduced to alcohols by the reagent.

Table 1

Acid Chloride	Aldehyde	% Yield	
		g.l.c.[a]	isolated[b]
2-nitrobenzoyl	2-nitrobenzaldehyde	72	73
3-nitrobenzoyl	3-nitrobenzaldehyde	80	75
4-nitrobenzoyl	4-nitrobenzaldehyde	67	60
4-methoxybenzoyl	4-methoxybenzaldehyde	87	75
3,4-dimethoxybenzoyl	3,4-dimethoxybenzaldehyde	80	86
4-chlorobenzoyl	4-chlorobenzaldehyde	74	80
4-toluoyl	4-tolualdehyde	94	79
4-cyanobenzoyl	4-cyanobenzaldehyde	100	74
benzoyl	benzaldehyde	76	
heptanoyl	heptaldehyde	97	
cinnamoyl	cinnamaldehyde	69	

a) using an internal standard

b) as pure aldehyde or 2,4-dinitrophenylhydrazone

Bis(triphenylphosphine) copper tetrahydroborate is a white crystalline compound, stable in air which gives stable solutions at room temperature in chloroform, benzene and acetone; it is insoluble in ether, ethanol and water. $(Ph_3P)_2CuBH_4$ is readily prepared by a modification of the original reduction of copper sulphate,[1] or by reduction of tris(triphenylphosphine) copper chloride.[2] Although considerable interest has been shown in crystallographic[3] and temperature dependent n.m.r. studies[4,5] on the compound, no reports of the reaction of $(Ph_3P)_2CuBH_4$ with organic compounds have been made.

The main features of the reduction are:

a) one mole of $(Ph_3P)_2CuBH_4$ is required to reduce the acid chloride.

b) acetone is a suitable solvent for the reaction; the yields in chloroform and dimethoxyethane are lower (table 2).

Table 2

No. of moles of triphenylphosphine	% Yield[a] of aldehyde from reduction of: 4-methoxybenzoyl	benzoyl	4-nitrobenzoyl	cinnamoyl	Solvent
0	36	39	44	50	Me_2CO
2	87[b]	76	67	69	Me_2CO
4	89	73	72	70	Me_2CO
0	25	30	29	33	$CHCl_3$
2	60	39	49	13	$CHCl_3$

a) yield by g.l.c., using an internal standard

b) yield in dimethoxyethane 16%

c) relatively low yields are obtained and much longer reaction times are necessary in the absence of free triphenylphosphine. The yields of aldehydes increase with increasing amounts (up to 2 moles) of added triphenylphosphine; further addition of triphenylphosphine does not improve the yield of aldehyde (table 2). A possible role for the triphenylphosphine may be the formation of an acyl phosphonium salt as an intermediate species which is reduced by the complex.

d) the reagent is compatible with a wide range of functional groups. Esters, ketones, cyanides, epoxides, imines, alkenes and alkynes are unaffected under the conditions of the reaction. α,β-Unsaturated acid halides give α,β-unsaturated aldehydes; reduction of cinnamoyl chloride gave only cinnamaldehyde; g.l.c. showed that cinnamyl alcohol, 3-phenylpropanol or 2-phenylpropanal were absent in the reaction mixture.

e) as expected acid halides with electron withdrawing groups are more rapidly reduced than those halides with electron donating substituents.

f) $(Ph_3P)_2CuBH_4$ is added as a solid. As the reaction proceeds, the copper tetrahydroborate dissolves hydrogen is evolved and tris(triphenylphosphine) copper chloride precipitates. $(Ph_3P)_3CuCl$ may be recycled to bis(triphenylphosphine) copper tetrahydroborate in quantitative yield.[2] Triphenylphosphine borane, Ph_3PBH_3, can also be isolated from the reaction mixture.

Of the several methods[6,7] available for the reduction of acid halides to aldehydes, the use of lithium aluminium tri-tert-butoxyhydride at low temperatures is at present the method of choice.[8,9] The use of the hydridoirontetracarbonyl anion[10] has recently been reported, although the reagent is not compatible with nitro groups and gives poor yields of aldehydes from α,β-unsaturated acid halides; this reduction is closely related to the reduction of acid chlorides with $Na_2Fe(CO)_4$.[11]

Bis(triphenylphosphine) copper borohydride is a cheap reagent which is easily handled and should usefully extend the range of reagents available for the reduction of acid chlorides to aldehydes. The procedure given for the reduction of 3,4-dimethoxybenzoyl chloride is illustrative.

Experimental

Bis(triphenylphosphine) copper tetrahydroborate

Hydrated copper sulphate (16 g, 64 mmol) was stirred in a solution of triphenylphosphine (54 g, 200 mmol) in ethanol (1400 ml) to give, after one hour, a pale green solution. Finely powdered sodium borohydride (12 g, 320 mmol) was added with stirring; hydrogen was evolved and a white precipitate formed. After 1 hr, the crude product was collected by filtration and dissolved in chloroform (400 ml). The reaction mixture was filtered and ethanol (800 ml) was added to the filtrate. The precipitate was collected by filtration, and washed with ethanol and ether to give bis(triphenylphosphine) copper tetrahydroborate (32 g, 53 mmol, 83% based on copper sulphate) as white needles, m.p. 174-6° (lit.[1] 177°), $\nu_{max.}$ ($CHCl_3$) 2380, 2020, 1140 cm^{-1}.

Reduction of 3,4-dimethoxybenzoyl chloride

3,4-Dimethoxybenzoyl chloride (1.14 g, 5.7 mmol) in acetone (100 ml) was treated with triphenylphosphine (3.04 g, 11.6 mmol). To this solution at room temperature, solid bis(triphenylphosphine) copper tetrahydroborate (3.47 g, 5.8 mmol) was added and the reaction mixture stirred for 45 min. The white precipitate, tris(triphenylphosphine) copper chloride (4.9 g, 5.5 mmol), was removed by filtration and the acetone filtrate evaporated to dryness. The residue was extracted with ether (100 ml) (the ether insoluble residue was shown to be triphenylphosphine borane). The ether was removed, the residue redissolved in chloroform (60 ml) and the resulting solution stirred over cuprous chloride (1 g).[12] The reaction mixture was filtered, the chloroform evaporated and the residue extracted with methanol. The methanol extract was added to a solution of dinitrophenylhydrazine sulphate to give 3,4-dimethoxybenzaldehyde 2,4-dinitrophenylhydrazone (1.66 g, 4.8 mmol, 86%), m.p. 269-71° (lit.[13] 264-5°) identical with an authentic sample.[13]

REFERENCES

1. J. M. Davidson, Chem.Ind.(London), 1964, 2021.

2. F. Cariati and L. Naldini, Gazz.Chim.Ital., 1965, 95, 3.

3. S. J. Lippard and K. M. Melmed, J.Amer.Chem.Soc., 1969, 89, 3929.

4. C. H. Bushweller, H. Beall, M. Grace, W. J. Dewbett, and H. S. Bilofsky, J.Amer.Chem.Soc., 1971, 93, 2145.

5. H. Beall and C. H. Bushweller, Chem.Rev., 1973, 73, 465.

6. C. A. Buehler and D. E. Pearsen, Survey of Organic Syntheses, Vol. 2, p. 499, John Wiley & Son, New York etc., 1977; I. T. Harrison and S. Harrison, Compendium of Organic Synthetic Methods, Vol. 1, p. 132, 1971; Vol. 2, p. 53, 1974.

7. D. G. Smith and D. J. H. Smith, J.Chem.Soc. Chem.Commun., 1975, 459.

8. H. C. Brown and B. C. Subba Rao, J.Amer.Chem.Soc., 1958, 80, 5377.

9. J. E. Siggins, A. A. Larsen, J. H. Ackerman, and C. D. Carabateas, Org.Syn., 1973, 53, 52.

10. T. E. Cole and R. Pettit, Tetrahedron Lett., 1977, 781.

11. Y. Watanabe, T. Mitsudo, M. Tanaka, K. Yamamoto, T. Okajima, and Y. Takegami, Bull.Chem.Soc. Japan, 1971, 44, 2569.

12. Triphenylphosphine may be removed from a mixture of triphenylphosphine and organic compounds by stirring a chloroform solution over cuprous chloride; the reaction mixture is filtered, the chloroform removed and the organic compounds dissolved in ether or methanol. A 1:1 triphenylphosphine-copper chloride complex, Ph_3PCuCl, is formed which is soluble in chloroform but insoluble in ether or methanol.

13. A. I. Vogel, A Textbook of Practical Organic Chemistry Including Qualitative Organic Analysis, p. 688, Longmans, Green and Co., London, etc., 1954.