

# Nitrobenzene as hydrogen acceptor in Pd/C-catalyzed hydrogen transfer reaction

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**Abstract**—Nitrobenzene was found to work as an efficient hydrogen acceptor in the oxidation of allylic alcohols to give the corresponding enones in high yields.

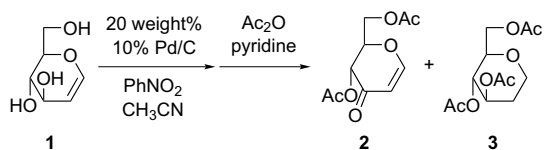
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Oxidation of alcohols is one of the most important transformation reactions in organic synthesis.<sup>1</sup> Hydrogen transfer reaction between alcohols and a hydrogen acceptor will afford the corresponding carbonyl and hydrogenated compounds of the hydrogen acceptor. A variety of metal complexes promote the hydrogen transfer reaction.<sup>2</sup> Among the many transition metals such as ruthenium, rhodium, iridium and others, we focused our attention on palladium complexes. Actually, we recently reported the oxidation of allylic alcohols and benzylic alcohols to the corresponding carbonyl compounds by the use of a Pd/C–ethylene system.<sup>3</sup> Instead of this system, Pd(OAc)<sub>2</sub>–vinyl acetate was also effective for the hydrogen transfer reaction.

There are some reports for transition metals-catalyzed reduction of nitrobenzene derivatives to aniline derivatives.<sup>4</sup> In this letter, we report that nitrobenzene can be used in hydrogen transfer reaction as an excellent hydrogen acceptor. On the other hand, in 1987, Murahashi et al. reported RuH<sub>2</sub>(PPh<sub>3</sub>)<sub>4</sub>-catalyzed oxidative transformation of alcohols and aldehydes to esters and lactones.<sup>5</sup> To our knowledge, there have been two recent reports in which nitrobenzene was used in Pd/C-catalyzed reactions as a hydrogen acceptor. In 2002, Cossy and Belotti reported the aromatization of enamines promoted by Pd/C in the presence of nitrobenzene and molecular sieves (MS) 4A under toluene reflux conditions.<sup>6</sup> The Nippon Steel Chemical group also disclosed dehydrogenative aromatization of 1,2,3,4-tetrahydro-

carbazole derivative.<sup>7</sup> In the latter case, even in the absence of nitrobenzene, the reaction proceeded; however, the authors described that the presence of nitrobenzene increased the yield. Both cases are aromatization reactions. Therefore, this report is the first example of the use of nitrobenzene as a hydrogen acceptor in Pd/C-catalyzed oxidation reaction of alcohols.

We examined the reaction of D-glucal **1** with a catalytic amount of Pd/C in the presence of nitrobenzene. The products were dehydrogenated enone (1,5-anhydrohex-1-en-3-ulose) **2** and hydrogenated 2-deoxy-1,5-anhydro-D-glucitol **3** (Scheme 1). The enone product obtained by this reaction is very useful, because it can be used as a substrate for glycosylation leading to the synthesis of 2-deoxy glycosides.<sup>8</sup> Therefore, several methods have been reported including PDC (pyridinium dichromate) so far. Among those, in 1993, Czernecki and his co-workers reported the oxidation of allylic alcohol of D-glucal with a stoichiometric amount of Pd(OAc)<sub>2</sub> in aqueous DMF (1% H<sub>2</sub>O).<sup>9</sup> They disclosed that several attempts aiming at oxidation with a catalytic amount of Pd(OAc)<sub>2</sub> in the presence of reoxidants such as copper acetate were unsuccessful.



Scheme 1.

**Keywords:** Oxidation; Hydrogen acceptor; Nitrobenzene.

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**Table 1.** Oxidation of glycals (**1**, **4** and **6**) by Pd/C–PhNO<sub>2</sub> system<sup>a</sup>

Entry	Glycals	PhNO <sub>2</sub> /equiv	Conditions		Products	Yield ( <b>2/3</b> ) <sup>b</sup>
			T/°C	t/h		
1		None	50	16		88 (47/53)
2		0.17	50	48		100 (78/22)
3		0.33	50	48		99 (>98/<2)
4		1	50	48		100 (100/0)
5		0.33	80	24		83 <sup>c</sup>
6		0.33	80	48		90 <sup>c</sup>

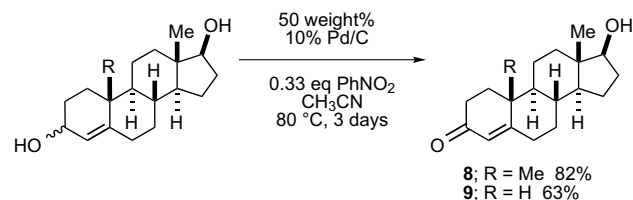
<sup>a</sup> All reactions were carried out in CH<sub>3</sub>CN in the presence of 20 wt % of 10% Pd/C.<sup>b</sup> Combined yield. The ratio was determined by <sup>1</sup>H NMR analysis.<sup>c</sup> Isolated yield after silica-gel column chromatography.

The ratio of dehydrogenated enone and hydrogenated glucitol depended on the amount of nitrobenzene. Even in the presence of 0.33 equiv of nitrobenzene, the formation of the hydrogenated product of glucal was only less than 2% (Table 1, entry 3). These results clearly demonstrate that nitrobenzene works as an efficient hydrogen acceptor.<sup>10</sup> Nitrobenzene was much easier to be hydrogenated than the double bond in D-glucal. Furthermore, 1 equiv of nitrobenzene captures 3 equiv of hydrogen. It is interesting that the complete conversion of nitrobenzene to aniline was not observed. That is, when D-glucal was treated with 20 wt % of 10% Pd/C in the presence of 0.33 equiv of nitrobenzene, nitrobenzene should be consumed completely, and 0.33 equiv of aniline was produced theoretically; however, about 30% nitrobenzene remained. This surprising observation was explained by the spillover phenomenon. The hydrogen atom on metal particles (Pd) may easily migrate to supports (carbon), which have a hydrogen acceptor site.<sup>11</sup>

In the case of the use of nitromethane (0.33 equiv) instead of nitrobenzene as hydrogen acceptor for this reaction, the ratio of dehydrogenated enone and hydrogenated glucitol (**2:3**) was 53:47 (92% yield). This means that nitromethane worked much less efficiently as hydrogen acceptor than nitrobenzene.

Not only D-glucal, but also D-galactal **4** and L-rhamnal **6** were converted to the corresponding enones (**5** and **7**) under similar conditions (Table 1, entries 5 and 6). In both cases, hydrogenated products of **4** and **6** were not obtained. Furthermore, allylic alcohols of the A ring in steroid compounds were also oxidized effectively to afford testosterone **8** and 19-nortestosterone **9** in 82% and 63% yield, respectively (Scheme 2).

A typical procedure is as follows (Table 1, entry 3): A mixture of D-glucal (231 mg, 1.58 mmol), Pd/C

**Scheme 2.**

(Aldrich, 47.8 mg), nitrobenzene (54.4  $\mu$ L, 0.53 mmol) and CH<sub>3</sub>CN (2 mL) was stirred at 50 °C for 48 h. After confirmation of the completion of the reaction, pyridine (0.8 mL) and acetic anhydride (0.6 mL) were added, and the whole was stirred for 12 h at room temperature. The palladium precipitate was filtered through a small amount of Celite and the filtrate was concentrated. Purification by silica-gel column chromatography afforded the product (342.9 mg, 99%). The ratio **2:3** was determined as 98:2 by <sup>1</sup>H NMR analysis. All spectral data of the products were consistent with those reported.<sup>12</sup>

In conclusion, the present method has the following characteristic features: (1) Secondary allylic alcohols are oxidized to the corresponding enones in high yield. (2) Nitrobenzene works as an efficient hydrogen acceptor. Three moles of hydrogen are captured by one mole of nitrobenzene. (3) The reactions take place under mild and environment-friendly conditions.

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### Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.tetlet.2005.05.095](https://doi.org/10.1016/j.tetlet.2005.05.095).

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