Highly Selective Insertion into Aromatic C–H Bonds in Rhodium(II) Triphenylacetate-catalysed Decomposition of α-Diazocarbonyl Compounds

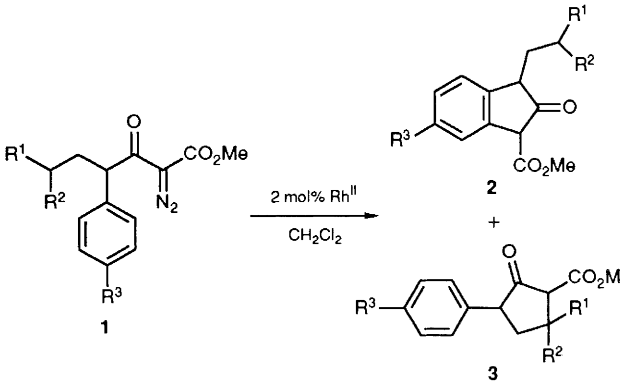
Shun-ichi Hashimoto, Nobuhide Watanabe and Shiro Ikegami*

Faculty of Pharmaceutical Sciences, Teikyo University, Sagamiko, Kanagawa 199-01, Japan

Rhodium(II) triphenylacetate, which features a bulky bridging ligand, has been demonstrated to exhibit an exceptionally high order of selectivity for aromatic C–H insertion over aliphatic C–H insertion or cyclopropanation in catalytic decompositions of α-diazocarbonyl compounds, thus providing an expedient and general entry to variously substituted indan-2-ones.

With the advent of rhodium(II) carboxylate catalysts, intramolecular C–H insertion reactions of α-diazocarbonyl compounds have offered a potentially powerful tool for the construction of both carbocycles, especially cyclopentanones, and heterocycles.[1,2] Lack of site-selectivity, however, appears to preclude their application to the synthesis of complex organic molecules. Considering that the bridging ligand of the rhodium(II) catalysts is one of the most fundamental factors responsible not only for the reactivity but also for the site selectivity in C–H insertion reactions, our efforts centred upon the development of new rhodium(II) catalysts. Recently we have disclosed that rhodium(II) triphenylacetate [$Rh_2(tpa)_4$], which features a bulky bridging ligand on the rhodium, exhibits an exceptionally high order of selectivity for C–H insertion into methylene over methine in catalytic decompositions of α-diazo-β-keto esters appended to a cyclic system, affording bicyclic compounds in preference to spirocyclic compounds.[3] As yet another interesting and synthetically useful feature of this catalyst, we now report that [$Rh_2(tpa)_4$] exhibits virtually complete selectivity for aryl insertion not only over aliphatic insertion but also over cyclopropanation in competitive catalytic decompositions of α-diazocarbonyl compounds, providing an expedient and general entry to variously substituted indan-2-ones.

Despite a number of reports on intramolecular direct C–H insertion into aromatic and heteroaromatic rings,[2,4] only limited attention has been focused on systems where both aromatic and aliphatic C–H insertions are possible.[5–7] In this context, Taber and Ruckle, Jr. demonstrated that aryl insertion was approximately equal in energy with methylene insertion through the [$Rh_2(OAc)_4$]-catalysed competitive



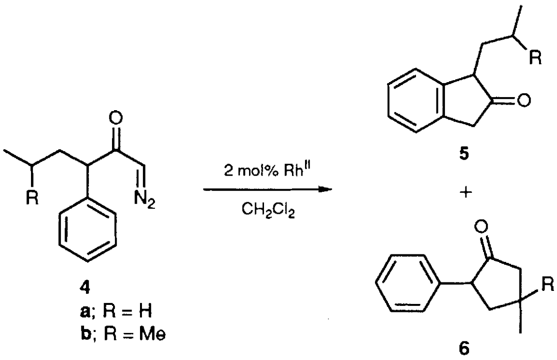
a; R^1 = Me, R^2 = R^3 = H
b; R^1 = R^2 = Me, R^3 = H
c; R^1 = H, R^2 = CH=CH$_2$, R^3 = H
d; R^1 = H, R^2 = Ph, R^3 = H
e; R^1 = R^2 = R^3 = Me
f; R^1 = R^2 = Me, R^3 = OMe
g; R^1 = R^2 = Me, R^3 = F

Scheme 1

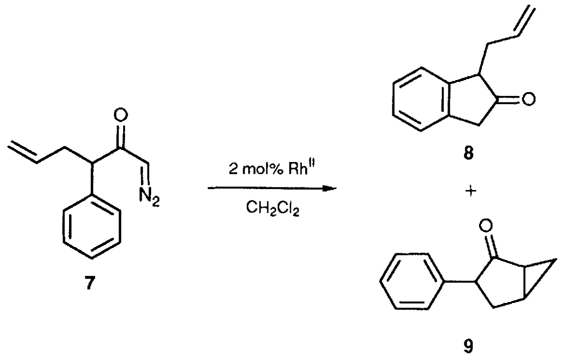
Table 1 Rhodium(II)-catalysed intramolecular C–H insertion of α-diazo-β-keto esters **1**[a]

					Product[b]	
Entry	Substrate	Catalyst	*T*/°C	*t*/h	Yield (%)[c]	**2**:**3**[d]
1	**1a**	[$Rh_2(OAc)_4$]	23	5	86	54:46
2	**1a**	[$Rh_2(O_2CCF_3)_4$]	0	1	74	79:21
3	**1a**	[$Rh_2(O_2CPh)_4$]	0	5	84	76:24
4	**1a**	[$Rh_2(O_2CCMe_3)_4$]	0	1	81	56:44
5	**1a**	[Rh_2(1-adamantate)$_4$]	23	1	86	54:46
6	**1a**	[$Rh_2(NHAc)_4$]	23	4	71	71:29
7	**1a**	[$Rh_2(O_2CCHPh_2)_4$]	0	1.5	90	85:15
8	**1a**	[$Rh_2(O_2CCMePh_2)_4$]	0	1.5	84	96:4
9	**1a**	[$Rh_2(O_2CCPh_3)_4$]	23	5	92	96:4
10	**1b**	[$Rh_2(OAc)_4$]	23	3	75	38:62
11	**1b**	[$Rh_2(O_2CCMePh_2)_4$]	23	3	95	93:7
12	**1b**	[$Rh_2(O_2CCPh_3)_4$]	40	8	78	>99:<1[e]
13	**1c**	[$Rh_2(O_2CCPh_3)_4$]	23	7	75	>99:<1[e]
14	**1d**	[$Rh_2(O_2CCPh_3)_4$]	23	5	80	>99:<1[e]
15	**1e**	[$Rh_2(O_2CCPh_3)_4$]	40	8	82	>99:<1[e]
16	**1f**	[$Rh_2(O_2CCPh_3)_4$]	40	8	81	>99:<1[e]
17	**1g**	[$Rh_2(OAc)_4$]	23	2	94	<1:>99[e]
18	**1g**	[$Rh_2(O_2CCPh_3)_4$]	40	6	75	>99:<1[e]

[a] Rhodium(II) catalyst (0.012 mmol) was added in one portion to a stirred solution of **1** (0.6 mmol) in CH_2Cl_2 (10 ml) at the indicated temperature under argon atmosphere. After the reaction was complete, the mixture was concentrated *in vacuo*, and chromatographed. [b] All new compounds were fully characterized by ^1H NMR (400 MHz), IR and high resolution mass spectral analysis. [c] Isolated total yield. [d] The ratio was based on the isolated yield. [e] The minor product was not detected.



Scheme 2



Scheme 3

cyclisation of α-diazo-β-keto ester **1a**, which gave the indan-2-one **2a** and the cyclopentanone **3a** in a ratio of 1.2 : 1.[5] Thus we directed our initial efforts to intramolecular C–H insertion of **1a** with a variety of rhodium(II) catalysts (2 mol%) with differing electronic and steric influences imparted on the rhodium(II) centre by its ligands (Scheme 1). A seen from Table 1, [$Rh_2(tpa)_4$] and rhodium(II) 2,2-diphenylpropionate proved to be the catalysts of choice for causing predominant insertion into the aromatic C–H bond over the methylene C–H bond (entries 8 and 9). From the fact that rhodium(II) diphenylacetate, which has similar electronic properties showed a modest selectivity (entry 7), it was suggested that the larger steric bulk of the bridging ligand on the rhodium might retard the methylene C–H insertion to favour predominantly the aromatic C–H insertion. This effect was more pronounced when the methine C–H bond was put into competition with the aromatic one. Cyclisation of **1b** catalysed by [$Rh_2(tpa)_4$] led exclusively to the formation of **2b** with no detectable amount of **3b** (entry 12), whereas rhodium(II) 2,2-diphenylpropionate slightly diminished the selectivity (entry 8 *vs.* 11). Since methine insertion is demonstrated to be electronically favoured but sterically disfavoured when compared to methylene insertion,[5] these results can be well accounted for by the difference in steric shielding by the bridging ligands on the rhodium, demonstrating the exceptional bulkiness of the bridging triphenylacetate ligands that overrides the electronic effects. While the mechanistic profile is not clear at present, it is also noteworthy that the steric bulk of the ligands does not appear to interfere with aromatic C–H insertions. The additional examples listed in Table 1 show that the highly selective C–H insertion process with [$Rh_2(tpa)_4$] allows for considerable variation in both aliphatic chains and aromatic rings. In this regard, it is of particular interest that the complete reversal of the site selection was observed with 4-fluoro derivative **1g** by switching the catalyst from [$Rh_2(OAc)_4$] to [$Rh_2(tpa)_4$] (entry 17 *vs.* 18).

Armed with these results, the similar competitive cyclisation with α-diazoketones **4** was next explored. While Nakatani reported that [$Rh_2(OAc)_4$]-catalysed intramolecular C–H insertion of **4a** produced **5a** and **6a** in 65 and 13% yields, respectively,[6] we were gratified to find that virtually complete selectivity (>99 : 1) for aromatic C–H insertion was achieved with **4b** as well as with **4a** through the use of [$Rh_2(tpa)_4$] (Scheme 2, 0 °C, 15 min) (% isolated yield; **5a**, 80; **5b**, 84).

Finally, it is worth noting that [$Rh_2(tpa)_4$] catalysis favours aryl insertion over cyclopropanation. Thus, [$Rh_2(tpa)_4$]-catalysed cyclisation of **7** (0 °C, 15 min) led to the formation of the indan-2-one **8** in 83% yield, with no trace of the cyclopropane **9**, whereas [$Rh_2(OAc)_4$]-catalysis of **7** was reported to give **8** and **9** in 26 and 63% yields, respectively (Scheme 3).[6]

In summary, the superiority of [$Rh_2(tpa)_4$] over the commonly used catalysts has been further demonstrated by virtually complete selectivity for aromatic C–H insertion. The present catalytic process has advantages of providing a facile access to variously substituted indan-2-ones,[8] and has practical value as well as operational simplicity.

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