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1,6-dienes with N-Tosyl Hydrazones

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A palladium-catalyzed heck-type cascade cyclization of (Z)-1-lodo-1,6-dienes with N-tosyl hydrazones was reported. Alkylpalladium intermediate coupled with diazo compound generating the second alkylpalladium species bearing two β -H, which generated terminal alkene as major products in anti-Zaitsev way via the highly regioselective β -H elimination. It provided a new way to synthesize tetrahydropyridine derivates bearing terminal alkene.

Diazo compounds have been found wide applications in modern synthetic chemistry since Noyori reported the asymmetric cyclopropanation of alkenes with diazo compounds in the 1960s.^[1] In particular, transition-metal catalyzed transformations via active metal-carbene intermediates, played an important role in the revolution of modern organic synthetic methods.^[2] Compared to the wellestablished Rh, Cu, and Ru catalyzed reactions, palladiumcatalyzed transformations involving Pd-carbene intermediates have received relative less attention, which might due to the huge different reactivity of palladium-carbene species with the corresponding Rh(II) and Cu(I) compounds.^[3] The palladium carbenes have been proposed as active intermediates in some involved reactions,^[4] however, nondiazo the migration/insertion process was first demonstrated in the palladium-catalyzed reaction of benzyl halides and (trimethylsilyl)diazomethane by Van Vranken group in 2001.^[5] From then on, various elegant transformations have been achieved in palladium carbene involved cross-couplings^[6] by Van Vranken,^[7] Wang,^[8] Barluenga and Valdés,^[9] and others.^[10]

So far, there are some procedures for the construction of carbon-carbon double bond via palladium carbene intermediates, among which N-tosyl hydrazones has been

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coupling reactions.^[11] Wang group reported the cross-coupling of terminal alkynes with carbene precursors bearing θ -H to construct conjugated enynes (a, scheme 1).^[8e] For the Csp^2 coupling with carbene precursors bearing θ -H, polysubstituted alkenes could be delivered (Scheme b).^[8d,8f,9,10d-e,10j-o] Some strategies were also realized in the reaction of benzyl/allyl halides and carbene precursors to afford styrene or 1,3-diene derivatives (Scheme 1c).^[5,7a,8a-b] Although Pd-catalyzed crosscoupling reactions using N-tosyl hydrazones as carbene precursors has been extensively investgated in the past years, it is still rare on the reactions between alkylpalladium and carbenes,^[9f] which might be a new protocol for the construction of functionalized alkenes.

developed into a convenient carbenes precursor in numerous

Our group has kept on developing new methodologies on



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Heck-type reactions.^[12] The key alkylpalladium intermediate inspired us to study its reaction with carbene intermediates, which has rarely been explored.^[7d] In 2013, Gu group reported a palladium-catalyzed Heck-type cascade reaction of organic halides with N-tosyl hydrazones via the alkylpalladium species $IV^{[13]}$ bearing one θ -H (d, scheme 1). (Z)-1-lodo-1,6-dienes was a valuable block in constructing kinds of heterocycles reported by Tong group.^[14] To our interest, if vinyl iodide **1a** reacts with 2 to generate the alkylpalladium intermediate V, there will be two β -H to eliminate. Basing on the thermodynamic stability, 3aa-II was proposed to be the major products (e, scheme 1), however, the kinetics determined terminal alkene 3aa-I was obtained as the major product (f, scheme 1). Herein, we reported our new research on palladium-catalyzed cascade reaction of of (Z)-1-lodo-1,6-dienes and N-tosyl hydrazones to construct tetrahydropyridine derivatives possessing a terminal alkene.

Initially, our study commenced with cascade reaction of (Z)-N-(3-iodo-2-phenylallyl)-4-methyl-N-(2-methylallyl)benzenesulfonamide 1a with 4-methyl-N'-(1phenylethylidene)benzenesulfonohydrazide 2a catalyzed by PdCl₂(PPh₃)₂ using 3.0 equivalent of tBuOLi as base in MeCN under N₂ (Entry 1, Table 1). As expected, a mixture with two isomers terminal alkene 3aa-I and internal alkene 3aa-II were obtained in 39% yield with a ratio of 78:22 (Entry 1). When PdCl₂(dppf) was used, the yield was not so good, but the ratio of **3aa-I** and **3aa-II** was improved to 90:10 (Entry 2). Delightfully, the yield could be increased to 53% by using $Pd(PPh_3)_4$ with a ratio of 82:18 (entry 3). Interestingly, the combination of Pd(OAc)₂ and PPh₃ gave product up to 88% yield and 89:11 ratio (entry 4). Gratifily, the desired products was obtained in 88% by using Pd(dba)₂/PPh₃, and the teminal alkene selectivity was up to 88 to 12(entry 5). Furthermore, we

Table 1 Reaction Optimizations ^{a,b}					
F	Ph-) → N ₂ HTs + N ₂ HTs Ph Me	Cataylst/Ligand tBuOLi/MeCN T, N2	s Me	h Ph Me Ph + N Me Me
	1a	2a	3aa	-1	3aa-II
	entry	catalyst	ligand	<i>t</i> [°C]	Yield% ^b (3aa-I:II)
	1	PdCl ₂ (PPh ₃) ₂	-	80	39 (78:22)
	2	PdCl ₂ (dppf)	-	80	32 (90:10)
	3	$Pd(PPh_3)_4$	-	80	53 (82:18)
	4	Pd(OAc) ₂	PPh ₃	80	82 (89:11)
	5	Pd(dba)₂	PPh ₃	80	88 (88:12)
	6	Pd(dba) ₂	PCy ₃	80	65 (86:14)
	7	Pd(dba) ₂	P(2-furyl) ₃	80	76 (85:15)
	8	Pd(dba) ₂	dppe	80	33 (84:16)
	9	Pd(dba) ₂	dppp	80	37 (88:12)
	10	Pd(dba) ₂	dppf	80	28 (91:9)
	11	Pd(dba) ₂	BINAP	80	30 (89:11)
	12	Pd(dba) ₂	PPh_3	50	78(90:10)
^a Reaction conditions: 1a (0.2 mmol 1.0 equiv.) 2a (0.24)					

[°]Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), **2a** (0.24 mmol, 1.2 equiv.), [Pd] (0.01 mmol, 5 mol%), Ligand (0.02 mmol, 10 mol%), tBuOLi (0.6 mmol, 3.0 equiv.), MeCN (2.0 mL). ^bIsolated yields.

screeninged several ligands, such as PCy₃, P(2-furyl)₃, dppe, dppp, dppf and BINAP, however, no better results were obtained (entries 6-11). If the temperature was lowered down to 50 °C, the yield was decreased to 78% though the ratio was a little better (entry 12). Finally, Pd(dba)₂ (5 mol%), PPh₃ (10 mol%) and tBuOLi (3.0 equiv.) in MeCN at 80 °C under N₂ atmosphere were chosen to the standard conditions (entry 5). With the optimized conditions in hand, we then aimed to



^aReaction conditions: **1** (0.2 mmol, 1.0 equiv.), **2** (0.24 mmol, 1.2 equiv.), Pd(dba)₂ (0.01 mmol, 5 mol%), PPh₃ (0.02 mmol, 10 mol%), tBuOLi (0.6 mmol, 3.0 equiv.), solvent (2.0 mL). ^bIsolated yields. ^C**3-I:3-II** is the ratio of terminal alkene and internal alkene.

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^aReaction conditions: **1** (0.2 mmol, 1.0 equiv.), **2** (0.24 mmol, 1.2 equiv.), Pd(dba)₂ (0.01 mmol, 5 mol%), PPh₃ (0.02 mmol, 10 mol%), *t*BuOLi (0.6 mmol, 3.0 equiv.), solvent (2.0 mL). ^bIsolated yields. ^c**5-I:5-II** is the ratio of terminal alkene and internal alkene.

explore the substrate scope. It was found that the scope of the N-tosyl hydrazones 2 was expansive, allowing for efficient coupling with 1 (Table 2). The aryl hydrazones bearing strong electron-donating group such as methoxyl, provided the desired product in good yield (3ab and 3ac). Halides substitutions on the phenyl could survive very well (3ad-3ah). Not only fluro and chloro, but also bromo and iodo could afford the corresponding products in moderate to high yields. It was worth mentioning that the products bearing active bromo and iodo substitutions could be easily transferred to more complex molecules via cross-couplings, which was potential applied in synthsis (3af-3ah). The strong electronwithdrawing group such as CN, could provide the product in relative low yield (3ai). The reaction of substrates bearing alkyl (e.g. ethyl, butyl and dodecyl) could afford the corresponding terminal alkenes in good to excellent yields (3ba-3da). The reaction of 1a and N-tosyl benzaldehyde hydrazones 2j could also give the internal alkenes 3aj in 87% yield. To investigate the steric effect to regioselectivity, more bulky groups nBu and Ph at the C=C bond of substrate 1 were tested and gave corresponding terminal alkenes (3ea-3fa) with better selectivity. Notably, the substrate N-tosyl benzaldehyde hydrazones 2k lead to corresponding product 3ak in 83% yields with totally E selectivity, which was confirmed via the result of NOESY spectra.

Subsequently, substrates containing oxygen tether were also tested under the standard conditions (Table 3). Both aromatic vinyl iodides bearing electron withdrawing/donating group and alkyl iodides delivered the corresponding products in good yield (**5aa-5ea**). The bromo group on substrate **b** could



survive very well under the standard condition, afford **5eb** in 75% yield.

A plausible catalytic cycle for this cross-coupling reaction was shown in Scheme 2. It might start with the oxidative addition of the (Z)-N-(3-iodo-2-phenylallyl)-4-methyl-N-(2methylallyl)-benzenesulfonamide 1a to palladium(0) to generate the palladium(II) complex 6. After the intramolecular insertion via 6-exo cyclization, alkylpalladium species 7 was formed. Subsequently, the reaction of 7 with carbene which generated via dediazoniation of the in situ generated diazo compound 9, produced the second alkylpalladium species 8, bearing two β -hydride. The elimination of β -H_a delivered the major product terminal alkene **3aa-I** via anti Zaitsev way. Considering on the structure of intermediate 8, H_a is less hinder than H_b, so the dynamically stable product **3aa-I** was easy to be generated. Alternatively, the minor product was the thermodynamically stable alkene **3aa-II** formed via β -H_b elimination.

Conclusions

In conclusion, we developed a palladium-catalyzed heck-type intramolecularly cyclization of (Z)-1-lodo-1,6-dienes and coupling with N-tosyl hydrazones. It provided a new way to synthesize tetrahydropyridine derivates bearing terminal alkene. The highly regioselective β -H elimination produced dynamically stable terminal alkene as major product rather than thermodynamic stable internal alkenes, which might due to the steric hindrance of β -H in palladium intermediate **8**. Investigation to the mechanism and further applications of this methodology will be reported in due cause.

Conflicts of interest

There are no conflicts to declare.

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Notes and references

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- 1 H. Nozaki, S. Moriuti, H. Takaya, R. Noyori, *Tetrahedron Lett*. 1966, **7**, 5239.
- 2 (a) T. Ye, M. A. McKervey, Chem. Rev., 1994, 94, 1091. (b) M.
 P. Doyle, M. A. McKervey, T. Ye, Modern Catalytic Methods for Organic Synthesis with Diazo Compounds, Wiley, New York, 1998. (c) F. Z. Dörwald, Metal Carbenes in Organic Synthesis, Wiley-VCH, Weinheim, 1999. (d) P. A. Evans, Modern Rhodium-Catalyzed Organic Reactions, Wiley-VCH, Weinheim, 2005. (e) Y. Xia, D. Qiu, J. Wang, Chem. Rev., 2017, 117, 13810.
- 3 (a) A. J. Anciaux, A. J. Hubert, A. F. Noel, N. Petiniot, P. Teyssié, J. Org. Chem., 1980, 45, 695. For a review, see: (b) M. P. Doyle, Chem. Rev., 1986, 86, 919.
- 4 T. Mitsudo, M. Kadokura, Y. Watanabe, *Tetrahedron Lett.*, 1985, **26**, 5143.
- 5 K. L. Greenman, D. S. Carter, D. L. Van Vranken, *Tetrahedron*, 2001, **57**, 5219.
- For some reviews, see: (a) Z. Zhang, J. Wang, *Tetrahedron*, 2008, 64, 6577. (b) N. M. G. Franssen, A. J. C. Walters, J. N. H. Reek, B. de Bruin, *Catal. Sci. Technol.*, 2011, 1, 153. (c) J. Barluenga, C. Valdes, *Angew. Chem.*, *Int. Ed.*, 2011, 50, 7486. (d) Z. Zhang, Y. Zhang, J. Wang, *ACS Catal.*, 2011, 1, 1621. (e) Y. Zhang, J. Wang, *Top. Curr. Chem.*, 2012, 327, 239. (f) Y. Zhang, J. Wang, *Eur. J. Org. Chem.* 2011, 1015. (g) Z. Shao, H. Zhang, *Chem. Soc. Rev.*, 2012, 41, 560. (h) Q. Xiao, Y. Zhang, J. Wang, *Acc. Chem. Res.*, 2013, 46, 236.
- (a) K. L. Greenman, D. L. Van Vranken, *Tetrahedron* 2005, **61**, 6438. (b) S. K. Devine, D. L. Van Vranken, *Org. Lett.*, 2007, **9**, 2047. (c) S. K. Devine, D. L. Van Vranken, *Org. Lett.*, 2008, **10**, 1909. (d) R. Kudirka, D. L. Van Vranken, *J. Org. Chem.*, 2008, **73**, 3585 (e) R. Kudirka, S. K. J. Devine, C. S. Adams, D. L. Van Vranken, *Angew. Chem.*, *Int. Ed.*, 2009, **48**, 3677. (f) A. Khanna, C. Maung, K. R. Johnson, T. T. Luong, D. L. Van Vranken, *Org. Lett.*, 2012, **14**, 3233. (g) E. S. Gutman, V. Arredondo, D. L. Van Vranken, *Org. Lett.*, 2014, **16**, 5498. (h) M. Kitamura, R. Yuasa, D. L. Van Vranken, *Tetrahedron Letters*, 2015, **56**, 3027. (i) I. D. U. A. Premachandra, T. A. Nguyen, C. Shen, E. S. Gutman, D. L. Van Vranken, *Org. Lett.*, 2015, **17**, 5464. (j) V. Arredondo, S. C. Hiew, E. S. Gutman, I. D. U. A. Premachandra, D. L. Van Vranken, *Angew. Chem., Int. Ed.*, 2017, **56**, 4156.
- 8 (a) S. Chen, J. Wang, Chem. Commun., 2008, 4198. (b) Q. Xiao, J. Ma, Y. Yang, Y. Zhang, J. Wang, Org. Lett., 2009, 11, 4732. (c) L. Zhou, F. Ye, Y. Zhang, J. Wang, J. Am. Chem. Soc., 2010, 132, 13590. (d) X. Zhao, G. Wu, C. Yan, K. Lu, H. Li, Y. Zhang, J. Wang, Org. Lett., 2010, 12, 5580. (e) L. Zhou, F. Ye, J. Ma, Y. Zhang, J. Wang, Angew. Chem., Int. Ed., 2011, 50, 3510. (f) L. Zhou, F. Ye, Y. Zhang, J. Wang, Org. Lett., 2012, 14, 922. (g) Q. Xiao, B. Wang, L. Tian, Y. Yang, J. Ma, Y. Zhang, S. Chen, J. Wang, Angew. Chem., Int. Ed., 2013, 52, 9305. (h) X. Wang, Y. Xu, Y. Deng, Y. Zhou, J. Feng, G. Ji, Y. Zhang, J. Wang, S. Xu, Y. Zhang, J. Wang, J. Org. Chem., 2015, 80, 6109. (j) K. Wang, S.

Chen, H. Zhang, S. Xu, F. Ye, Y. Zhang, J. Wang, *Org. Biomol. Chem.*, 2016, **14**, 3809.

- 9 (a) J. Barluenga, P. Moriel, C. Valdés, F. Aznar, Angew. Chem., Int. Ed., 2007, 46, 5587. (b) J. Barluenga, M. Tomás-Gamasa, P. Moriel, F. Aznar, C. Valdés, Chem. Eur. J., 2008, 14, 4792. (c) J. Barluenga, M. Escribano, P. Moriel, F. Aznar, C. Valdés, Chem. Eur. J., 2009, 15, 13291. (d) J. Barluenga, M. Tomás-Gamasa, F. Aznar, C. Valdés, Chem. Eur. J., 2010, 16, 12801. (e) J. Barluenga, M. Escribano, F. Aznar, C. Valdés, Angew. Chem., Int. Ed., 2010, 49, 6856. (f) J. Barluenga, M. Tomás-Gamasa, F. Aznar, C. Valdés, Adv. Synth. Catal., 2010, 352, 3235. (g) J. Barluenga, L. Florentino, F. Aznar, C. Valdés, Org. Lett., 2011, 13, 510. (h) J. Barluenga, N. Quiñones, M.-P. Cabal, F. Aznar, C. Valdés, Angew. Chem., Int. Ed., 2011, 50, 2350. (i) L. Florentino, F. Aznar, C. Valdés, Org. Lett., 2012, 14, 2323. (j) A. Jiménez-Aquino, J. A. Vega, A. A. Trabanco, and C Valdés, Adv. Synth. Catal., 2014, 356, 1079. (k) R. Barroso, M.-P. Cabal, R. Badía-Laiño, C. Valdés, Chem. Eur. J., 2015, 21, 16463. (m) M. Paraja, R. Barroso, M. P. Cabal, C. Valdés, Adv. Synth. Catal., 2017, 359, 1058.
- 10 A. C. Albeniz, P. Espinet, R. Manrique, A. Perez-Mateo, Angew. Chem., Int. Ed., 2002, 41, 2363. (b) M. P. López-Alberca, M. J. Mancheño, I. Fernandez, M. Gomez-Gallego, M. A. Sierra, R. Torres, Org. Lett., 2007, 9, 1757. (c) J. M. Goll, E. Fillion, Organometallics, 2008, 27, 3622. (d) Treguier, B.; Hamze, A.; Provot, O.; Brion, J.-D.; Alami, M. Tetrahedron Lett., 2009, 50, 6549. (e) E. Brachet, A. Hamze, J.-F. Peyrat, J.-D. Brion, M. Alami, Org. Lett., 2010, 12, 4042. (f) F. Zhou, K. Ding, Q. Cai, Chem. Eur. J., 2011, 17, 12268. (g) Z.-S. Chen, X.-H. Duan, L.-Y. Wu, S. Ali, K.-G. Ji, P.-X. Zhou, X.-Y. Liu, Y.-M. Liang, Chem. Eur. J., 2011, 17, 6918. (h) I. Meana, A. C. Albeniz, P. Espinet, Organometallics, 2012, 31, 5494. (i) I. Meana, A. Toledo, A. C. Albeniz, P. Espinet, Chem. Eur. J., 2012, 18, 7658. (j) H. Chen, L. Huang, W. Fu, X. Liu, H. Jiang, Chem. Eur. J., 2012, 18, 10497. (k) M. Roche, A. Hamze, J.-D. Brion,; M. Alami, Org. Lett., 2013, 15, 148. (I) M. Roche, A. Hamze, O. Provot, J.-D. Brion, M. Alami, J. Org. Chem., 2013, 78, 445. (m) Q. Yang, H. Chai, T. Liu, Z. Yu, Tetrahedron Lett., 2013, 54, 6485. (n) J. Feng, B. Li, Y. He, Z. Gu, Angew. Chem., Int. Ed., 2016, 55, 2186. (o) M.-C. Belhomme, D. Wang, K. J. Szabó, Org. Lett., 2016, 18, 2503. (p) Y. Xie, P. Zhang, L. Zhou, J. Org. Chem., 2016, 81, 2128.
- For the migration/insertion process for Cu carbenes, see: (a)
 L. Zhou, Y. Shi, Q. Xiao, Y. Liu, F. Ye, Y. Zhang, J. Wang, Org. Lett., 2011, 13, 968. (b) X. Zhao, G. Wu, Y. Zhang, J. Wang, J. Am. Chem. Soc., 2011, 133, 3296. (c) Q. Xiao, Y. Xia, H. Li, Y. Zhang, J. Wang, Angew. Chem., Int. Ed., 2011, 50, 1114. (d) F. Ye, X. Ma, Q. Xiao, H. Li, Y. Zhang, J. Wang, J. Am. Chem. Soc., 2012, 134, 5742. (e) M. L. Hossain, F. Ye, Y. Zhang, J. Wang, J. Org. Chem., 2013, 78, 1236.
- 12 (a) F. Yan, H. Liang, J. Song, J. Cui, Q. Liu, S. Liu, P. Wang, Y. Dong, H. Liu, Org. let., 2017, 19, 86. (b) X. Dong, Y. Han, F. Yan, Q. Liu, P. Wang, K. Chen, Y. Li, Z. Zhao, Y. Dong, H. Liu, Org. lett. 2016, 18, 3774. (c) H. Liang, L. Meng, X. Chi, S. Yao, H. Chen, L. Jiao, Q. Liu, D. Zhang, H. Liu, Y. Dong, Asian J. Org. Chem. 2018, 7, 1793. (d) X. Dong, J. Cui, J. Song, Y. Han, Q. Liu, Y. Dong, H. Liu, Chem. Commun., 2017, 53, 4903. (e) H. Liang, F. Yan, X. Dong, Q. Liu, X. Wei, S. Liu, Y. Dong, H. Liu, Chem. Commun., 2017, 53, 3138. (f) J. Cui, H. Wang, J. Song, X. Chi, L. Meng, Q. Liu, D. Zhang, Y. Dong and H. Liu, Org. Biomol. Chem., 2017, 15, 8508.
- (a) X. Liu, X. Ma, Y. Huang, Z. Gu, Org. Lett., 2013, 15, 4814.
 (b) X. Liu, Z. Gu, Org. Chem. Fron., 2015, 2, 778.
- 14 (a) H. Liu, C. Li, D. Qiu, X. Tong, J. Am. Chem. Soc., 2011, 133, 6187. (b) H. Liu, L. Wang, X. Tong, Chem. Commun., 2011, 47, 12206. (c) Z. Xie, P. Wu, L. Cai, X. Tong, Tetrahedron Letters, 2014, 55, 2160. (d) Z. Jiang, L. Hou, C. Ni, J. Chen, D. Wang, X. Tong, Chem. Commun., 2017, 53, 4270.