Elimination Reactions of Halohydrin Derivatives with a Palladium(0) Complex

Toshio SUGITA,* Yoshimi SHIRAIWA, Masayuki HASEGAWA, and Katsuhiko ICHIKAWA

Department of Hydrocarbon Chemistry, Faculty of Engineering, Kyoto University, Sakyo-ku, Kyoto 606

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Stilbene bromohydrin derivatives (Ph–CHBr–CHY–Ph: Y=OAc, OSO_2CH_3, OCH_3, SCH_3) and stilbene dibromide underwent β-elimination reaction with tetrakis(triphenylphosphine)palladium(0) to give stilbene. The stereochemistry of eliminations is nonselective except in the case of dibromide, where *anti*-selectivity is observed. A coupling reaction occurred favorably in the case of Y=OCH_3.

Organometallic compounds substituted by oxygen groups at the β-position have well been known as oxymetallation adducts when the metals are heavy ones such as mercury and thallium, and it is clear that the acid-catalyzed deoxymercuration proceeds in *anti* fashion. In the case of palladium, oxypalladation adducts of olefins have been postulated as intermediates of the Wacker oxidation of ethylene to acetaldehyde and many other palladium(II)-catalyzed reactions of olefins. Although unusually stable alkoxypalladation adducts of ethylene have been isolated,[1] the oxypalladation adducts are usually not isolable except for some atypical examples, in which the complexes are stabilized by the chelation of intramolecular double bonds,[2] because of their propensity to undergo elimination.

Previously, we reported that *syn*-elimination was favored when bromohydrin derivatives were treated with butyllithium, and that, particularly, 1-bromo-2-methoxy-1,2-diphenylethane (**5**) gave a stereospecific *syn*-elimination product in nonpolar solvents. In this reaction, we postulated a β-methoxylithium compound as a transient intermediate.[3]

Phosphine complexes of palladium(0) undergo oxidative addition reaction with alkyl halides, making a carbon–palladium σ-bond. If bromohydrin derivatives undergo oxidative addition to palladium complexes, the oxypalladation compounds should be produced. In this paper, we wish to report the results of the reactions of stilbene bromohydrin derivatives and dibromide with a palladium(0) complex.

Results and Discussion

The reactions of stilbene dibromide (**2**) and bromohydrin derivatives, 1-bromo-2-acetoxy-1,2-diphenylethane (**3**), 1-bromo-2-methylsulfonyloxy-1,2-diphenylethane (**4**), 1-bromo-2-methoxy-1,2-diphenylethane (**5**), and 1-bromo-2-methylthio-1,2-diphenylethane (**6**), with tetrakis(triphenylphosphine)palladium(0) (**1**) in degassed benzene produced only stilbene (**7**) in good yields, except in the case of **5**. In the case of **5**, a coupling product, 1,4-dimethoxy-1,2,3,4-tetraphenylbutane (**8**), was the primary product, accompanied by a small amount of *trans*-**7**. The structure of **8** was identified by means of its analytical and spectral data. As the NMR spectrum is simple, the **8** obtained seems to be diastereomerically not so complex, but its stereochemical structure has not yet been confirmed.

Oxypalladation adducts of olefins almost without exception eliminate palladium, accompanied by β-hydrogen, to produce olefins on which the oxygen groups remain. Only one report on the deoxypalladation-type eliminations has, to our knowledge, been made by Heck.[4] In contrast with the usual behavior of oxypalladation adducts, stilbene was the only elimination product, and no vinyl ether, esters, or other products derived from them were detected in the present case. If the reactions occurred by a series of steps, the oxidative addition of substrates to the palladium(0) complex to produce β-oxypalladium intermediates and the subse-

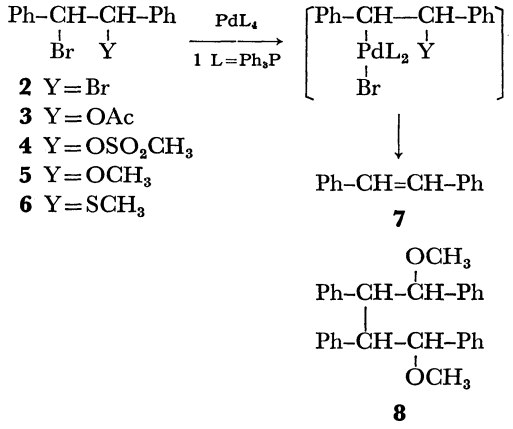

Table 1. Reaction of stilbene bromohydrin derivatives with palladium(0) complex[a]

Substrate (mmol)		$(Ph_3P)_4Pd$ (mmol)	Product yield (%)[b]	
			trans-**7**	Others
dl-**2**	(0.88)	0.89	60	*cis*-**7** 20
meso-**2**	(0.89)	0.87	94	
threo-**3**	(0.87)	0.87	45[c]	
erythro-**3**	(0.87)	0.90	48[c]	
threo-**4**	(0.87)	0.87	84	
erythro-**4**	(0.88)	0.87	70	
threo-**5**	(0.87)	0.87	(12)	**8** (60)
erythro-**5**	(0.75)	0.75	(11)	**8** (67)
erythro-**5**	(1.76)[d]	1.76	(trace)	**8** (20)
erythro-**6**	(0.88)	0.87	98	

a) Unless otherwise noted, in degassed benzene (100ml) at 80 °C under argon for 2 h. b) Isolated yields. The values in parentheses were determined by GLPC. c) The actual yields were higher than those indicated because incomplete chromatographic separations were achieved. d) In 100 ml of degassed benzene at room temperature for 30 h.

quent elimination of palladium from these intermediates, stilbene should be formed by the elimination of the palladium and the β-substituents.

Whether the present elimination proceeds *via* β-oxypalladium intermediates or by another mechanism, *e.g.*, the palladium-catalyzed synchronous elimination of the bromine and the heteroatom groups, is yet uncertain. When the leaving group is methoxyl, however, a coupling reaction takes place, together with elimination. Stille and Lau reported that the oxidative additions of 9-bromofluorene and α-bromophenylacetate to **1** gave, as the coupling products, 9,9'-bifluorenyl and ethyl 2,3-diphenylsuccinate respectively.[5] They concluded that these coupling products were attributable to the decomposition of transient alkylpalladium intermediates. An analogous reaction can be expected in the case of methoxy bromide (**5**), which undergoes oxidative addition to **1** to give the coupling product (**8**) and dibromobis(triphenylphosphine)palladium(II). Since methoxyl group is a poor leaving group, the coupling reaction is favored over the elimination. In the reactions of the other substrates, only the elimination reaction takes place, because the acetoxyl, methylsulfonyloxy, and methylthio groups as well as bromide are better leaving groups.

From these considerations, it is plausible to consider that the β-oxy- and β-thio-substituted bromides undergo oxidative addition to the palladium(0) complex to afford the β-oxy- and β-thiopalladium(II) complexes, which then eliminate the palladium accompanied by the β-substituents. As the palladium of the palladium-complex intermediates is coordinatively saturated by a strong phosphine ligand in the present case, it is considered to be difficult to abstract the β-hydrogen as a hydride, and so deoxypalladation-type elimination occurs.

Since both *erythro* and *threo* isomers of the bromohydrin derivatives gave only *trans*-**7**, the eliminations are considered to proceed nonstereoselectively. Stille and his co-workers reported that the oxidative addition of optically active phenethyl bromides to palladium(0) complexes proceeded with inversion of configuration at the carbon bearing bromine,[6] and that the decomposition of the oxidative addition products in the coupling reactions proceeded *via* a radical mechanism.[5] The loss of stereoselectivity in the elimination reactions of the bromohydrin derivatives with **1** can be consistently explained. The β-oxy- and β-thiopalladium complexes formed with inversion of configuration at the carbon bearing bromine eliminate the palladium *via* a radical mechanism, though no CIDNP could be observed, and the stereoselectivity is lost during the process of decomposition of the palladium complexes.

As contrasted with the other substrates, *dl*-**2** underwent a elimination reaction with **1** to give *cis*-**7** in a 20% yield. The fact that the thermodynamically very unstable *cis*-**7** was obtained from the *dl*-isomer as well as the fact that *meso*-**2** gave only *trans*-**7** indicates that the reaction proceeds with *anti* stereoselectivity. Since bromide is a better leaving group, the reaction seems to proceed more concertedly. An analogous result was obtained from the reaction of **2** with butyllithium.[3]

Experimental

The substrates were prepared as previously reported.[3] Tetrakis(triphenylphosphine)palladium(0) (**1**) was prepared by the reduction of dichlorobis(triphenylphosphine)palladium-(II) with hydrazine.[7]

General Procedure of the Elimination Reactions. A solution of 0.300 g (0.88 mmol) of *dl*-**2** and 1.032 g (0.89 mmol) of **1** in 100 ml of degassed anhydrous benzene was heated at 80 °C under argon for 2 h. The mixture was cooled and poured into water, and then extracted with ether. The ether extract was dried over magnesium sulfate, and a yellow complex precipitated was removed by filtration. GLPC analysis (150 °C, 5% Silicone SE-30 on Chromosorb W, 1 m) of the concentrated filtrate showed the presence of *cis*- and *trans*-**7**. The concentrated filtrate was dissolved in warm hexane, the undissolved crystal was filtered off, from which 33 mg of triphenylphosphine oxide was isolated. The filtrate was again concentrated and chromatographed by means of a silica-gel (Wakogel C-200) column, using hexane as an eluant; 32.1 mg (20%) of *cis*- and 95.4 mg (60%) of *trans*-**7** were isolated, their identities were confirmed by GLPC and NMR.

Reaction of 1-Bromo-2-methoxy-1,2-diphenylethane (5) with 1. Formation of 1,4-Dimethoxy-1,2,3,4-tetraphenylbutane (8). (a) A 2.67 g (9.17 mmol) sample of *erythro*-**5** was allowed to react with 10.58 g (9.15 mmol) of **1** in 400 ml of degassed anhydrous benzene at 70 °C under argon for 4 h. The reaction mixture was then worked up as described above. GLPC analysis (150 and 250 °C, SE-30 on Chromosorb W, 1 m) indicated that several components were present in the hexane-soluble product (0.96 g). *trans*-Stilbene and biphenyl were confirmed by the retention-time comparisons with authentic samples. The main peak, appearing at a longer retention time, was isolated as follows: the hexane-soluble product was chromatographed by means of a silica-gel (Wakogel C-200) column using mixed elutants the compositions of which were gradually changed from pure hexane to pure benzene. The fractions eluted with mixtures of benzene: hexane=7: 3 and 9: 1 were combined and concentrated. The product was purified twice more by means of the column chromatograph and finally by recrystallization with hexane to give **8**, mp 139—139.5 °C, yield 85.5 mg. Found: C, 85.48; H, 7.06%. Calcd for $C_{30}H_{30}O_2$: C, 85.27; H, 7.16%. IR ($CHCl_3$) 1600, 1490, 1450, 1100, 695, 585 cm^{-1}. NMR ($CDCl_3$) δ=7.20—6.67 (m, 20, C_6H_5), 4.45 (d, 2, J=6 Hz, CH–OR), 3.65 (d, 2, J=6 Hz, CH–Ph), 3.15 (s, 6, OCH_3). MS (75 eV), *m/e* (relative intensity), 422 (M^+, 0.03), 407 (0.02), 390 (0.03), 389 (0.03), 375 (0.01), 358 (0.7), 301 (0.3), 300 (0.3), 270 (1), 211 (17), 179 (43), 165 (26), 122 (78), 121 (98), 105 (59), 91 (100), 77 (93).

(b) To 100 ml of a degassed benzene solution of 2.03 g (1.76 mmol) of **1** was added 0.512 g (1.76 mmol) of *erythro*-**5**. The solution was allowed to stand at an ambient temperature under argon. After 30 h, an orange-red crystalline precipitate, dibromobis(triphenylphosphine)palladium(II), was isolated by filtration, mp 283 °C (dec) (lit,[5] mp 230—250 °C dec), Found: C, 54.68; H, 3.88%. Calcd for $C_{36}H_{30}Br_2P_2Pd$: C, 54.66; H, 3.82%.

The filtrate was concentrated to give a mixture of crystalline solids, which were then taken up in hexane. The undissolved substance was filtered off, and the filtrate was concentrated. The residue was taken up in ether and washed with water. The ether solution was passed through a short alumina column, bis(2-ethylhexyl) phthalate was added as an internal standard, and then it was submitted to GLPC analysis (230 °C, 5% SE-30 on Chromosorb W, 1 m). The

analysis showed the presence of *trans*-**7** (a small amount) and **8** (20% yield).

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