NOVEL SYNTHESIS OF DIAZETIDINE-2,4-DIONE BY RING EXPANSION OF DIAZIRIDINONE

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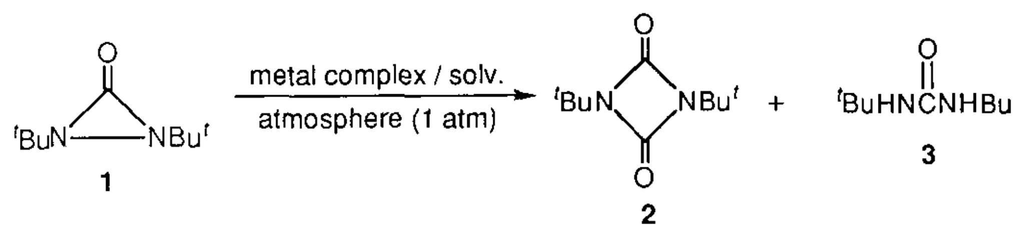
Abstract-Treatment of *N,N'*-di-*tert*-butyldiaziridinone with $Ni(CO)_4$ under an atmosphere of carbon monoxide caused a carbonylative ring expansion to give di-*tert*-butyldiazetidinedione in good yield. In the presence of diphenylketene under the conditions, azetidinedione derivative was obtained.

Three-membered heterocycles have long been known as potential building blocks for the synthesis of numerous types of heterocycles.[1] Among such small rings, diaziridinones[2] would be expected to show unique ring-opening reactivity because of their highly strained three-membered structures which consist of a carbonyl carbon and two nitrogen atoms.[1-3] In fact, cycloaddition and addition-cyclization reactions of *N,N'*-di-*tert*-butyldiaziridinone (**1**) have already been reported by our group[4] and by Greene and co-workers.[5] It is also noteworthy that the carbonylative ring expansion of heterocycles has been developed by Alper's group,[6] especially as this relates to small ring heterocycles. A carbonylation reaction of this type represents a useful method in organic synthesis, since it provides a convenient and effective one-pot procedure for ring homologation. From these points of view, we report herein the transition metal-mediated carbonylative ring expansion of a diaziridinone (**1**) leading to 1,3-diazetidine-2,4-dione derivative. It is well kown that diazetidinedione derivatives can be converted into functional materials and that some have fungicidal, herbicidal and insecticidal activities.[7] These facts prompted us to investigate this reaction as a new procedure for the synthesis of diazetidinedione.[8]



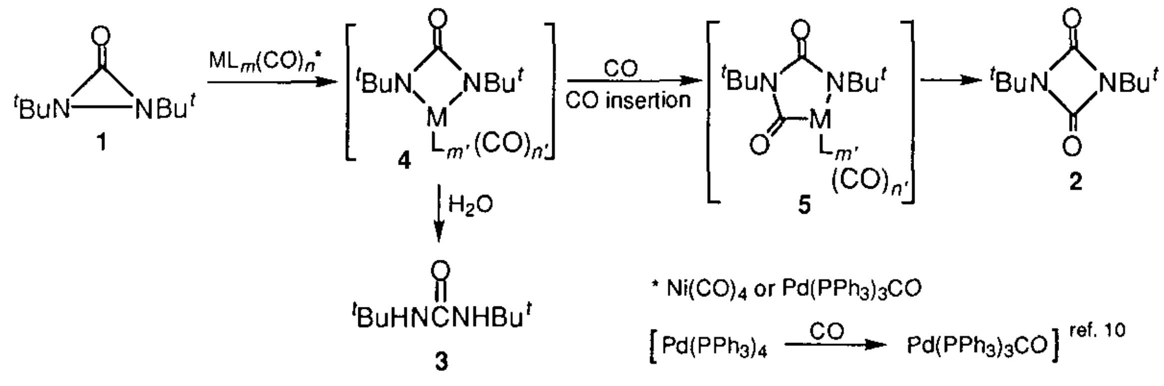
Treatment of *N,N'*-di-*tert*-butyldiaziridinone (**1**) with an equimolar amount of $Ni(CO)_4$ under an atmosphere of carbon monoxide in DMF at 50 °C for 3 h afforded di-*tert*-butyldiazetidinedione (**2**) in 62% yield, along with *N,N'*-di-*tert*-butylurea (**3**) in 13% yield (Table 1, run 1). The suitable reaction temperature and time were found to be 70 ~ 90 °C and 1 ~ 3 h, respectively (runs 2-5).[9] Since the yield of the reaction was drastically decreased when the reaction was run under nitrogen atmosphere, CO was required for the reaction (run 6). When 0.1 equiv of $Ni(CO)_4$ was employed, a small amount of **2** was obtained under the conditions (run 7). The use of THF as a solvent instead of DMF was not effective for the reaction (run 8). Diazetidinedione (**2**) was not obtained in the case with $Fe(CO)_5$ or $W(CO)_6$ instead of $Ni(CO)_4$ (runs 9, 10). It was found that 0.1 equiv of $Pd(PPh_3)_4$ catalyzed the present reaction to give **2** in 35% yield (run 11).[10] These results indicate that $Ni(CO)_4$ and $Pd(PPh_3)_4$ both represent viable catalysts for the insertion of CO into the nitrogen-nitrogen bond of diaziridinone (**1**). A ring expansion accompanied by the fission of the nitrogen-nitrogen bond of **1** is very rare, but one instance of which has been previously reported by us.[4]

Table 1. Carbonylation of Diaziridinone **1** Using Metal Complex under a CO Atmosphere

run	metal complex (equiv)	solv.	atmosphere	temp. (°C)	time (h)	yield (%)	
						2	**3**
1	$Ni(CO)_4$ (1)	DMF	CO	50	3	62	13
2	$Ni(CO)_4$ (1)	DMF	CO	70	3	71	13
3	$Ni(CO)_4$ (1)	DMF	CO	70	1	75	15
4	$Ni(CO)_4$ (1)	DMF	CO	70	10	72	17
5	$Ni(CO)_4$ (1)	DMF	CO	90	3	74	15
6	$Ni(CO)_4$ (1)	DMF	N_2	70	3	37	10
7	$Ni(CO)_4$ (0.1)	DMF	CO	70	3	1	12
8	$Ni(CO)_4$ (1)	THF	CO	reflux	3	25	25
9	$Fe(CO)_5$ (1)	DMF	CO	70	3	0	26
10	$W(CO)_5$ (1)	DMF	CO	70	3	0	12
11	$Pd(PPh_3)_4$ (0.1)	DMF	CO	70	3	35	26

A possible mechanism for carbonylative ring expansion of diaziridinone (**1**) is shown in Scheme 1. The oxidative addition of diaziridinone could occur on the metal [$Ni(CO)_4$ or $Pd(PPh_3)_3CO$] with

Scheme 1. Possible Mechanism for Formation of **2** and **3**.

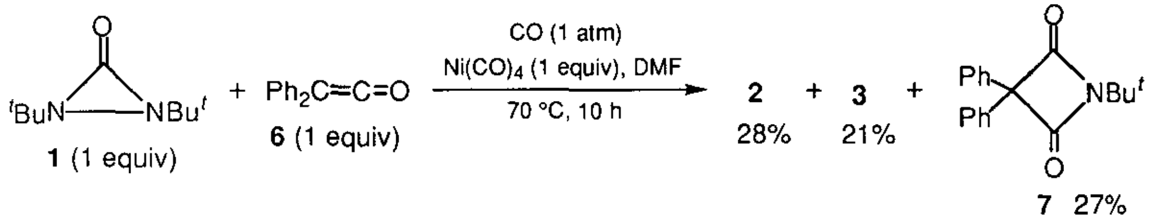


* $Ni(CO)_4$ or $Pd(PPh_3)_3CO$

$[Pd(PPh_3)_4 \xrightarrow{CO} Pd(PPh_3)_3CO]$ ref. 10

cleavage of the nitrogen-nitrogen bond of **1**. Subsequently, the insertion of carbon monoxide into the nitrogen-metal bond of complex (**4**) could proceed to give metallacycle (**5**), followed by reductive elimination to afford diazetidinedione (**2**). The urea derivative (**3**) would be formed by the reaction of the unreacted complex (**4**) with water either in DMF or during work up.

The above results led us to investigate the application of the present reaction system to another type of reaction, which involves a dipolalophile. When diaziridinone (**1**) was treated with diphenylketene (**6**) in the presence of $Ni(CO)_4$ under an atmosphere of CO, the azetidinedione derivative (**7**) was obtained in 27% yield, along with **2** and **3**. Azetidinedione (**7**) does not represent a 1 : 1 cycloadduct of **1** with diphenylketene, but formally that of *N*-*tert*-butylisocyanate with diphenylketene. Although the reaction paths leading to **7** are not clear, possible pathways can be considered. Since compound (**7**) was not obtained by the reaction of isolated **2** with **6** under the present conditions, diphenylketene would react with either intermediate (**4**) followed by insertion of CO and reductive elimination, or intermediate (**5**) followed by reductive elimination, to give **7**. While azetidine-2,4-diones can be prepared by the carbonylation of α-lactams,[11] our findings demonstrate the possibility of a unique ring expansion reaction with appropriate dipolarophiles accompanied by carbonylation.



In summary, we have demonstrated here a novel synthesis of diazetidine-2,4-dione by a ring expansion reaction of *N*,*N*'-di-*tert*-butyldiaziridinone with carbon monoxide utilizing $Ni(CO)_4$ or $Pd(PPh_3)_4$. The present reaction is the first approach to such heterocycles by CO insertion into diaziridinone involving cleavage of its N-N bond. Interestingly, the reaction proceeded catalytically in the case with $Pd(PPh_3)_4$. Moreover, a new methodology to synthesize the 4-membered rings has been developed by the reaction of diaziridinone-$Ni(CO)_4$-CO system with diphenylketene. An investigation of this reaction in the presence of other dipolarophiles is now underway.

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8. Only one preparative method has been reported to date; see, J. C. Stowell, *J. Org. Chem.*, 1971, **36**, 3056.
9. The general procedure is as follows: A solution of diaziridinone (**1**) (199 μL, 1 mmol) and $Ni(CO)_4$ (130 μL, 1 mmol) in DMF (2.3 mL) was stirred under a carbon monoxide atmosphere at 70 °C. After 1 h, 1*N* HCl was added, and the resulting white precipitate was collected by filtration and purified by sublimation (80 °C, 1 mmHg) to give **2** (148.5 mg) in 75% yield. The filtrate was extracted with ether (100 mL X 3), washed with water (50 mL X 3) and dried over $MgSO_4$. After filtration, the solvent was evaporated to give **3** (25.4 mg) in 15% yield.
10. It is known that the reaction of $Pd(PPh_3)_4$ with CO affords $Pd(PPh_3)_3CO$; see, H. Alper, C. P. Perera, and F. R. Ahmed, *J. Am. Chem. Soc.*, 1981, **103**, 1289.
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