

Ruthenium Complex-catalysed Synthesis of 1,3-Disubstituted 2,3-Dihydroimidazol-2-ones from *N,N'*-Disubstituted Ureas and Vicinal Diols

Teruyuki Kondo, Shinji Kotachi and Yoshihisa Watanabe*

Department of Hydrocarbon Chemistry, Faculty of Engineering, Kyoto University, Sakyo-ku, Kyoto 606-01, Japan

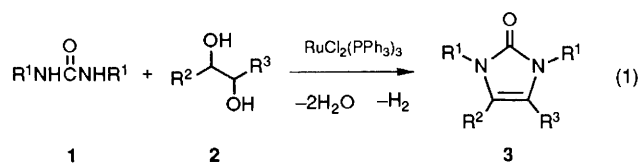
Various 1,3-disubstituted 2,3-dihydroimidazol-2-ones are readily prepared by the reaction of *N,N'*-disubstituted ureas with vicinal-diols in the presence of a catalytic amount of ruthenium complex in fair to good yields.

Recently, interest in the chemistry of imidazole and imidazolone derivatives has been stimulated by their importance as intermediates in the synthesis of naturally occurring compounds such as biotin, hydantoin and allantoin.¹ However, there are few facile and widely applicable synthetic routes to imidazolones in particular,² and to the best of our knowledge, there are no examples of transition metal complex-catalysed syntheses of imidazolones. In the course of our studies on ruthenium catalysis, we have already reported ruthenium-catalysed *N*-alkylation of amines³ and amides⁴ with alcohols, and *N*-heterocyclization of aromatic amines with alcohols⁵ or diols.⁶ Here, we report the first example of a novel ruthenium-catalysed selective synthesis of 1,3-disubstituted 2,3-dihydroimidazol-2-ones from *N,N'*-disubstituted ureas and vicinal-diols [eqn. (1)].

Representative results are summarized in Table 1. For example, the reaction of *N,N'*-dimethylurea with propylene glycol in the presence of a catalytic amount of RuCl₂(PPh₃)₃

afforded 1,3,4-trimethyl-2,3-dihydroimidazol-2-one in 79% yield (run 2). Although Butler *et al.* reported the synthesis of 2,3-dihydroimidazol-2-ones from ureas and acyloins, *N,N'*-disubstituted ureas did not react with acyloins and the corresponding 1,3-disubstituted 2,3-dihydroimidazol-2-ones could not be synthesized.^{2c} The present reaction, therefore, offers a novel and effective method for the selective synthesis of 1,3-disubstituted 2,3-dihydroimidazol-2-ones.

Various 1,3-disubstituted 2,3-dihydroimidazol-2-ones were obtained from the reaction of *N,N'*-disubstituted ureas with vicinal-diols in fair to good yields. On the other hand, when *N*-ethylurea was employed in the reaction with butane-2,3-diol, the mixture of 1-ethyl-4,5-dimethyl-2,3-dihydroimidazol-2-one and 1,3-diethyl-4,5-dimethyl-2,3-dihydroimidazol-2-one was obtained (*ca.* 7 : 3). The latter product, *i.e.* 1,3-diethyl-4,5-dimethyl-2,3-dihydroimidazol-2-one, might be obtained from the reaction of *N,N'*-diethylurea, which was generated by the thermal disproportionation of *N*-ethylurea,^{7†} with butane-2,3-diol.



† A similar reaction feature was observed in our previously reported ruthenium-catalysed synthesis of *N,N'*-diarylureas from *N*-arylsubstituted formamides and aminoarenes.⁸

Table 1 RuCl₂(PPh₃)₃-catalysed synthesis of 1,3-disubstituted 2,3-dihydroimidazol-2-ones from *N,N'*-disubstituted ureas and vicinal-diols^a

Run	Urea	Diol	Product ^b (%)
1 ^c			73
2 ^d			79
3 ^e			51
4 ^f			40
5			20 ^g
6			70

^a A mixture of *N,N'*-disubstituted urea (5.0 mmol), diol (10 mmol), RuCl₂(PPh₃)₃ (0.20 mmol) and THF (4.0 ml) was heated at 180 °C for 12 h under an argon atmosphere. ^b Determined by GLC. ^c For 24 h. ^d A 50 ml Pyrex flask equipped with a reflux condenser was employed as a reactor in place of a 50 ml stainless autoclave and the reaction was carried out under reflux in diglyme (5.0 ml) for 12 h. ^e A mixture of *cis*- and *trans*-cyclohexanediol was used. ^f For 6 h. ^g Isolated yield.

The effect of reaction temperature was examined in the reaction of *N,N'*-dimethylurea with ethylene glycol. At 180 °C, 1,3-dimethyl-2,3-dihydroimidazol-2-one was obtained in 40% yield (run 4 in Table 1). The present reaction also proceeded at 150 °C (yield 35%), but at 120 °C, the yield of 1,3-dimethyl-2,3-dihydroimidazol-2-one was only 8%.

Furthermore, catalytic activities of several transition metal complexes in the reaction of *N,N'*-dimethylurea with butane-2,3-diol were examined and the results are summarized in Table 2. RuCl₂(PPh₃)₃ showed high catalytic activity, but RuCl₃·*n*H₂O showed quite low catalytic activity (runs 1 and 2). Among the other group 8–10 metal complexes, only the PtCl₂(PhCN)₂-SnCl₂·2H₂O system, which also catalyses *N*-alkylation of amines with alcohols,⁹ showed catalytic activity (run 3). However, rhodium and palladium complexes showed almost no catalytic activities (runs 6 and 7).

During the present reaction, a stoichiometric amount of gaseous hydrogen evolved spontaneously.‡ Thus, the addition of a hydrogen acceptor is not necessary in the present reaction.

‡ After the reaction of *N,N'*-dimethylurea (10 mmol) with butane-2,3-diol (5.0 mmol) in the presence of RuCl₂(PPh₃)₃ (0.20 mmol) under reflux in diglyme (5.0 ml) for 12 h, 4.0 mmol of hydrogen was detected in the gas phase, together with the formation of 1,3,4,5-tetramethyl-2,3-dihydroimidazol-2-one in 63% yield.

Table 2 Catalytic activities of several transition metal complexes in the reaction of *N,N'*-dimethylurea with butane-2,3-diol^a

Run	Catalyst (mmol)	Yield ^b (%)
1 ^c	RuCl ₂ (PPh ₃) ₃ (0.20)	73
2	RuCl ₃ · <i>n</i> H ₂ O(0.05)	5
3	PtCl ₂ (PhCN) ₂ (0.10) + SnCl ₂ ·2H ₂ O(0.10)	43
4	PtCl ₂ (PPh ₃) ₂ (0.10) + SnCl ₂ ·2H ₂ O(0.10)	8
5	SnCl ₂ ·2H ₂ O(0.10)	0
6	RhCl(PPh ₃) ₃ (0.10)	7
7	PdCl ₂ (PPh ₃) ₂ (0.10)	0

^a A mixture of *N,N'*-dimethylurea (5.0 mmol), butane-2,3-diol (10 mmol), catalyst, and THF (4.0 ml) was heated at 180 °C for 6 h under an argon atmosphere. ^b The yield of 1,3,4,5-tetramethyl-2,3-dihydroimidazol-2-one determined by GLC. ^c For 24 h.

We now believe that ruthenium-catalysed oxidation of vicinal-diols to the corresponding acyloins should be the key step of the present reaction as in our previously reported *N*-alkylation of amines with alcohols catalysed by a ruthenium complex.³ The subsequent condensation of ureas with carbonyl compounds¹⁰ (in the present reaction, acyloins) and dehydration of the condensation products¹¹ have been already ascertained. Actually, under the present reaction conditions, acetoin instead of butane-2,3-diol reacted smoothly with *N,N'*-dimethylurea even in the absence of RuCl₂(PPh₃)₃ catalyst to give 1,3,4,5-tetramethyl-2,3-dihydroimidazol-2-one in good yield (*ca.* 80%).

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