Effective Catalysts for Transfer Hydrogenation of Ketones and Imines by Propan-2-ol : Ruthenium-Hydride or Ruthenium-Dihydride Complexes

Eiichiro Mizushima, Motowo Yamaguchi, and Takamichi Yamagishi*
Department of Industrial Chemistry, Faculty of Engineering, Tokyo Metropolitan University, Minami-ohsawa, Hachioji, Tokyo 192-03

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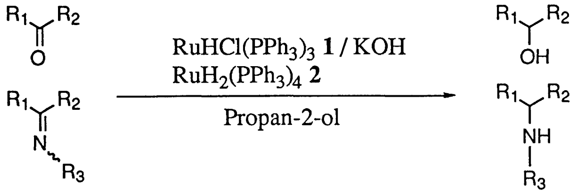
The ruthenium-hydride complexes, $[RuHCl(PPh_3)_3]$ and $[RuH_2(PPh_3)_4]$ act as very active catalyst for transfer hydrogenation of ketones and imines by propan-2-ol. The ruthenium-dihydride complex, $[RuH_2(PPh_3)_4]$, could catalyze the transfer hydrogenation without base.

Transition metal catalyzed transfer hydrogenation[1-3] with propan-2-ol is a convenient method to reduce ketones and imines since there is no need to employ a high hydrogen pressure or to use hazardous reducing agents. It has only been during recent years that satisfactory results for catalytic activity and enantioselectivity have been reported in the reaction of simple ketones with ruthenium catalyst bearing specific ligand.[4] In the presence of co-catalyst NaOH, commonly used $[RuCl_2(PPh_3)_3]$ acts as a good catalyst for the transfer hydrogenation of ketones but it is not clear what kind of complex is the actual active species.[2b] In general, it is supposed that the reaction proceeds through the metal-hydride intermediate.[5] We are interested in the catalytic ability of hydridochlorotris(triphenylphosphine)ruthenium[6] **1** generated from $[RuCl_2(PPh_3)_3]$ and that of dihydridotetrakis(triphenylphosphine)ruthenium[7] **2** for transfer hydrogenation of ketones and imines. Herein we report that in the presence of the co-catalyst KOH, the ruthenium(II)-monohydride complex **1** shows high activity for the transfer hydrogenation of ketones and imines in propan-2-ol, and that the ruthenium(II)-dihydride complex **2** can hydrogenate ketones and imines without KOH (Scheme 1).



Scheme 1.

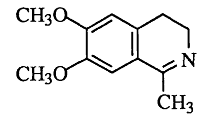
Transfer hydrogenation of several ketones and imines by the complex **1** or **2** proceeded very smoothly in the presence of co-catalyst KOH in propan-2-ol at reflux temperature under nitrogen atmosphere. The results were summarized in Table 1 and 2. As shown in Entries 1, 2 and 3 (Table 1), the catalytic activity of the complexes **1** and **2** are much higher than that of $[RuCl_2(PPh_3)_3]$[2b]. The high TOF, 2000 h^{-1}, was obtained during the first 5 minutes (Entry 1). The activity of the complex **2** was nearly same as that of the complex **1**. The complex **1** catalyzed transfer hydrogenation of 1'- or 2'-acetonaphthone very effectively in up to 96% yield within 1 h (Entries 4 and 5). The transfer hydrogenation proceeded even at room temperature in the presence of base (Entries 7 and 8), while the reaction of ketones using ruthenium-phosphine catalysts such as $[RuCl_2(PPh_3)_3]$[2b] and the diphosphine complexes, $[RuBr_2(P\text{-}P)_2]$[8], required high temperature.

Table 1. Transfer hydrogenation of ketones catalyzed by ruthenium hydride complexes **1** and **2**[a]

Entry	Ketone Substrate R_1	R_2	Catalyst	Time /h	Temp /°C	Yield[b] /%
1	Ph-	Me-	**1**	1	85	67 (48)[c]
2	Ph-	Et-	**1**	1	85	57 (18)[c]
3	Ph-	Et-	**2**	1	85	53
4	1'-Nap-	Me-	**1**	1	85	96
5	2'-Nap-	Me-	**1**	1	85	83
6	Ph-	Ph-	**1**	1	85	60
7[d]	2'-Nap-	Me-	**1**	4	r.t.	50
8[d]	$-CH_2(CH_2)_3CH_2-$		**1**	1	r.t.	50

[a] Reaction was carried out in propan-2-ol at 85 °C unless otherwise noted. **1** or **2** / Substrate / KOH = 1 / 1000 / 5. [b] Yield was determined by GLC or 270-MHz ^1H NMR analysis. [c] Values in parentheses refer to the results of $[RuCl_2(PPh_3)_3]$ system.[2b] [d] **1** / Substrate / KOH = 1 / 200 / 5.

Table 2. Transfer hydrogenation of imines catalyzed by ruthenium hydride complexes **1** and **2**[a]

Entry	Imine Substrate R_1	R_2	R_3	Cat.	Time /h	Yield[b] /%
1	Ph-	H-	$PhCH_2-$	**1**	5	95 (93 /18h)[c]
2	2'-Nap-	H-	$PhCH_2-$	**1**	5	96 (91 /18h)[c]
3	Ph-	Me-	$PhCH_2-$	**1**	18	84 (48 /18h)[c]
4	Ph-	Me-	$PhCH_2-$	**2**	18	89
5	2'-Nap-	Me-	$PhCH_2-$	**1**	18	95
6	Ph-	Ph-	$PhCH_2-$	**1**	18	21
7[d]				**1**	18	90

[a] Reaction was carried out in propan-2-ol at 85 °C unless otherwise noted. **1** or **2** / Substrate / KOH = 1 / 200 / 5. [b] Yield was determined by 270-MHz ^1H NMR analysis. [c] Values in parentheses refer to the results of $[RuCl_2(PPh_3)_3]$ system.[9] [d] Cyclic imine was used as a substrate.

Transfer hydrogenation of imines also proceeded smoothly in the presence of **1** or **2** and KOH in propan-2-ol at reflux temperature though the reaction rate is lower than those of ketones.

Table 3. Transfer hydrogenation of ketones and imines catalyzed by ruthenium complexes **1** and **2** in the absence of KOH[a]

Entry	Substrate	Catalyst	Time /h	Yield[b] /%
1	Acetophenone	**1**	3	0
2		**2**	3	93
3	2'-Acetonaphthone	**1**	3	0
4		**2**	3	97
5	*N*-(α-methyl benzylidene) benzylamine	**1**	5	0
6		**2**	5	83
7[c]		**2**	18	89
8[c,d]		**2**	18	89
9	*N*-(2'-naphthyl-methylidene)benzylamine	**2**	5	95

[a] Reaction was carried out in propan-2-ol at 85 °C in the absence of KOH. **1** or **2** / Ketone = 1 / 200, **1** or **2** / Imine = 1 / 50. [b] Yield was determined by 270-MHz ^{1}H NMR or GLC analysis. [c] **2** / Imine = 1 / 200. [d] Reaction was carried out in the presence of KOH; **2** / Imine / KOH = 1 / 200 / 5.

As shown in Table 2, with the complexes **1** and **2**, aldimines and ketimines were readily reduced by propan-2-ol. Ketimine, *N*-(α-methylbenzylidene)benzylamine was reduced in good yields at 85 °C (Entries 3 and 4).[10] The substrates having a 2'-naphthyl unit were ruduced very easily (Entries 2 and 5).

Transfer hydrogenation of ketones and imines was carried out in the absence of base (KOH) with the complex **1** or **2** and the results were summarized in Table 3. The reaction did not proceed at all with **1**. To be noted, the reaction with ruthenium dihydride complex **2** proceeded without KOH to afford alcohols and amines in good yields. This is the first example of ruthenium catalyzed transfer hydrogenation of ketones and imines without base.[11] The presence of KOH afforded no apparent acceleration to the catalytic activity of the complex **2** (Entries 7 and 8). In aprotic solvent, this ruthenium dihydride complex **2** could catalyze the isomerization of the imine, while monohydride complex could not cause the isomerization.[12] These results suggest that ruthenium dihydride complex **2** is the true catalyst for the transfer hydrogenation of ketones and imines.

In summary, the catalytic activity for transfer hydrogenation of ketones and imines greatly increased by using the ruthenium hydride complex **1**-KOH or complex **2** systems. Using the ruthenium dihydride complex **2**, the reaction proceeded without KOH. We are now applying this ruthenium dihydride system to the asymmetric reactions.

References and Notes

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10 When the reaction was performed at room temperature, the product could not be detected.

11 Recently, on the 43rd organometallic chemistry symposium of Japan, Noyori et al. reported that the ruthenium$^{\mathrm{II}}$-arene complex bearing *p*-TsN(C_6H_5)CH(C_6H_5)CHNH ligand catalyzed the reduction of acetophenone without KOH.

12 The complex **2** catalyzed the isomerization of *N*-(α-methylbenzylidene)benzylamine to *N*-benzylidene-α-methylbenzylamine in dry dioxane at reflux temperature, while the complex **1** could not cause the isomerization of the imine.