Ruthenium-catalysed Transfer Hydrogenation of Imines by Propan-2-ol

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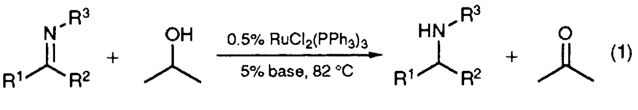
Imines are readily transfer hydrogenated by propan-2-ol under mild reaction conditions in the presence of a catalytic amount of $RuCl_2(PPh_3)_3$ and base.

We reported recently on ruthenium-catalysed hydrogen transfer reactions that proceed under mild conditions.[1,2] Thus, ruthenium-catalysed procedures for transfer hydrogenation of ketones by propan-2-ol[1] and oxidation of alcohols by acetone[2] were developed. An important feature of these reactions is that the presence of a catalytic amount of base is necessary.

A large number of ruthenium-catalysed hydrogen transfer reactions have been studied,[1–4] but the corresponding transfer hydrogenation of imines is less studied.[5]† owing to the synthetic interest of the latter reaction we decided to extend our previous studies on transfer hydrogenation to imines. Herin, we present our preliminary studies on the ruthenium-catalysed transfer hydrogenation of imines by propan-2-ol [eqn. (1)].



(1)

The reduction of imines was performed in refluxing propan-2-ol using $RuCl_2(PPh_3)_3$ (0.5 mol%) as catalyst and K_2CO_3 (5 mol%) as base. Some results of this study are listed in Table 1.‡ As can be seen from Table 1, the reactivity of imines depends on both steric and electronic effects. Aldimines generally react faster than ketimines, and aliphatic imines are more reactive than aromatic imines. Ketimines with only aliphatic substituents gave unsatisfactory results (entry 11, Table 1). Here polymerization or decomposition of the imine could be involved.[6a]

When compared with the ruthenium-catalysed transfer hydrogenation of ketones,[1] the reaction rate of imines is much lower. Both steric and electronic effects may lead to a slower hydrogen transfer from propan-2-ol to imines compared to ketones.[7]

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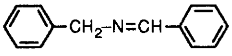
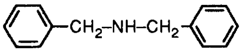
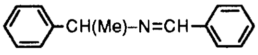
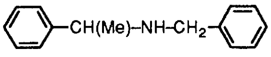
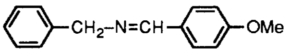
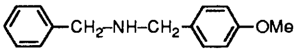
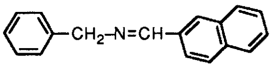
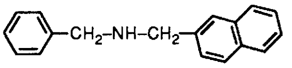
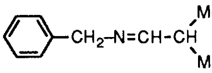
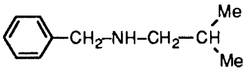
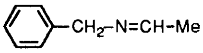
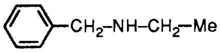
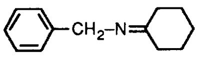
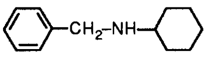
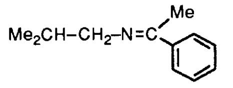
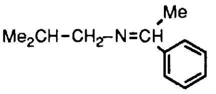
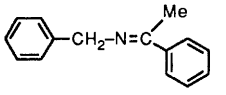
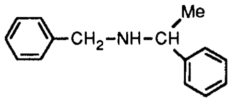
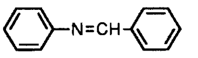
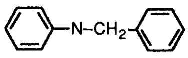
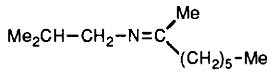
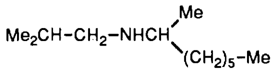
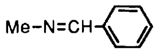
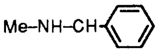
† Iridium[5a] and rhodium[5b] complexes have been reported to catalyse the transfer hydrogenation of imines, but only one and two substrates, respectively, are reported. Transfer hydrogenation of imines is inferred in ruthenium-catalysed alkylation of amines by alcohols.[5c] Recently, Bhaduri[5d] reported the $Ru_3(CO)_{12}$-catalysed transfer hydrogenation of benzylidene anilines.

‡ The reactions were carried out on a 2 mmol scale in 15 ml propan-2-ol with a substrate to catalyst ratio of 200 : 1. K_2CO_3 (13.8 mg, 0.1 mmol) was used as base. A gentle nitrogen stream was maintained and the acetone formed together with propan-2-ol was distilled off during the reaction. The reactions were monitored by TLC (GC could not provide reliable analytical results, which is probably due to the instability of imines at high temperature). After complete consumption of imines, except for entries 8 and 9 in Table 1, the solvent was evaporated using a rotary evaporator and the residue was dissolved in diethyl ether. The solution was subjected to a silica gel pad to remove inorganic salts and the solution obtained was diluted with diethyl ether and treated with 1.1 equiv. of 54% HBF_4 in diethyl ether. The precipitated ammonium salts were filtered off, washed with diethyl ether, air-dried and characterized by ^{1}H NMR spectroscopy. The BF_4-salts could be purified by recrystallization from CH_2Cl_2–diethyl ether. In the cases of entries 8 and 9, the solvent was evaporated after the given time. The residue was dissolved in $CDCl_3$ and 1,2-dichloroethane was added as internal standard. ^{1}H NMR spectra of these solutions were recorded and the yields were determined by integration.

Table 1 $RuCl_2(PPh_3)_3$-catalysed transfer hydrogenation of imines by propan-2-ol in the presence of base[a]

Entry	Substrate	Product[b]	Yield (%)[c]	t/h
1			93	18
2			91	18
3			94	18
4			95	18
5			90	3
6			78	3
7			86	18
8			67[d]	60
9			48[d]	18
10			92	18
11			54[e]	18
12			87	9

[a] The reactions were carried out on a 2 mmol scale in 15 ml propan-2-ol with a substrate to catalyst ratio of 200 : 1, and in all cases 13.8 mg (0.1 mmol) of K_2CO_3 was used as base. Imines were prepared according to the general methods described in literature.[6] [b] Products except for entries 8 and 9 were isolated as BF_4-ammonium salts and characterized by ^1H NMR spectroscopy. [c] Isolated yields unless otherwise noted. [d] In this case the yield was determined by integrating the CH_2-group of the amine against an internal standard (1,2-dichloroethane). [e] The rest could not be identified.

In the transfer hydrogenation of imines, the ruthenium catalyst differs from the rhodium catalyst[5b] in that the former does not catalyse the isomerization between PhCH(Me)N=CHPh and Ph(Me)C=NCH$_2$Ph as the latter does. Thus, these two substrates exhibit no reactivity difference in the rhodium-catalysed reaction,[5b] while in the ruthenium-catalysed reaction the aldimine reacted *ca.* two times faster than the ketimine (see entries 2 and 9, Table 1).

The presence of a catalytic amount of base such as K_2CO_3 or NaOH is necessary for the transfer hydrogenation of imines, which has also been observed for transfer hydrogenation of ketones by propan-2-ol and dehydrogenation of secondary alcohols by acetone.[1,2,5,8] Thus, as illustrated in Fig. 1, in the absence of additional base no reaction occurred even after 18 h. Further, it was found that the reaction rate was slightly lower when NaOH was used as the base in place of K_2CO_3 (Fig. 1).

It is important that the propan-2-ol employed is dry since water reacts reversibly with imine affording amine and an aldehyde or a ketone.[6] Under the reaction conditions the aldehyde could react with the ruthenium catalyst to give carbonyl or hydridocarbonyl complexes[1,2,9] or η^2-carboxylate complexes,[10] which would deactivate the catalyst.

Since ruthenium complexes with 2,2′-bis(diphenylphosphino)-1,1′-binaphthalene (binap) and 1,4-bis(diphenylphosphino)butane (dppb) as ligands are more reactive than $RuCl_2(PPh_3)_3$ for transfer hydrogenation of ketones,[11] we thus tried to use these complexes for the transfer hydrogenation of imines. However, complexes with bidentate phosphine ligands exhibit much lower reactivity than $RuCl_2(PPh_3)_3$ in the reaction with imines (Table 2). One reason why transfer hydrogenation of ketones is favoured by rigid bidentate ligands, while that of imines is favoured by monodentate

Table 2 Influence of ligands on the ruthenium-catalysed transfer hydrogenation of *N*-benzylideneaniline by propan-2-ol[a]

	Conversion (%)[b]		
t/h	$RuCl_2(PPh_3)_3$	$1/n[RuCl_2(cod)]_n$–dppb[c]	$Ru_2Cl_4(binap)_2NEt_3$
2	47.3	8.3	12.3
5	75.1	22.4	16.6
8	87.9		

[a] The reactions were performed on a 2 mmol scale in 15 ml propan-2-ol with a substrate to catalyst ration of 200 : 1, and in each case 0.1 mmol of K_2CO_3 was used as a base. [b] Conversion was determined by GC. [c] cod = cycloocta-1,5-diene.

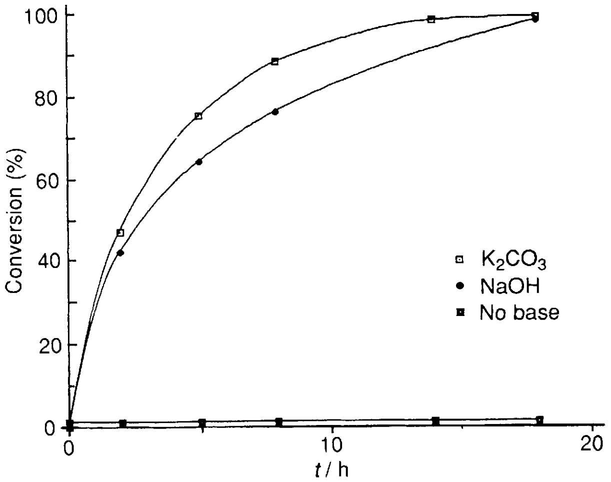


Fig. 1 The influence of base on the transfer hydrogenation of *N*-benzylideneaniline by propan-2-ol

ligands could be the higher steric demand of the imines compared to ketones.

This novel ruthenium-catalysed transfer hydrogenation of imines should be of synthetic interest for the transformation of a keto function to an amine under mild conditions.

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References

1 R. L. Chowdhury and J. E. Bäckvall, *J. Chem. Soc., Chem. Commun.*, 1991, 1063.
2 G.-Z. Wang and J. E. Bäckvall, *J. Chem. Soc., Chem. Commun.*, 1992, 337.
3 (*a*) Y. Sassons and G. L. Rempel, *Tetrahedron Lett.*, 1974, 4133; (*b*) Y. Sassons and J. Blum, *Tetrahedron Lett.*, 1971, 2167, and references cited therein; (*c*) Y. Sassons and J. Blum, *J. Org. Chem.*, 1975, **40**, 887; (*d*) W. A. Fordyce, R. Wilczynski and J. Halpern, *J. Organomet. Chem.*, 1985, **296**, 115; (*e*) D. E. Linn, Jr. and J. Halpern, *J. Am. Chem. Soc.*, 1987, **109**, 2969; (*f*) D. E. Linn, Jr. and J. Halpern, *J. Organomet. Chem.*, 1987, **330**, 155.
4 (*a*) T. A. Smith and P. M. Maitlis, *J. Organomet. Chem.*, 1985, **289**, 385; (*b*) Y. Ishi, K. Osakada, T. Ikariya, M. Saburi and S. Yoshikava, *J. Org. Chem.*, 1986, **51**, 2034; (*c*) S. I. Murahashi, T. Naota, K. Ito, Y. Maeda and H. Taki, *J. Org. Chem.*, 1987, **52**, 4319; (*d*) S. Ganguly, F. L. Joslin and D. M. Roundhill, *Inorg. Chem.*, 1989, **28**, 4562; (*e*) D. Ma and X. Lu, *J. Chem. Soc., Chem. Commun.*, 1989, 890; (*f*) Y. Tshuli, S. Kutachi, K. Huh and Y. Watanabe, *J. Org. Chem.*, 1990, **55**, 580.
5 (*a*) F. Martinelli, G. Mestroni, A. Camus and G. Zassinovich, *J. Organomet. Chem.*, 1981, **220**, 383; (*b*) H. A. Brune, J. Unsin, R. Hemmer and M. Reichhardt, *J. Organomet. Chem.*, 1989, **369**, 335; (*c*) Y. Watanabe, Y. Tsuji, H. Ige, Y. Ohsugi and T. Ohta, *J. Org. Chem.*, 1984, **49**, 3359; (*d*) S. Bhaduri, N. Sapre, K. Sharma, P. G. Jones and G. Carpenter, *J. Chem. Soc., Dalton Trans.*, 1990, 1305.
6 B. S. Furniss, A. J. Hannaford, P. W. G. Smith and A. R. Tatchell, *Vogel's Textbook of Practical Organic Chemistry*, John Wiley, New York, 5th edn., 1989, (*a*) section 8.16; (*b*) section 6.5.
7 J. A. J. M. Vekemans, J. P. G. Versleijen and H. M. Buck, *Tetrahedron Asymmetry*, 1991, **2**, 949, and references cited therein.
8 (*a*) G. Zassinovich, A. Camus and G. Mestroni, *J. Mol. Catal.*, 1980, **9**, 345; (*b*) G. Mestroni, G. Zassinovich, A. Camus and F. Martinelli, *J. Organomet. Chem.*, 1980, **198**, 87; (*c*) R. Spogliarich, G. Zassinovich and M. Graziani, *J. Organomet. Chem.*, 1979, **179**, C45; (*d*) D. Müller, G. Umbrich, B. Weber and A. Pfaltz, *Helv. Chim. Acta*, 1991, **74**, 232.
9 (*a*) *Inorganic Synthesis*, ed. G. W. Parshall, McGraw-Hill, New York, 1974, vol. XV, ch. 3, and references cited therein; (*b*) L. S. V. D. Suys, G. J. Kubas and K. G. Cauton, *Organometallics*, 1991, **10**, 1033, and references cited therein; (*c*) P. S. Hallman, B. R. McGarvey and G. Wilkinson, *J. Chem. Soc. A*, 1968, 3143; (*d*) B. N. Chaudret, D. J. Cole-Hamilton, R. S. Nohr and G. Wilkinson, *J. Chem. Soc., Dalton Trans.*, 1977, 1546; (*e*) J. Chatt, B. L. Shaw and A. E. Field, *J. Chem. Soc.*, 1964, 3466; (*f*) E. Benedetti, G. Bracci, G. Shrana, F. Salvatti and B. Grassi, *J. Organomet. Chem.*, 1972, **37**, 361.
10 C. Bianzini, E. Fanetti, P. Frediani, M. Graziani, M. Peruzini and A. Polo, *J. Chem. Soc., Chem. Commun.*, 1991, 1336.
11 R. L. Chowdhury, G.-Z. Wang and J. E. Bäckvall, unpublished results.