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The Migration of Double Bond under the Neutral Conditions. The Transformation of α-Alkylidene Cyclic Carbonyl Compounds to α,β-Unsaturated Cyclic Carbonyl Compounds

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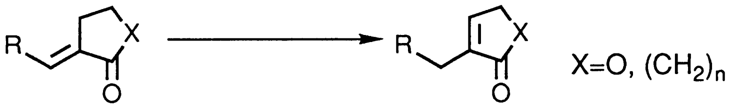
The transformation of α-alkylidene cyclic carbonyl compounds to α,β-unsaturated cyclic carbonyl compounds was achieved. In the presence of catalytic amount of triethylsilane, tris(triphenylphosphine)rhodium chloride was found to affect the migration of double bonds. Because of the neutral nature of reaction medium, the reaction proceeded in a clean manner without side reactions.

The migration of the double bond is one of the important transformations in the organic synthesis.[1)] Among them, the transformation of α-alkylidenelactones to α,β-unsaturated lactones (eq. 1) is of value because that serves the convenient way for the synthetically useful lactones like butenolides.[2)] Although several methods for that purpose were disclosed in the past,[1)] sometimes the reaction suffered from undesired side reaction (see below). In this paper, we report the new method for the transformation of α-alkylidene cyclic carbonyl compounds to α,β-unsaturated cyclic carbonyl compounds under the completely neutral condition.[3)]

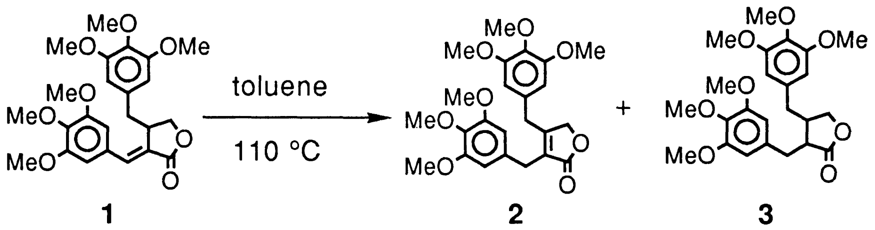


(eq. 1)

During the attempted tris(triphenylphosphine)rhodium chloride catalyzed hydrosilylation[4)] of **1** to **3**, the formation of byproduct (**2**), which was formed by the double bond migration reaction, was observed as the serious side reaction (Scheme 1, run 1). As the migration of the double bond was not observed in the absence of triethylsilane, it was assumed that the observed migration reaction is the consequence of the reversible rhodium catalyzed hydrosilylation reaction.

Based on these observations, it was expected that the well known hydrosilylation reaction might afford the double bond migrated product exclusively when the only catalytic amount of silane was used. In fact, the reaction of **1** with catalytic amount of tris(triphenylphosphine)rhodium chloride (3 mol%) and triethylsilane (7 mol%) in refluxing toluene afforded **2** in 93% yield (Scheme 1, run 2). Satisfied with this successful result, the double bond migration reaction was carried out with several α-alkylidene cyclic carbonyl compounds, and the results are shown in Table 1.

Generally, the reaction proceeded in good yield and could be applied not only for the double bond migration of α-alkylidenebutyrolactones but also for those of valerolactone or cycloalkanones (Table 1, run 3-

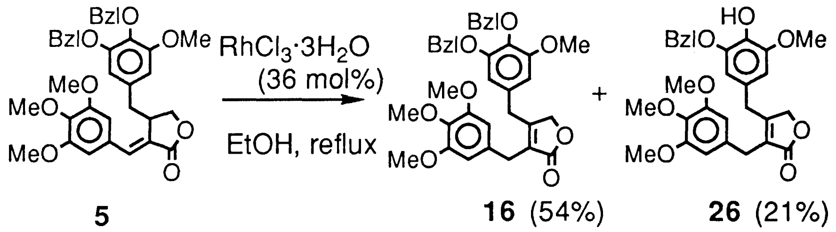


Run	Condition	Yield/% (2/3)[a]
1	$Rh(PPh_3)_3Cl$ (0.7 mol%), Et_3SiH (50 eq.)	80 (1/3)
2	**$Rh(PPh_3)_3Cl$ (3 mol%), Et_3SiH (7 mol%)**	**93 (100/0)**

a) Isolated yield. Ratios were based on the isolated yields of the each product.

Scheme 1. hydrosilylation and isomerization of **1**.

7). In all cases, the reactions resulted in the only very low conversion in the absence of triethylsilane. The neutral nature of the reaction condition is worth noticing. When the double bond migration of **5** was attempted using rhodium chloride (ethanol, reflux, 18 h),[1a)] the reaction required relatively large amount (36 mol%) of catalyst to the completion, and the expected product (**16**) was accompanied by the substantial amount of byproduct (**26**) which was produced probably by the action of hydrogen chloride generated in the reaction mixture (Scheme 2). The addition of potassium carbonate as the acid scavenger could not eliminate this undesired debenzylation reaction (K_2CO_3; 100 mol%, $RhCl_3 \cdot 3H_2O$; 36 mol%, ethanol, reflux, 20 h) affording **26** (12%) and **16** (46%). In contrast to these results, **5** afforded **16** as the only isolable product under the triethylsilane-$Rh(PPh_3)_3Cl$ catalyzed reaction, and no trace of debenzylated products could be detected (Table 1, run 2). These facts demonstrate the usefulness of this method for the transformation of complex molecules which possess acid labile groups. This reaction was also applicable to the compounds with polycyclic systems (**11**-**13**) affording expected products (Table 1, run 8-10).



Scheme 2. Double bond migration of **5** using rhodium chloride.

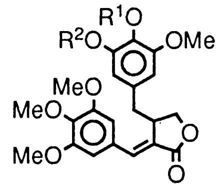
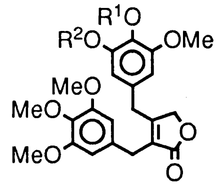
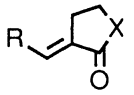
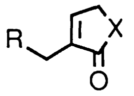
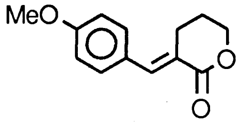
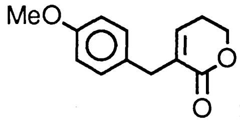
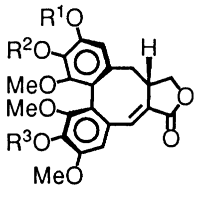
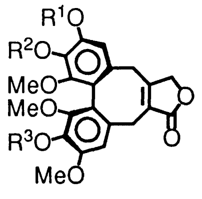
Unfortunately, this versatile reaction could not be applied to the compound possessing nitro group (Table 1, run 11). In this case, **14** was not consumed at all probably by the deactivation of catalyst with nitro group suggesting the incompatibility of the reaction with highly coordinating functional groups.

At this stage, it is assumed that the double bond migration would be the result of the rhodium catalyzed hydrosilylation and subsequent dehydrosilylation reaction as shown in scheme 3. Usually, hydrosilylation of **I** with triethylsilane under the influence of tris(triphenylphosphine)rhodium chloride affords silyl enol ether (**III**) by way of the intermediate (**II**) which is in the equilibrium between **I** and **III**.[5)] However, under the condition where the concentration of triethylsilane is low, the equilibrium would shift to favor the reactant. Consequently, enol ether (III) once formed would be dehydrosilylated by way of **II**. At this time, the decomposition of **II** has two possibilities, *i.e.*, decomposition by the elimination of Ha (path A) or Hb (path B). Through path A, the starting material (I) would be recovered and the recovered **I** would repeat the same hydrosilylation sequence again. On the other hand, path B would result in the production of the double bond migrated product (IV).[1b)]

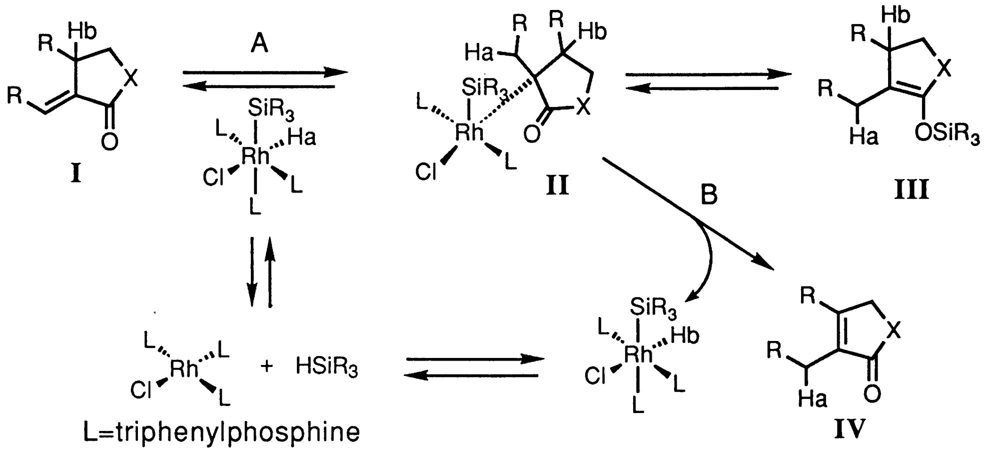
This hypothesis was supported by the following facts. First, the formation of the considerable amount of saturated product was observed in the presence of excess amount of triethylsilane, probably because the high concentration of triethylsilane shift the equilibrium to the silyl enol ether (III). Second, the migration reaction was retarded considerably without triethylsilane suggesting the direct participation of triethylsilane in this reaction.

A typical experimental procedure is described for the reaction of **12** to **23**. A solution of **12** (1.27 g, 2.98 mmol), tris(triphenylphosphine)rhodium chloride (83 mg, 0.92 mmol, 3 mol%), and triethylsilane (0.035 ml, 0.22 mmol, 7 mol%) in toluene (25 ml) was heated under reflux for 14 h, and then the solvent was evaporated.

Table 1. $Rh(PPh_3)_3Cl$-Et_3SiH catalyzed double bond migration reactions.

Run	Starting material	Product (yield; %)[a)]
		
1	**4**: R^1, R^2=CH_2	**15**: 99
2	**5**: R^1=R^2=benzyl	**16**: 87
		
3	**6**: R=$(CH_2)_2CH_3$, X=O	**17**: 94
4	**7**: R=*p*-methoxyphenyl, X=O	**18**: 80
5	**8**: R=*p*-methoxyphenyl, X=CH_2	**19**: 70
6	**9**: R=*p*-methoxyphenyl, X=$(CH_2)_2$	**20**: 57
7	 **10**	 **21**: 89
		
8	**11**: R^1=R^2=benzyl, R^3=Me	**22**: 94
9	**12**: R^1, R^2=CH_2, R^3=Me	**23**: 94
10	**13**: R^1, R^2=CH_2, R^3=benzyl	**24**: 84
11	**14**: R^1, R^2=CH_2, R^3=*p*-nitrobenzyl	**25**: 0

a) Isolated yield.



Scheme 3. Hypothetical mechanism for the triethylsilane-tris(triphenylphosphine)rhodium chloride catalyzed double bond migration reaction.

The residue was chromatographed (silica gel, AcOEt-hexane 1:2) to give **23** as a colorless solid (1.20 g, 94%).

In conclusion, the mild and efficient method for the double bond migration was established. The utilization of this essentially mild isomerization reaction to the natural products synthesis will be published elsewhere in due course.

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