Pergamon

SCIENCE DIRECT®

Tetrahedron Letters 44 (2003) 9201–9203

TETRAHEDRON
LETTERS

Hydrogen transfer type oxidation of alcohols by rhodium and ruthenium catalyst under microwave irradiation

Masaaki Takahashi, Koichiro Oshima and Seijiro Matsubara*

Department of Material Chemistry, Graduate School of Engineering, Kyoto University, Kyoutodaigaku-katsura, Nishikyo, Kyoto 615-8510, Japan

Received 5 September 2003; revised 30 September 2003; accepted 3 October 2003

Abstract—Secondary alcohols were converted into the corresponding ketones by methyl acrylate and rhodium catalyst efficiently under microwave irradiation. Treatment of primary alcohols with the same condition resulted in the recovery of the starting materials. Primary alcohols were converted into aldehydes by hydrogen transfer reaction using methyl vinyl ketone and ruthenium catalyst under microwave irradiation.

An oxidation of alcohols has required the efficiency and selectivity, and also been argued from the point of view of safety. The use of stoichiometric amount of hazardous oxidizing reagent should be avoided.[1] The solvent is also tried to change to non-hazardous solvent including water. For these reasons, transition metal catalyzed reaction using air or oxygen has been reported as a preferable system.[2] Hydrogen transfer type oxidation catalyzed with a transition metal compound may also be desirable in some cases, as the use of alkene as hydrogen acceptor diminishes a difficulty and danger of oxidation reaction. Hayashi reported palladium catalyzed oxidation by ethene.[3] The method is really attractive, but unfortunately only applicable for benzylic and allylic alcohols. The catalytic ability of transition metal complex for hydrogen transfer from alkanol to alkene had been well investigated and shown that rhodium complex was more active than ruthenium, platinum, and palladium complexes.[4] We planned to use rhodium complex as a catalyst and tried to oxidize secondary aliphatic alcohol with alkene. For completion of these hydrogen transfer, microwave irradiation was proved to be effective.[5]

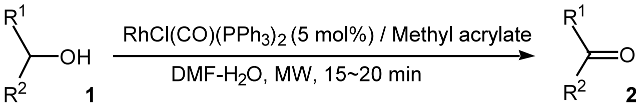

Figure 1. Oxidation of secondary alcohols by Rh(I) and methyl acrylate.

Oxidation of alkanol was examined as follows (Fig. 1). As microwave system, we used Discover system from CEM corporation.[6] In a pressure 10 ml vial which can be sealed by a septum, a mixture of alkanol (**1**, 1.0 mmol), methyl acrylate (2.0 mmol), and $RhCl(CO)(PPh_3)_2$ (0.05 mmol) in water (3.0 ml) and *N*,*N*-dimethylformamide (1.0 ml) was placed. Microwave (200W) was irradiated maintaining 140°C and 200 psi for 15 min. After being cooled, the reaction mixture was extracted with hexane. The combined hexane solution was passed through a short silica gel column and concentrated in vacuo. The residue was analysed by ^{1}H NMR and purified by a short silica gel column, as the need arose.

Results of the reaction in Figure 1 are shown in Table 1. The secondary alcohols were oxidized to the corresponding ketones (entries 1–4, and 7). Without microwave irradiation, these reactions resulted in the recovery of starting alcohols. Primary alcohols, both of benzylic and saturated ones, were not oxidized and resulted in recovery of starting material (entries 5 and 6). As shown in Figure 2, a mixture of primary and secondary alcohols was treated with the above condition. Only secondary alcohol was oxidized and the primary alcohol was recovered unchanged. In Figure 3, the diol **3**, which contained primary and secondary alcohol moieties, was also converted into keto alkanol **4** in good yield.[7]

---

* Corresponding author. Tel.: +81-75-383-2441; fax: +81-75-383-2438; e-mail: matsubar@mc.kyoto-u.ac.jp

0040-4039/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tetlet.2003.10.032

Table 1. Oxidation of secondary alcohols via Figure 1[a]

Entry	Alcohol **1**		Product **2**		Yield[b]
1	5-Tetradecanol	**1a**	5-Tetradecanone	**2a**	86%
2	Cyclododecanol	**1b**	Cyclododecanone	**2b**	99
3	Cyclooctanol	**1c**	Cyclooctanone	**2c**	68
4	4-*t*-Butylcyclohexanol	**1d**	4-*t*-Butylcyclohexanone	**2d**	27
5	*n*-Tridecanol	**1e**	Recovery of alcohol	–	~0
6	Benzyl alcohol	**1f**	Recovery of alcohol	–	~0
7	1-*p*-Tolyl-1-hexanol	**1g**	*p*-Tolyl pentyl ketone	**2g**	99

[a] Reaction was conducted via Figure 1. The procedure was shown in text.

[b] Isolated yields.

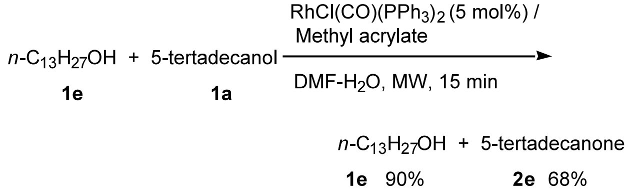

Figure 2. Selective oxidation of a secondary alcohol in the presence of a primary one.

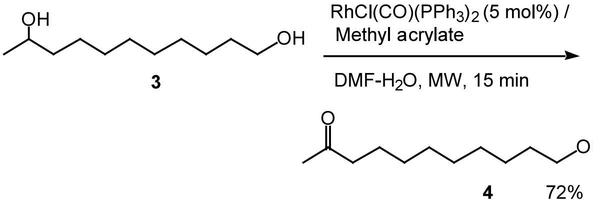

Figure 3. Conversion of a diol into keto alcohol.

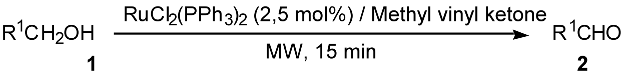

Figure 4. Oxidation of primary alcohols by Ru(II) and methyl vinyl ketone.

We tried to overcome the difficulties of the oxidation of primary alcohol under the conditions in Figure 1. Prolonged reaction time and use of methyl vinyl ketone instead of methyl acrylate were not effective. The ruthenium-catalyzed reaction, however, was effective for hydrogen transfer type oxidation of primary alcohol.[8] As shown in Figure 4, primary alcohols were tried to oxidize into aldehydes. A procedure for the oxidation reaction of primary alcohol was as follows. In a pressure 10 ml vial which can be sealed by septum, a mixture of alkanol (1.0 mmol), methyl vinyl ketone (2.0 mmol), and $RuCl_2(PPh_3)_3$ (0.025 mmol) was placed without solvent. Microwave (200 W) was irradiated maintaining 120°C and 200 psi for 15 min. The results are summarized in Table 2.

In both reactions in Figures 1 and 4, an oxidation of a substrate carrying C–C double bond contained some difficulty. A migration of the C–C double bond was observed in both cases. As shown in Figure 5, treatment of 2-undecen-4-ol (**5**) with the rhodium catalyst and methyl acrylate gave a mixture of 4-undecanone and 2-undecen-4-one. In the ruthenium-catalyzed reaction, the migration was also observed as shown in entry 5 of Table 2.

When the migration of C–C double bond via hydride shift reaches the α-carbon of the hydroxyl group, ketone was obtained via enol form. The isomerization reaction may proceed completely dependant on the catalyst. The efficiency of the catalyst in Figure 6 was examined as shown in Table 3. A procedure for the isomerization reaction was as follows. In a pressure 10 ml vial which can be sealed by a septum, a mixture of alkanol (1.0 mmol) and catalyst (0.025 mmol) in water (3.0 ml) and *N*,*N*-dimethylformamide (1.0 ml) was placed. Microwave (200W) was irradiated maintaining 180°C and 200 psi for 15 min.

Some of the transition metal compounds have an ability of C–C double bond migration via hydride shift

Table 2. Oxidation of primary alcohols via Figure 4[a]

Entry	Alcohol		Product		Yield[b]
1	*n*-Heptanol	**1h**	Heptanal	**2h**	45%
2	*n*-Tridecanol	**1e**	Tridecanal	**2e**	77
3	Benzyl alcohol	**1f**	Benzaldehyde	**2f**	54
4	1,7-Heptanediol	**1i**	Heptanedial	**2i**	53
5	Citronerol	**1j**	Citroneral[c]	**2j**	53
6	(Cyclododecanol	**1b**	Cyclododecanone	**2b**	54)

[a] Reaction was conducted via Figure 4. The procedure was shown in text.

[b] Isolated yields.

[c] Accompanying the aldehydes with a migrated C–C double bond in 21% yield.

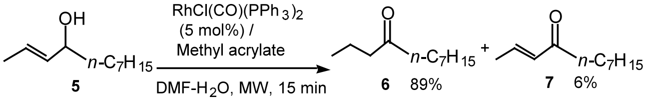

Figure 5. Treatment of allylic alcohol **5** with rhodium catalyst and methyl acrylate.

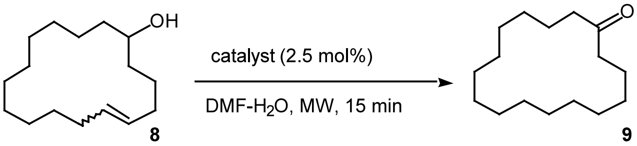

Figure 6. Isomerization of a cycloalkenol into a saturated ketone via hydride shift.

Table 3. Isomerization reaction of **8** into **9** in Figure 6[a]

Entry	Catalyst	Yield of ketone[b]
1	$RuCl_2(PPh_3)_3$	88%
2	$RhCl(CO)(PPh_3)_2$	<5
3	$NiCl_2$	<5
4	$Ru_3(CO)12$	19
5	$RhCl_3$	6
6	$CoCl_2(PPh_3)_2$	<5
7	$Pd_2Cl_4(PPh_3)_2$	28

[a] Reaction was conducted via Figure 6. The procedure was shown in text.

[b] Isolated yields.

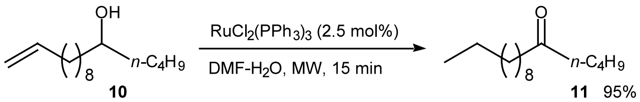

Figure 7. Isomerization of alkenol **10** into a saturated ketone **11** via hydride shift.

under microwave irradiation, and $RuCl_2(PPh_3)_3$ showed a remarkable efficiency for the reaction in Figure 6.[9] As shown in Figure 7, a completely isolated C–C double bond from hydroxyl group in **10** was also migrated to α-position to afford ketone **11**, with $RuCl_2(PPh_3)_3$ as catalyst.

The transition metal catalyzed intermolecular hydride shift from alkanol to enone was promoted effectively by microwave irradiation. In the same way, ruthenium-catalyzed intramolecular hydride shift was also accelerated by microwave irradiation. The procedures are simple and will give a way for microwave chemistry concerning organometallic chemistry.

Acknowledgements

This work was supported financially by a Grant-in-Aid for Scientific Research from The Ministry of Education, Science, Sports, and Culture. The financial supports from Chugai Pharmaceutical Company and Takahashi Industrial and Economic Research Foundation are also acknowledged. The authors also deeply grateful to Professor M. Hayashi (Kobe University) for valuable discussions.

References

1. *Handbook of Reagents for Organic Synthesis. Oxidizing and Reducing Agents*; Burk, S. D.; Danheiser R. L., Eds.; John Wiley & Sons Ltd: Chichester, 1999; pp. 1–550.
2. (a) Hanyu, A.; Takezawa, E.; Sakaguchi, S.; Ishii, Y. *Tetrahedron Lett*. **1998**, *39*, 5557–5560; (b) Uozumi, Y.; Nakao, R. *Angew. Chem., Int. Ed. Engl*. **2003**, *42*, 194–197; Nishimura, T.; Onoue, T.; Ohe, K.; Uemura, S. *J. Org. Chem*. **1999**, *64*, 6750–6755; Peterson, K. P.; Larock, R. C. *J. Org. Chem*. **1998**, *63*, 3185–3189; (c) Maeda, Y.; Kakiuchi, N.; Matsumura, S.; Nishimura, T.; Kawamura, T.; Uemura, S. *J. Org. Chem*. **2002**, *67*, 6718–6724; Gianna, R.; Betzemeiter, B.; Quichi, S.; Knochel, P. *Tetrahedron* **2002**, *58*, 3985–3991.
3. Hayashi, M.; Yamada, K.; Nakayama, S.; Hayashi, H.; Yamazaki, S. *Green Chem*. **2000**, *2*, 257–260.
4. (a) Beaupere, D.; Nadjo, L.; Uzan, R.; Bauer, P. *J. Mol. Cat*. **1982**, *14*, 129–131; (b) Beaupere, D.; Massoui, M.; Ralainirina, R.; Uzan, R. *Nouv. J. Chim*. **1986**, *10*, 493–498; (c) Sato, S.; Matsuda, I.; Izumi, Y. *J. Organomet. Chem*. **1988**, *344*, 71–88.
5. (a) Bogdal, D.; Lukasiewicz, M.; Pielichowski, J.; Miciak, A.; Bendnarz, S. *Tetrahedron* **2003**, *59*, 649–653; (b) Kiasat, A. R.; Kazemi, F.; Rafati, M. *Syn. Commun*. **2003**, *33*, 601–605; (c) Bogdal, D.; Lukasiewicz, M. *Synlett* **2000**, 143; (d) Heravi, M.; Ajami, D.; Aghapoor, K.; Ghassemzadeh, M. *J. Chem. Soc., Chem. Commun*. **1999**, 833–834.
6. Hayes, B. L. *Microwave Synthesis*; CEM Publishing: Matthews, 2002.
7. (a) Martin, J.; Martin, C.; Faraj, M.; Bregeault, J. M. *Nouv. J. Chem*. **1984**, *8*, 141–143; (b) Bressan, M.; Morandini, F.; Rigo, P. *J. Organomet. Chem*. **1983**, *247*, C8–10; (c) Grigg, R.; Mitchell, T. R. B.; Tongpenyai, N. *Synthesis* **1981**, 442–444.
8. (a) Markó, I. E.; Giles, P. R.; Tsukazaki, M.; Chellé-Regnaunt, I.; Urch, C. J.; Brown, S. M. *J. Am. Chem. Soc*. **1997**, *119*, 12661–12662; (b) Yamaguchi, K.; Mori, K.; Mizugaki, T.; Ebitani, K.; Kaneda, K. *J. Am. Chem. Soc*. **2000**, *122*, 7144–7145; (c) Dijksman, A.; Marino-Gonzalez, A.; Payeras, A. M.; Arends, I. W. C. E.; Sheldon, R. A. *J. Am. Chem. Soc*. **2001**, *123*, 6826–6833.
9. (a) Zaw, K.; Henry, P. M. *Organometallics* **1992**, *11*, 2008–2015; (b) Komiya, S.; Yamamoto, A. *J. Mol. Cat*. **1979**, *5*, 279–292; (c) Casey, C. P.; Cyr, C. R. *J. Am. Chem. Soc*. **1973**, *95*, 2248–2253.