Reactions of Elemental Phosphorus and Phosphines with Electrophiles in Superbasic Systems: XII.¹ Synthesis of Unsymmetrical Tertiary Phosphine Oxides from Red Phosphorus and Organyl Halides

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Received April 12, 2000

Abstract—Alkyldibenzyl- and benzyldialkylphosphine oxides were prepared in one stage by direct phosphorylation of a mixture of alkyl bromides and benzyl chloride with red phosphorus under the conditions of phase-transfer catalysis (concentrated aqueous KOH solution–dioxane–benzyltriethylammonium chloride).

Red phosphorus reacts with benzyl chloride in superbasic systems such as alkali metal hydroxide– polar hydroxyl-free solvent (DMSO, hexamethylphosphoramide) to form tribenzylphosphine oxide as the main product (yield up to 65%), and also small amounts of tribenzylphosphine and tetrabenzylphosphonium chloride [2, 3]. Phosphorylation of benzyl chloride or alkyl bromides with the system red phosphorus–KOH under the conditions of phase-transfer catalysis allows preparation of the corresponding tertiary phosphine oxides in a 50-65% yield [3, 5]. Reactions with alkyl bromides also yield small amounts of dialkylphosphine oxides and alkyl dialkylphosphinates [2, 4].

In this work we studied simultaneous phosphorylation of alkyl bromides and benzyl chloride with red phosphorus with the aim of one-stage synthesis of difficultly accessible unsymmetrical tertiary phosphine oxides. Previously known methods are multistage and involve the use of aggressive phosphorus chlorides [6-8].

We have found that red phosphorus reacts with a mixture of ethyl or propyl bromide **Ia**, **Ib** with benzyl chloride **II** at 65–70°C in a system including concentrated KOH solution, dioxane, and phasetransfer catalyst (benzyltriethylammonium chloride) to form a mixture of symmetrical and mixed tertiary phosphine oxides: trialkyl-, benzyldialkyl-, alkyldibenzyl-, and tribenzylphosphine oxides **III–VI**. Their total yield is up to 40% (see table, run nos. 1–4).

P + RBr +	PhCH ₂ Cl	KOH-H ₂ O	• R ₃ P=O +	\mathbb{R}_2 PCH ₂ Ph				
Ia, Ib	П		IIIa, IIIb	IVa, IVb				
		Q						
+ $(PhCH_2)_2 \overset{\parallel}{P}R$ + $(PhCH_2)_3 P=O$								
	Va,	Vb	VI					
	R =	Et (a), <i>i</i>	<i>i</i> -Pr (b).					

Due to the large difference in boiling points and solubility, individual phosphine oxides IVa, IVb and

Phosphorylation of alkyl bromides (RBr) and benzyl chloride with red phosphorus under the conditons of phase-transfer catalysis^a

Run no.	R	Molar ratio RBr : PhCH ₂ Cl	Conversion of PhCH ₂ Cl, ^b %	Yield, ^c %			
				ш	IV	V	VI
1	Et	2:1	72	4	10	13	5
2	Et	3:1	86	5	15	17	2
3	Et	4:1	100	6	14	16	3
4	<i>n</i> -Pr	3:1	84	3	12	16	5
5	<i>n</i> -Pr	1:1	60	_d	2	14	16

^a 0.13 mol of red phosphorus and 0.05 mol of benzyl chloride. The reaction was carried out at 65–75% °C in the system KOH–H₂O–dioxane–phase-transfer catalyst (benzyltriethylammonium bromide). ^b In run no. 2 the conversion of EtBr was 97%; in run no. 4 the conversion of *n*-PrBr was 52%; in the other experiments the conversion of RBr was not determined. ^c Yields of phosphine oxides **IV–VI** are based on the consumed benzyl chloride. Yield of trialkylphosphine oxides **III** is based on the amount of alkyl bromide taken. ^d Product is not formed.

¹ For communication XI, see [1].

Va, Vb can be readily isolated pure. Their yield depends primarily on the ratio of the starting organyl halides. For example, the main products of phosphorylation of equimolar amounts of propyl bromide and benzyl chloride are tribenzyl- and dibenzylpropylphosphine oxides. Their yields are 16 and 14%, respectively, while dipropylbenzylphosphine oxide is formed in a 2% yield, and no tripropylphosphine oxide was found under these conditions (see table, run no. 5). This fact shows that the rate of the reaction of red phospohorus with benzyl chloride is higher than with alkyl bromides. With a 2–3-fold molar excess of alkyl bromide Ia, Ib relative to benzyl chloride (see table, run nos. 1, 2, 4) the yield and relative content of unsymmetrical phosphine oxides IVa, IVb and Va, Vb in the reaction mixture are increased. These compounds were isolated pure in a 15-17% yield. The yield of symmetrical phosphine oxides is low (2-6%), and the conversion of organyl halides Ia (or **Ib**) and **II** is 52–97% and 72–86%, respectively. Further increase in the molar ratio EtBr : PhCH₂Cl to 4:1 is not appropriate, because it practically does not affect the yield and ratio of phosphine oxides III-VI (see table, run no. 3).

Note that under the examined conditions the conversion of alkyl bromides I is higher than the yield of the final products III–V. This means that alkyl bromides are evidently involved not only in phosphorylation but also in some other transformations, e.g., in base-catalyzed dehydrobromination or hydrolysis. Indeed, in run no. 2 (see table) formation of ethanol was observed. Furthermore, in the case of phosphorylation of butyl bromide with red phosphorus under the conditions of phase-transfer catalysis [2] we have previously observed the formation of 1-butene (identified by gas chromatography and mass spectrometry) along with tributylphosphine oxide.

In the ¹H NMR spectra of alkyldibenzylphosphine oxides the signal of methylene protons in the PhCH₂P=O fragment is a multiplet consisting of 6 lines. This is due to the fact that the protons in each CH₂ group are diastereotopic and give an *AB* quartet: J_{AB} 14.9 (**Va**), 14.7 Hz (**Vb**). Each component of this system is also split owing to the coupling with phosphorus in a doublet with the close values of the coupling constant: J_{HP} 14.9 (**Va**), 14.7 Hz (**Vb**). The protons in two CH₂ groups are mutually equivalent. In the ³¹P-decoupled ¹H NMR spectra of these phosphine oxides, the multiplet of the CH₂ group transforms into an *AB* quartet.

EXPERIMENTAL

The IR spectra were registered on a Specord IR-75 spectrometer in KBr pellets or in thin layer. The ¹H

NMR spectra were recorded on a Bruker DPX-400 spectrometer, and the ³¹P NMR spectra, on a Jeol FX-90Q spectrometer. The NMR spectra were obtained in $CDCl_3$ against internal HMDS and external 85% phosphoric acid. The GLC analysis was carried out on a Chrom-4 chromatograph (2400 × 3-mm column, 1% polyethylene glycol 20 000 on NaCl, thermal conductivity detector, helium carrier gas). Symmetrical phosphine oxides **IIIa**, **IIIb**, and **VI** were identified spectroscopically using the authentic samples [2].

Benzyldiethylphosphine oxide IVa and dibenzylethylphosphine oxide Va (see table, run no. 2). A solution of 40.0 g of KOH in 27 ml of water was added dropwise with stirring to a mixture of 4.0 g of red phosphorus, 16.4 g of ethyl bromide, 6.3 g of benzyl chloride, and 0.1 g of benzyltriethylammonium chloride in 40 ml of dioxane. The reaction mixture was heated at 65-75°C for 4 h and cooled to room temperature; the organic layer was separated, dried over potassium carbonate, and fractionated. A fraction with bp 50-100°C was isolated at atmospheric pressure (8.4 g). According to GLC data, it contained 0.4 g of ethyl bromide (conversion 97%), 1.4 g of ethanol (20% yield), and 6.6 g of dioxane. The second fraction with bp 105-115°C consisted of dioxane. The residue containing phosphine oxides IIIa-Va and **VI** in a 20:49:26:5 molar ratio (³¹P NMR data) was fractionated in a vacuum. Benzyl chloride, 0.87 g (conversion 86%), triethylphosphine oxide, 0.35 g (5%), and 1.3 g (15%) of phosphine oxide **IVa** were isolated. Data for IVa: bp 166–170°C/1 mm Hg; published data [6]: 148-149°C/0.5 mm Hg. IR spectrum: v(P=O) 1160 cm⁻¹. ¹H NMR spectrum, δ , ppm: 1.15 d.t (6H, CH₃, ³J_{HP} 16.4 Hz), 1.65 d.q (4H, CH₂, ² J_{PH} 11.3 Hz), 3.06 d (2H, CH₂, ² J_{PH} 14.3 Hz), 7.24 m (5H, C₆H₅). ³¹P NMR spectrum: $\delta_{\rm p}$ 48.3 ppm. Found, %: C 67.37; H 8.74; P 15.60. C₁₁H₁₇OP. Calculated, %: C 67.33; H 8.73; P 15.78.

The bottom residue was dissolved in 15 ml of ether and filtered to remove the crystalline residue A; the ether was removed, and the residue was washed with hexane. Phosphine oxide **Va**, 0.96 g (17%), was obtained, mp 64–66°C. IR spectrum: v(P=O) 1180 cm⁻¹. ¹H NMR spectrum, δ , ppm: 1.06 d.t (3H, CH₃, ³J_{PH} 16.7 Hz), 1.56 d.q (2H, CH₂, ²J_{PH} 11.6 Hz), 3.07 m (4H, CH₂, ²J_{PH} = J_{AB} = 14.9 Hz), 7.24 m (10H, C₆H₅). ³¹P NMR spectrum: δ_P 44.3 ppm. Found, %: C 73.92; H 7.54; P 10.54. C₁₆H₁₉OP. Calculated, %: C 74.42; H 7.36; P 12.02. The crystalline residue A was washed with ether and dried in a vacuum to give 0.1 g (2%) of tribenzylphosphine oxide.

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Benzyldipropylphosphine oxide IVb and dibenzylpropylphosphine oxide Vb (see table, run no. 4). A solution of 40.0 g of KOH in 27 ml of water was added dropwise with stirring to a mixture of 4.0 g of red phosphorus, 18.45 g of propyl bromide, 6.3 g of benzyl chloride, and 0.1 g of benzyltriethylammonium chloride. The reaction mixture was kept for 5 h at $70-75^{\circ}$ C, cooled to room temperature, and the organic layer was separated. Propyl bromide (8.8 g, 52% conversion) and dioxane were distilled off, and the residue containing phosphine oxides IIIb-Vb and VI in a ratio of 20:48:30:2, respectively (³¹P NMR data), was fractionated in a vacuum. Benzyl chloride. 1.0 g (84% conversion), tripropylphosphine oxide, 0.3 g (3%), and phosphine oxide IVb, 1.1 g (12%, bp 167-171°C/1.5 mm Hg) were obtained. IR spectrum of **IVb**: v(P=O) 1170 cm⁻¹. ¹H NMR spectrum, δ, ppm: 0.98 m (6H, CH₃), 1.58 m (8H, CH₂), 3.08 d $(2H, CH_2, {}^2J_{PH} 14.4 Hz), 7.24 m (5H, C_6H_5).$ ³¹P NMR spectrum: $\delta_{\rm P}$ 45.2 ppm. Found, %: C 69.63; H 9.27; P 12.73. C₁₃H₂₁OP. Calculated, %: C 69.64; H 9.37; P 13.84.

The bottom residue was dissolved in 15 ml of ether and filtered to remove the crystalline precipitate B; the ether was removed, and the residue was washed with hexane. Phosphine oxide **Vb**, 0.9 g (16%), was obtained, mp 92–94°C (94–96°C [7]). IR spectrum: v(P=O) 1180 cm⁻¹. ¹H NMR spectrum, δ , ppm: 0.93 m (3H, CH₃), 1.54 m (4H, CH₂), 3.07 m (4H, CH₂, ²J_{PH} = J_{AB} = 14.7 Hz), 7.24 (10H, C₆H₅). ³¹P NMR spectrum: $\delta_{\rm P}$ 42.8 ppm. Found, %: C 75.97; H 7.98; P 11.02. C₁₇H₂₁OP. Calculated, %: C 75.00; H 7.72; P 11.40. The crystalline precipitate B was washed with ether and dried in a vacuum to give 0.2 g (4%) of tribenzylphosphine oxide.

REFERENCES

- Shaikhudinova, S.I., Kazantseva, T.I., Gusarova, N.K., Dmitriev, V.V., and Trofimov, B.A., *Zh. Obshch. Khim.*, 2001, vol. 71, no. 1, pp. 64–67.
- Gusarova, N.K., Malysheva, S.F., Rakhmatulina, T.N., Dmitriev, V.I., Shaikhudinova, S.I., Sinegovskaya, L.M., and Trofimov, B.A., *Zh. Obshch. Khim.*, 1990, vol. 60, no. 4, pp. 828–832.
- Trofimov, B.A., Rakhmatulina, T.N., Gusarova, N.K., and Malysheva, S.F., *Usp. Khim.*, 1991, vol. 60, no. 12, pp. 2619–2632.
- Trofimov, B.A., Gusarova, N.K., and Brandsma, L., Main Group Chem. News, 1996, vol. 4, no. 1, pp. 18–24.
- Gusarova, N.K., Malysheva, S.F., Arbuzova, S.N., and Trofimov, B.A., *Izv. Ross. Akad. Nauk, Ser. Khim.*, 1998, no. 9, pp. 1695–1702.
- Tsivunin, V.S., Kamai, G.S., and Kormachev, V.V., *Zh. Obshch. Khim.*, 1965, vol. 35, no. 10, pp. 1819–1821.
- Z'ola, M.I., Zhuravleva, L.P., and Kirsanov, A.V., Zh. Obshch. Khim., 1970, vol. 40, no. 9, pp. 1937–1942.
- Zhuravleva, L.P., Suleimanova, M.G., Kovalyukh, N.N., and Kirsanov, A.V., *Zh. Obshch. Khim.*, 1971, vol. 41, no. 9, pp. 1950–1953.