Steric Mechanism of Formation of the PdCl π-allyl Derivative from [6β-^{2}H]Cholest-4-ene

By IAN J. HARVIE and FRANCIS J. MCQUILLIN
(*Department of Organic Chemistry, University of Newcastle upon Tyne, Newcastle upon Tyne* NE1 7RU)

Summary [6β-^{2}H]Cholest-4-ene reacts with [$(PhCN)_2PdCl_2$] to give the α 4—6 η and β 4—6 η PdCl derivatives with specifically *syn* 6-H, or 6-^{2}H elimination, respectively.

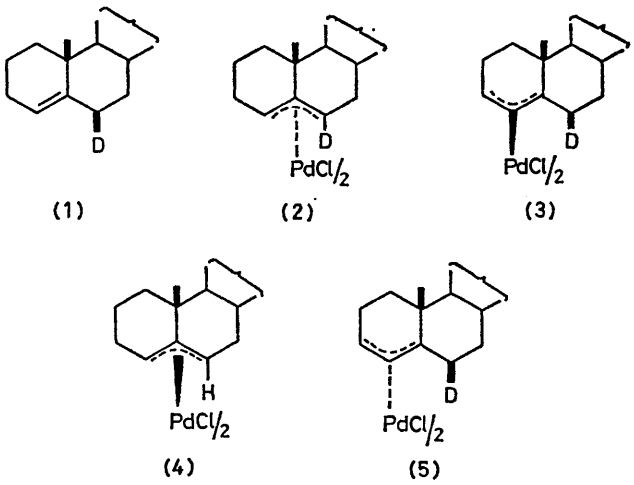
A SERIES of steroid-4-en-3-ones was found[1] to yield specifically α 4—6 η PdCl derivatives. The orientation of the PdCl residue derives both from n.m.r. data,[1] and from the observed[2] displacement of PdCl by $\bar{C}H(CO_2Me)$ with the expected[3] inversion of stereochemistry. However, use of a 6β-^{2}H-steroid-4-en-3-one disclosed an unexpected lack of stereospecificity at the π-$PdCl_2$ → π-allyl–PdCl stage as between elimination of 6α- and 6β-H. The unchanged steroid showed no deuterium loss, and we concluded that the apparent duality of mechanism could result from (a) specifically *syn*, *i.e.* 6α-H, transfer, to Pd together with (b) a superimposed H loss mediated by the 3-oxo group which is known[4] preferentially to labilise 6β-H.

To exclude process (b) and to identify the mechanism characteristic of PdCl π-allyl formation from alkenes we have examined the reaction of [6β-^{2}H]cholest-4-ene (**1**) (from action of $LiAlH_4$–$AlCl_3$[5] on [6β-^{2}H]cholest-4-en-3-one[6]).

Cholest-4-ene has already been shown[7] to give α and β 4—6 η PdCl derivatives with [$(PhCN)_2PdCl_2$], and with Na_2PdCl_4–HOAc–Ac_2O–NaOAc these products are accompanied by the α and β 3—5 η PdCl derivatives.

From (**1**), ^{2}H 88%, and [$(PhCN)_2PdCl_2$] in $CHCl_3$ (reflux) we obtained 40% of the α 4—6 η PdCl derivative (**2**), ^{2}H 87·8%, δ 3·73 (1H, m) and 1·12 (3H, s), and 15% of the β 3—5 η PdCl complex (**3**), ^{2}H 88%, δ 5·27 (1H, d), 4·85 (1H, m), and 1·42 (3H, s), together with recovered (**1**), ^{2}H 88%.

These results indicate specifically *syn* elimination of 6α-H in the formation of (**2**), and a marked isotopic discrimination making the β 3—5 η rather than the β 4—6 η PdCl complex the kinetic product of $PdCl_2$ co-ordination to the β side of the alkene.

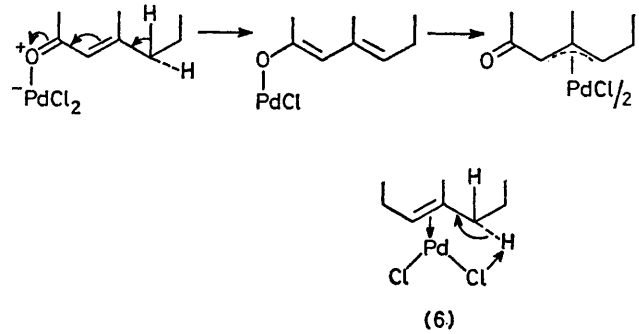


The method of PdCl complex formation in a melt[1] {[6β-^{2}H]cholest-4-ene, ^{2}H 83·3%, [$(PhCN)_2PdCl_2$], and dry $CaCO_3$, 4 equiv. at 100 °C, 2 h} gave additional information. The α 4—6 η derivative (**2**) (40%), ^{2}H 82·5%, was accompanied by the β 4—6 η PdCl complex (**4**) (< 3·5%), ^{2}H 0%, δ 3·65 (2H, m) and 1·55 (3H, s), the β 3—5 η derivative (**3**) (26%), ^{2}H 83·1%, and the α 3—5 η PdCl complex (**5**) (5%), ^{2}H 83%, δ 5·13 (1H, d) 4·83 (1H, m), and 0·90 (3H, s).

These findings support the conclusion that the process: alkene–$PdCl_2$ → π-allyl PdCl involves stereospecific loss of hydrogen *syn* to palladium and also that the 6β, *i.e. trans* H, loss in the steroid-4-en-3-one series[1] must be attributed to the influence of the 3-oxo group.

From a comparison of the ratio of α 4—6 η to β 4—6 η PdCl derivatives, from [6β-^{2}H]cholest-4-ene, *i.e.* > 11·5, with the ratios reported[7] for the undeuteriated steroid under differing experimental conditions, *viz.* 46/14 = 3·28 or 26/8 = 3·26 it is possible to derive an approximate isotope factor of > 3·5 for the formation of the cholest-4-ene π-allyl derivative. This is rather larger than would be expected for a process of insertion of Pd into the CH bond; k_H/k_D for the Pt^{II} catalysed exchange reaction[8] of alkanes was found to be *ca.* 1·7. A value of > 3·5 is, however, consistent with a mechanism such as that shown at (**6**), in which H is transferred as H^+ and an eliminating chloride ligand acts as proton acceptor.

In the earlier work[1] with the [6β-^{2}H] steroid-4-en-3-one we found evidence of preferential elimination of 6β-H, *i.e. trans* to the $PdCl_2$ residue. This steric preference is characteristic of a process in which the electrons of the 6β bond enter the π system of the enone by polarisation of the oxo group. The recovered steroid-4-en-3-one showed no loss of ^{2}H, *i.e.* enolisation seems to be excluded. However, an equivalent process arising from $PdCl_2$ co-ordination to the oxo group may be envisaged (Scheme). This process



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represents a second route for PdCl π-allyl formation where the alkene bond is placed $\alpha\beta$ or $\beta\gamma$ to an oxo group. The second step requires a 1,3- (or 1,5-) shift, specifically on the α-face of the steroid, but it is possible to envisage an oxa-allyl intermediate;[9] the PdCl residue will presumably be in bonding interaction with the π-system of the 3,4-alkene bond.

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