THE REACTION OF TRIPHENYLPHOSPHINE SULFIDE WITH ALKYLLITHIUM REAGENTS*

DIETMAR SEYFERTH** AND DEAN E. WELCH***

Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Mass. (U.S.A.)

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We have shown[1,2] that triphenylphosphine oxide reacts with alkyllithium reagents as shown below.

$$(C_6H_5)_3PO + RCH_2Li \rightarrow (C_6H_5)_2P(O)CH_2Li + C_6H_6$$

The mechanism of this reaction was demonstrated to involve a very rapid exchange step followed by a slower, but still rapid, metalation reaction:

$$(C_6H_5)_3PO + RCH_2Li \rightarrow (C_6H_5)_2P(O)CH_2R + C_6H_5Li$$

$$(C_6H_5)_2P(O)CH_2R + C_6H_5Li \rightarrow (C_6H_5)_2P(O)CH(R)Li + C_6H_6$$

An investigation of the action of alkyllithium reagents on triphenylphosphine sulfide (TPPS) has revealed that under proper conditions a similar sequence of exchange followed by metalation leads to (α-lithioalkyl)diphenylphosphine sulfides.

$$(C_6H_5)_3PS + RCH_2Li \rightarrow (C_6H_5)_2P(S)CH_2R + C_6H_5Li$$

$$(C_6H_5)_2P(S)CH_2R + C_6H_5Li \rightarrow (C_6H_5)_2P(S)CH(R)Li + C_6H_6$$

When a slurry of TPPS in ether was treated with ethereal methyllithium, no visible reaction occurred. Analysis of a hydrolyzed aliquot of this reaction mixture showed that it contained no benzene. However, addition of tetrahydrofuran (THF) to such an ethereal reaction mixture immediately produced a deep red, homogeneous solution which gave a positive Gilman Color Test I[3]. In subsequent preparative reactions an ether–THF reaction medium was used. Treatment of such $(C_6H_5)_2P(S)CH_2Li$-containing solutions with hydrobromic acid, solid Dry Ice and triphenyltin chloride gave $(C_6H_5)_2P(S)CH_3$ (74%), $(C_6H_5)_2P(S)CH_2COOH$ (39%) and $(C_6H_5)_2P(S)CH_2Sn(C_6H_5)_3$ (74%) respectively. In all cases the benzene yield was nearly quantita-

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tive. A similar reaction occurred between ethyllithium and TPPS. In diethyl ether a reddish-brown solution containing suspended solid was formed, but after 3 h the benzene yield was only 12%. Addition of THF immediately gave a deep red, homogeneous solution, which after 10 min contained benzene (84%) and gave a positive Gilman Color Test I. Using an ether–THF reaction medium, the $(C_6H_5)_2P(S)CH(CH_3)Li$ formed was converted to $(C_6H_5)_2P(S)C_2H_5$ (78%) and $(C_6H_5)_2P(S)CH(CH_3)Sn(C_6H_5)_3$ (60%). Benzene yields were 80–90%.

If these TPPS reactions proceeded by the exchange-metalation mechanism found for the analogous triphenylphosphine oxide reactions, then the intermediacy of phenyllithium, formed in the exchange step, should be demonstrable experimentally. This was indeed the case. Thus addition of one molar equivalent of ethyllithium to one molar equivalent of TPPS was followed by quenching with D_2O after 5 min. Mass spectrographic analysis of the benzene produced in 87% yield showed that the benzene contained 43% monodeuteriobenzene. A parallel experiment carried out to determine the extent of conversion by quenching with triphenyltin chloride gave benzene (48%), tetraphenyltin (39%), ethyldiphenylphosphine sulfide (44%) and $(C_6H_5)_2P(S)CH(CH_3)$-$Sn(C_6H_5)_3$ (32%). A similar experiment with the molar ratio $C_2H_5Li/TPPS = 3$, again quenching with D_2O after 5 min, gave benzene in 88% yield containing 82% monodeuteriobenzene. Quenching such a reaction mixture, after the same elapsed time, with triphenyltin chloride, resulted in benzene (8%), tetraphenyltin (77%), ethyltriphenyltin (20%) and $(C_6H_5)_2P(S)CH(CH_3)Sn(C_6H_5)_3$ (77%). The yield of phenyllithium present after 5 min in the 3 C_2H_5Li + 1 TPPS reaction was checked independently by quenching the reaction mixture with trimethylchlorosilane. Benzene was formed in 12% yield and trimethylphenylsilane in 83% yield.

As in the case of the triphenylphosphine oxide experiments[2] the similarity of the reactions

$$(C_6H_5)_3PS + 3\,C_2H_5Li \rightarrow \xrightarrow{D_2O}$$

and

$$(C_6H_5)_2P(S)C_2H_5 + 2\,C_2H_5Li + C_6H_5Li \rightarrow \xrightarrow{D_2O}$$

was demonstrated. In both reactions the benzene isolated after the mixture had been quenched with D_2O following a reaction time of 5 min contained a high content of deuteriobenzene (82% in the first reaction, 86% in the second). These results and the high yield of benzene in the 1:1 experiment suggest that here also the initial exchange reaction is rapid and the metalation reaction is the slow step.

The deuteriobenzene and tetraphenyltin yields cited above are considerably higher than the yields of these products obtained in similar reactions with triphenylphosphine oxide. Thus it appears that the metalation of an alkyldiphenylphosphine sulfide is considerably slower than that of an alkyldiphenylphosphine oxide. This was confirmed in the case of $(C_6H_5)_2P(S)CH_3$ *vs.* $(C_6H_5)_2P(O)CH_3$. Ethereal solutions of methyldiphenylphosphine sulfide were treated rapidly with one molar equivalent of phenyllithium, and the reaction mixtures were quenched in D_2O. Quenching after 2 min gave benzene which contained 73% C_6H_5D (*i.e.*, only 27% metalation had occurred). Quenching another such mixture after 5 min gave benzene containing 48% C_6H_5D, and still another treated with D_2O after 8 min gave benzene containing 14% C_6H_5D. In a control experiment methyldiphenylphosphine oxide was completely metalated after 2 min, *i.e.*, the benzene collected was 100% C_6H_6. Since the metalation of methyldiphenylphosphine sulfide proceeded readily in ether, the THF required in the RCH_2Li–TPPS reaction apparently is necessary only for completion of the exchange reaction; it may be that there is a solubility factor involved. The lower reactivity of an alkylphosphine sulfide toward organolithium reagents is not surprising if one considers the lower polarity of the P–S bond and thus the lower reactivity (*i.e.*, acidity) of an α-hydrogen atom in an alkylphosphine sulfide as compared to an alkylphosphine oxide.

As in the case of the RCH_2Li–$(C_6H_5)_3PO$ reaction, there is no evidence which allows one to say whether the RCH_2Li–TPPS exchange step proceeds via a *P(V)* intermediate or via an S_N2 displacement at phosphorus.

The reactions described above constitute a convenient synthesis of organofunctional phosphine sulfides based on triphenylphosphine sulfide, which is easily prepared from commercially available triphenylphosphine.

EXPERIMENTAL

General comments

All experiments involving organolithium reagents were carried out in an atmosphere of prepurified nitrogen. Melting points are uncorrected. All benzene yields were calculated using quantitative gas chromatography with toluene as an internal standard. The columns used were Dow Corning 710 Silicone Fluid or General Electric SE-30 Grease on Chromosorb W, with helium as carrier gas. Normal operating conditions were: 80–100° jacket temperature, 10 p.s.i. helium, and 70° preheater temperature. The benzene was collected by preparative scale gas chromatography and analyzed for C_6H_5D content by mass spectrometry using a CEC, Model 21-130, mass spectrometer. Typical operating conditions were 20μ and voltage setting = 250. Microanalyses were performed by Dr. S. M. NAGY (M.I.T.) and by the Schwarzkopf Microanalytical Laboratory, Woodside, N.Y.

Preparation of alkyllithium reagents

Methyl- and ethyllithium were prepared from the corresponding bromide and lithium wire in ether; the latter, prepared at 0°, was used within 3 h after its preparation. All solutions were standardized by the double titration method of Gilman[4] using 1,2-dibromoethane in place of benzyl chloride.

Preparation of phosphine sulfides

Triphenyl-, ethyldiphenyl-, and methyldiphenylphosphine sulfides were prepared by adding a slight excess of sublimed sulfur to a solution of the respective phosphine in benzene. $(C_6H_5)_3PS$: m.p. 161–162° (lit.[5] m.p. 161°). $(C_6H_5)_2(C_2H_5)PS$: m.p. 65–66° (lit.[6] m.p. 65–66°). $(C_6H_5)_2(CH_3)PS$: b.p. 162–163°/0.4 mm, n_D^{25} 1.6503 (lit.[7] b.p. 181°/1.5 mm, n_D^{25} 1.6515); infrared spectrum, $CHCl_3$ solution, principal bands: 3020, 2950, 1480, 1430, 1400, 1305, 1285, 1105, 885, 680 cm^{-1}. (Found: C, 67.30; H, 5.73; S, 13.94. $C_{13}H_{13}PS$ calcd.: C, 67.22; H, 5.64; S, 13.80%.)

Ethyldiphenylphosphine was prepared as follows: A solution of 88 g (0.40 mole) of diphenylchlorophosphine in 400 ml of ether was treated with 360 ml of 1.11 *N* (0.40 mole) ethyllithium in ether. The addition was dropwise at such a rate so as to maintain reflux. A white solid precipitated almost immediately. After the addition, stirring was continued for 2 h and the mixture was left to stand overnight. The resulting brown ether layer was carefully decanted under nitrogen to a separate flask and distilled. It gave 78 g of pale yellow distillate, b.p. 110–121°/0.45 mm. A second distillation gave a colorless distillate, 73 g (85%), b.p. 104°/0.45 mm, which was stored under nitrogen. The reported[8] b.p. for ethyldiphenylphosphine is 184° at 22 mm.

Methyldiphenylphosphine was prepared using the same procedure as in the preparation of ethyldiphenylphosphine. The yield was 76%, b.p. 108–110°/0.15 mm. The reported[9] b.p. for methyldiphenylphosphine is 120–122°/0.15 mm.

Reactions of TPPS with methyllithium

(1) *Preparation of* $(C_6H_5)_2P(S)CH_2Sn(C_6H_5)_3$. TPPS (7.9 g; 26.8 mmoles) in 50 ml of diethyl ether and 25 ml of THF was treated with 26.8 mmoles of 1.58 *N* methyllithium in ether. The mixture was stirred for 1 h and the resulting amber solution was treated with 9.6 g (25 mmoles) of triphenyltin chloride in 40 ml of THF. Stirring was continued for 3 h. The mixture was filtered and the filtrate concentrated under vacuum to a yellow oil. The oil was dissolved in benzene, and ammonia was passed through the solution for 2 h. Filtration, concentration of the filtrate under vacuum, and addition of heptane precipitated 10.8 g (74%) of white crystals, m.p. 170–173°. Recrystallization from benzene–heptane gave 7.3 g (50%) of white crystals, m.p. 174–176°, whose infrared spectrum (KBr pellet) showed principal absorption bands at 3050, 1485, 1435, 1425, 1100, 1075, 1045, 1000, 775, 730 and 725 cm^{-1}. (Found: C, 63.84; H, 4.79; P, 5.33. $C_{31}H_{27}PSSn$ calcd.: C, 64.05; H, 4.68; P, 5.33%.)

(2) *Preparation of* $(C_6H_5)_2P(S)CH_2COOH$. TPPS (14.7 g; 50 mmoles) in 75 ml of diethyl ether and 25 ml of THF was treated with 50 mmoles of methyllithium in ether and stirred for 2 h. The resulting red solution was quickly poured onto excess Dry Ice. After the suspension had warmed to room temperature, 100 ml of water was added and the aqueous layer was made acidic with conc. HCl. The entire reaction mixture was concentrated under vacuum and the residue was extracted with warm benzene. The benzene extracts were dried over anhydrous magnesium sulfate. Addition of cyclohexane precipitated a white solid; m.p. 186–189°, 6.6 g (48%). Two recrystallizations from benzene gave 5.3 g (38.5%); m.p. 193–195°. Reported[10] m.p. 189–190° for (carboxymethyl)diphenylphosphine sulfide. Its infrared spectrum (KBr pellet) showed principal absorption at 1700, 1480, 1430, 1300, 1130, 1100, 860, 805, 745 and 677 cm^{-1}. (Found: C, 60.58; H, 4.71; S, 11.46; neutral equiv., 276.3. $C_{14}H_{13}O_2PS$ calcd.: C, 60.86; H, 4.74; S, 11.63%; neutral equiv., 276.32.)

(3) *Preparation of* $(C_6H_5)_2P(S)CH_3$. A suspension of 7.35 g (25 mmoles) of TPPS in 35 ml of ether and 15 ml of THF was treated dropwise with 16.32 ml of 1.53 *N* (25 mmoles) methyllithium in ether. The resulting deep red, homogeneous solution was stirred for 6 h at room temperature and quenched with 25 ml of water. The organic phase was found to contain 22.7 mmoles (91%) of benzene. The entire mixture then was concentrated under vacuum to an aqueous slurry. The residue was extracted twice with 30 ml of ether. The ether extracts were dried over magnesium sulfate. Filtration and removal of the ether under vacuum gave an opaque, oily residue. Distillation gave 4.3 g (74%) of colorless, viscous distillate; b.p. 155–157°/0.2 mm, n_D^{25} 1.6499. Its infrared spectrum was identical to that of authentic $(C_6H_5)_2P(S)CH_3$.

Reactions of TPPS with ethyllithium

(1) *Preparation of* $(C_6H_5)_2P(S)CH(CH_3)Sn(C_6H_5)_3$. A suspension of 14.7 g (50 mmoles) of TPPS in 25 ml of THF and 50 ml of ether was treated dropwise over $^1/_2$ h with 34.5 ml of 1.45 *N* ethyllithium in ether. The resulting deep red, homogeneous solution was stirred for 1 h and then quenched with 19.3 g (50 mmoles) of triphenyltin chloride in 30 ml of THF. The color of the reaction mixture faded slightly and a white solid precipitated. The resulting mixture was stirred for 6 h at room temperature and then heated at reflux for 7 h. The mixture was found to contain 77% of the theoretical yield of benzene. Then 25 ml of KF solution was added and the mixture was stirred for 30 min and then filtered. The filtrate was dried over magnesium sulfate and filtered. Removal of the solvent on a rotary evaporator gave a dark brown, viscous residue. Attempts to crystallize from CH_3OH–EtOAc or $CHCl_3$–heptane were not successful. Addition of benzene to the brown oil and standing, gave brown crystals which were removed by filtration. Concentration of the filtrate and addition of more benzene gave more crystals. The total yield of light yellow solid was 21 g, m.p. 218–225°. Two recrystallizations from chloroform gave 18 g (60%) of white, crystalline solid, m.p. 229–230°, whose infrared spectrum (chloroform solution) showed major absorption at 3020, 1485, 1438, 1428, 1100, 1075, 1020, 1000 and 690 cm^{-1}. (Found: C, 64.47; H, 4.90; S, 5.14. $C_{32}H_{29}PSSn$ calcd.: C, 64.56; H, 4.91; S, 5.39%.)

(2) *Preparation of* $(C_6H_5)_2P(S)C_2H_5$. A suspension of 7.35 g (25 mmoles) of TPPS in 35 ml of ether and 15 ml of THF was treated dropwise over *ca.* 20 min with 17.75 ml of 1.41 *N* (25 mmoles) ethyllithium in ether. The resulting deep red, homogeneous mixture was stirred for 5 h, cooled, and quenched with 20 ml of water. The organic phase contained 22.2 mmole (89%) of benzene. The organic phase was decanted and the residue was extracted with ether. The organic layers were combined and dried over anhydrous magnesium sulfate. Filtration and removal of solvent under vacuum gave a brown, oily residue. Extraction with ether and chilling the extracts gave white crystals, m.p. 64–66°. Additional crystals were recovered from the filtrate by concentrating and cooling. The total yield was 4.8 g (78%) of white crystals, m.p. 64–66°. A mixed melting point with authentic $(C_6H_5)_2P(S)C_2H_5$ was not depressed.

D_2O quenching experiments

(1) $C_2H_5Li/TPPS = 1$. A slurry of 7.4 g (25 mmoles) TPPS in 20 ml ether and 10 ml THF was treated rapidly with 25 mmoles of ethyllithium in ether. The resulting reddish-brown homogeneous solution was stirred for 5 min, cooled and quenched with 10 ml of D_2O. Analysis of the organic phase showed that it contained 87% of the theoretical yield of benzene. The benzene contained 43% monodeuteriobenzene.

Repeating the reaction and quenching with triphenyltin chloride gave a pale yellow solution and a white precipitate. The solution contained 11.9 mmoles (48%) of benzene. The mixture was treated with 10 ml of KF solution, filtered and the residue extracted with hot benzene. Cooling the benzene extracts precipitated 4.2 g (9.8 mmoles; 39%) of tetraphenyltin, m.p. 223–226°. A mixed melting point with authentic tetraphenyltin was not depressed. The filtrate from the first filtration was dried over magnesium sulfate and concentrated under vacuum to a yellow, oily residue. Extraction with ether and cooling the extracts gave 2.71 g (11 mmoles; 44%) of ethyldiphenylphosphine sulfide as white crystals, m.p. 63–66°. A mixed melting point with authentic ethyldiphenylphosphine sulfide was not depressed. The etherinsoluble oil was crystallized from benzene to give 4.8 g (32%) of $(C_6H_5)_2P(S)CH(CH_3)Sn(C_6H_5)_3$, m.p. 224–227°. A mixed melting point with authentic material was not depressed.

(2) *$C_2H_5Li/TPPS$ = 3.* The previous experiments were repeated using 25 mmoles of TPPS and 75 mmoles of ethyllithium. Quenching with D_2O after 5 min gave benzene in 88% yield which contained 82% C_6H_5D. Quenching with triphenyltin chloride (75 mmoles) gave: benzene (8%), tetraphenyltin (77%); ethyltriphenyltin (20%); and $(C_6H_5)_2P(S)CH(CH_3)Sn(C_6H_5)_3$ (77%).

(3) *Competitive metalation of ethyldiphenylphosphine sulfide.* A solution of ethyldiphenylphosphine sulfide (2.46 g; 10 mmoles) in 25 ml of ether and 5 ml of THF was treated very rapidly with a mixture of 9 ml of 1.11 *N* (10 mmoles) phenyllithium and 13.5 ml of 1.52 *N* (20 mmoles) ethyllithium in ether. The resulting amber solution was stirred for 5 min and quenched with D_2O. Analysis of the benzene formed (90%) showed that it contained 86% monodeuteriobenzene.

(4) *Metalation rates: $(C_6H_5)_2P(S)CH_3$ vs. $(C_6H_5)_2P(O)CH_3$.* Four separate experiments were run using 10 mmoles of phosphine oxide or sulfide in 25 ml of ether and 10 mmoles of phenyllithium in ether (added rapidly over *ca.* 10 sec). Three reactions were carried out with the sulfide and one with the oxide. The sulfide reaction mixtures were quenched independently with D_2O after 2 min, 5 min and 8 min and the oxide reaction mixture was quenched after 2 min. The results are shown below.

	Time before quench	*% C_6H_5D in benzene*
$(C_6H_5)_2P(S)CH_3$	2 min	73
	5 min	48
	8 min	14
$(C_6H_5)_2P(O)CH_3$	2 min	0

Trimethylchlorosilane quenching experiment

A suspension of 7.35 g (25 mmoles) of TPPS in 40 ml of ether and 10 ml of THF was treated as rapidly as possible with 51 ml of 1.47 *N* (75 mmoles) ethyllithium in ether. The resulting reddish-brown, homogeneous solution was stirred for 5 min and quenched with 8.50 g (79 mmoles) of trimethylchlorosilane in 25 ml of ether. The color of the reaction mixture faded rapidly and a white solid precipitated. The solution was analyzed by gas chromatography using Dow Corning 710 Silicone Fluid on firebrick at 200°, and found to contain 2.98 mmoles (12%) of benzene and 20.7 mmoles (83%) of trimethylphenylsilane. Collection of a sample of the trimethylphenylsilane by preparative scale gas chromatography gave a colorless liquid, n_D^{25} 1.4887. Reported[11] n_D^{25} 1.4883. Its infrared spectrum was identical to that of authentic trimethylphenylsilane.

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SUMMARY

The reaction of triphenylphosphine sulfide with methyl- and ethyllithium in ether–THF mixtures resulted in $(C_6H_5)_2P(S)CH_2Li$ and $(C_6H_5)_2P(S)CH(CH_3)Li$ respectively, which were characterized by hydrolysis, carbonation and reaction with triphenyltin chloride. Evidence is presented to show that the mechanism of formation of (α-lithioalkyl)diphenylphosphine sulfides by this route proceeds by an initial, very rapid exchange reaction which gives an alkyldiphenylphosphine sulfide and phenyllithium. The latter then metalates the alkyldiphenylphosphine sulfide to give the observed reagents in a subsequent slower step.

REFERENCES

1 D. Seyferth, D. E. Welch and J. K. Heeren, *J. Am. Chem. Soc.*, 85 (1963) 642.
2 D. Seyferth, D. E. Welch and J. K. Heeren, *J. Am. Chem. Soc.*, 86 (1964) 1100.
3 H. Gilman and F. Schulze, *J. Am. Chem. Soc.*, 47 (1925) 2002.
4 R. G. Jones and H. Gilman, *Organic Reactions*, Vol. VI, Wiley, New York, N.Y., 1951, pp. 339–366.
5 W. Strecker and C. Grossman, *Ber.*, 49 (1916) 63.
6 A. E. Arbuzov, *J. Russ. Phys. Chem. Soc.*, 42 (1910) 395.
7 R. A. Zingaro and R. E. McGlothlin, *J. Chem. Eng. Data*, 8 (1963) 226.
8 J. Meisenheimer, J. Casper, M. Hörning, W. Lauter, L. Lichtenstadt and W. Samuel, *Ann. Chem.*, 449 (1906) 213.
9 S. T. D. Gough and S. Trippett, *J. Chem. Soc.*, (1961) 4263.
10 K. Issleib and G. Thomas, *Chem. Ber.*, 94 (1961) 2244.
11 A. Bygdén, *Z. Physik. Chem. (Leipzig)*, 90 (1915) 243.