Pergamon

SCIENCE DIRECT®

Tetrahedron Letters 44 (2003) 7553–7556

TETRAHEDRON
LETTERS

Efficient preparation of (*Z*)-alkenyl derivatives from (*Z*)-vinyl (*N*,*N*-diisopropyl)carbamate via Ni-catalysed coupling reactions

François-Hugues Porée, Alexandre Clavel, Jean-François Betzer,* Ange Pancrazi and Janick Ardisson

Laboratoire de Synthèse Organique Sélective et Chimie Organométallique, CNRS-UCP-ESCOM, UMR 8123, 13, Bd de l'Hautil, F-95092 Cergy-Pontoise Cedex, France

Received 20 June 2003; accepted 24 July 2003

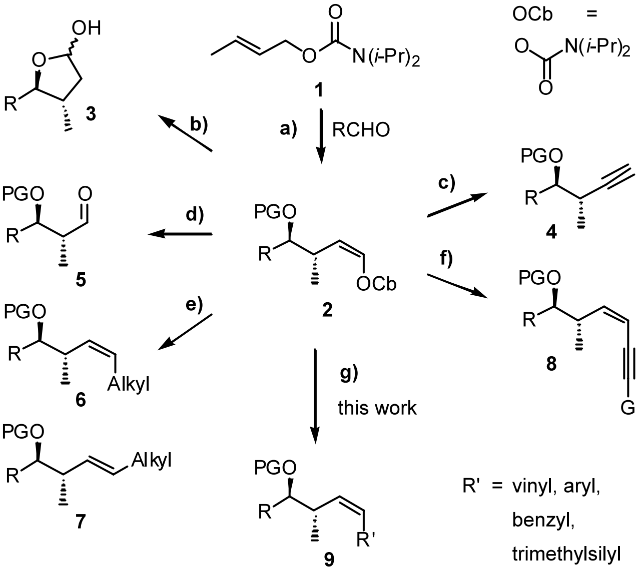
Abstract—A (*Z*)-vinyl (*N*,*N*-diisopropyl)carbamate treated with Grignard reagents, under Wenkert Nickel-catalysed conditions, gave access to several substituted (*Z*)-alkenyl derivatives. These Nickel-catalysed reactions, carried out with vinyl-, phenyl-, *p*-methoxyphenyl-, trimethylsilylmethylmagnesium bromide and benzylmagnesium chloride, led to the corresponding (*Z*)-alkenyl derivatives in good yields and high stereoselectivities.

The aldehyde allylation reaction described by Hoppe[1] was advantageously used in total synthesis.[2] Under original conditions, crotyl carbamate **1** treated with *n*-BuLi/(−)-sparteine in pentane/cyclohexane at −78°C, followed by transmetallation with Ti(O*i*-Pr)$_4$, led to an optically pure crotyltitane intermediate via a second order asymmetric induction. Reaction of this latter with an aldehyde gave the (*Z*)-*anti* homoallylic alcohol **2** in an enantioselective way (Scheme 1, a).

The synthetic utility of a vinyl (*N*,*N*-diisopropyl)-carbamate group was found by its transformation into lactol **3** (b),[2d,3] acetylenic **4** (c)[2b,c,4] or aldehyde **5** (d) function.[1,2] Preparation of (*Z*)- or (*E*)-alkyl compound **6** or **7** (e)[5] and enyne derivative **8** (f),[6] from (*Z*)-vinyl carbamates was also described.

For synthetic reasons we were interested to get an access, from carbamate **2**, to (*Z*)-vinyl products **9** (g) in which R′ could be, a vinyl, an aryl, a benzyl, or a trimethylsilylmethyl group. A direct access could be planned, via a metal insertion into the C–O bond of the carbamate moiety, in a coupling reaction as described by Kocienski[5a] for preparation of alkyl derivatives **6** and **7**. So we turned our efforts to the Wenkert method[7] to develop the preparation of **9**.

Generally Nickel-catalysed coupling reactions were effected and optimised in presence of catalytic amount of Ni(acac)$_2$ in Et$_2$O at room temperature,[8] or NiCl$_2$(tpp)$_2$[9] and NiCl$_2$(dppe)[5] in boiling benzene using an excess of the Grignard reagent.

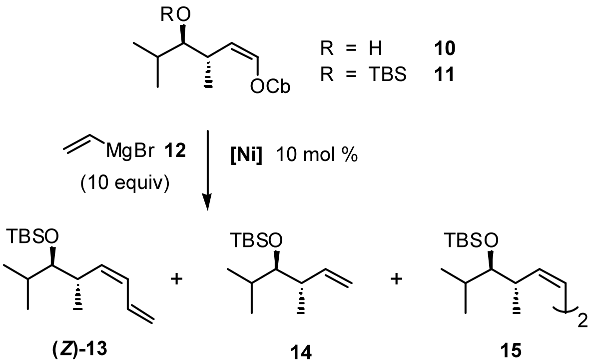


Scheme 1. Reactivity of vinyl carbamate function.

Keywords: Hoppe allylation; (*Z*)-vinyl (*N*,*N*-diisopropyl)carbamate; Nickel-catalysis; Wenkert cross-coupling reaction; Grignard reagent.

* Corresponding author. Tel.: 33 (0)1 30 75 61 86; fax: 33 (0)1 30 75 60 15; e-mail: jean-francois.betzer@chim.u-cergy.fr

0040-4039/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/S0040-4039(03)01804-5



Scheme 2. Cross coupling reaction between vinyl carbamate **11** and vinylmagnesium bromide.

The (*Z*)-*anti* vinyl carbamate **10**[3] was prepared via a Hoppe allylation of isobutyraldehyde in a racemic way. Reaction between *tert*-butyldimethylsilyl ether **11**, derived from **10**,[10] and vinylmagnesium bromide **12** in excess (Scheme 2), in presence of a catalytic amount of $Ni(acac)_2$ (10 mol%), at −5°C for 12 h in Et_2O, gave the expected dienyl derivative (*Z*)-**13** and the reduced compound **14** in a 80:20 ratio and 72% yield (Table 1, entry 1).[11] Employment of $NiCl_2$(dppe), at 0°C for 2 h, led to a 91:9 mixture of compounds (*Z*)-**13** and **14** in 65% yield (entry 2). In the last attempt, treatment with $NiCl_2$(dppp) in boiling toluene (3 h) resulted in formation of compound (*Z*)-**13** and homocoupling product **15** in a 70:30 ratio and a 89% yield (entry 3), the significant change was the formation of **15** and the disappearance of the reduced derivative **14**.

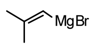
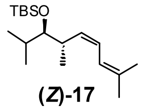
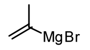
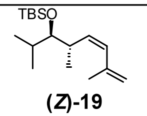
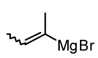
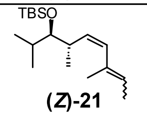
Application of these conditions into preparation of substituted dienes was performed with Grignard reagents **16**, **18** and **20**. In the case of isobutenylmagnesium bromide **16**, method **A** [$Ni(acac)_2$ 10 mol%, Et_2O, 0–5°C, 12 h], gave access to the pure compound (*Z*)-**17** in 57% yield (Table 2, entry 1). Under **B** [$NiCl_2$(dppp) 10 mol%, toluene, reflux, 3 h] or **C** [$Ni(acac)_2$ 10 mol%, toluene, reflux, 3 h] conditions, yield did not increase, and a non-identified isomer was detected, probably the (*E*)-**17** isomer (entries 2 and 3). Treatment of **11** with the Grignard reagent **18** applying **A** protocol, conducted to the (*Z*)-**19** derivative in good yield, together with a few amount of the reduced product **14** and also a non identified isomer (entry 4, 70% yield, (*Z*)-**19**/**14**/**15**/isomer 90:3:0:7). When the Grignard reagent **20** was used, application of method **A** give also the best result and the expected (*Z*)-**21** isomer was obtained in 73% yield as the only product (entry 5).

Table 1. Cross coupling reaction between vinyl carbamate **11** and vinylmagnesium bromide

Entry	[Ni][a]	Yield[b] (%)	(*Z*)-**13**/**14**/**15**[c]
1	$Ni(acac)_2/Et_2O$, −5°C, 12 h	72	80:20:0
2	$NiCl_2(dppe)/Et_2O$, 0°C, 2 h	65	91:9:0
3	$NiCl_2$(dppp)/toluene reflux, 3 h	89	70:0:30

[a] [Ni] = 10 mol%.
[b] Isolated yield.
[c] GC/MS analysis.

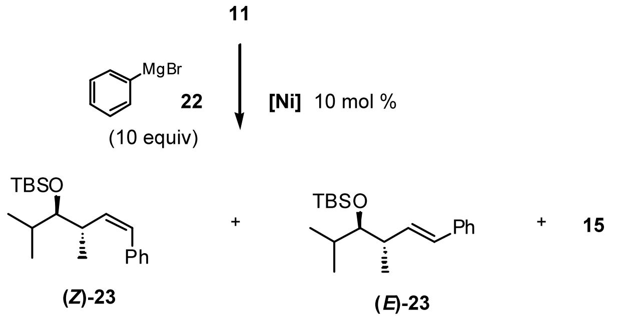
Table 2. Cross coupling of vinyl carbamate **11** with substituted vinylmagnesium bromides

Entry	Grignard Reagent	Method[a]	Coupling Product	Yield[b] Selectivity[c]
1		A[d]		**(*Z*)-17/14/15/isomer** **57%** 100:0:0:0
2	 **16**	B[d]	 **(*Z*)-17**	**(*Z*)-17/14/15/isomer** **56%** 89:4:0:7
3		C		**(*Z*)-17/14/15/isomer** **63%** 89:0:6:5
4	 **18**	A	 **(*Z*)-19**	**(*Z*)-19/14/15/isomer** **70%** 90:3:0:7
5	 **20**	A	 **(*Z*)-21**	**(*Z*)-21/14/15/isomer** **73%** 100:0:0:0

[a] Method **A**: $Ni(acac)_2$ 10 mol%, Et_2O, 0°C, 12 h, Grignard Reagent 10 equiv. Method **B**: $NiCl_2$(dppp) 10 mol%, toluene, reflux, 3 h, Grignard Reagent 10 equiv. Method **C**: $Ni(acac)_2$ 10 mol%, toluene, reflux, 3 h, Grignard Reagent 5 equiv. [b] Isolated Yield. [c] GC/MS analysis.

In continuation of our study, an investigation with phenylmagnesium bromide **22** was undertaken (Scheme 3).

Reaction of **11** with PhMgBr **22** under method **B** conditions, afforded the expected coupling product (*Z*)-**23** with the corresponding identified (*E*)-**23** isomer, and



Method **B** Yield : 95%[a] (*Z*)-**23**/(*E*)-**23**/**15** = 68:12:20[b]
Method **D**[c] Yield : 72%[a] (*Z*)-**23**/(*E*)-**23**/**15** = 72:25:0[b,d]

[a] Isolated yield. [b] GC/MS analysis. [c] Method **D**: $Ni(acac)_2$ 10 mol%, DIBAL-H 20 mol%, PPh_3 20 mol%, Et_2O, 0°C, 12 h, Grignard Reagent 5 equiv. [d] The reduced compound **14** was isolated in 3% yield.

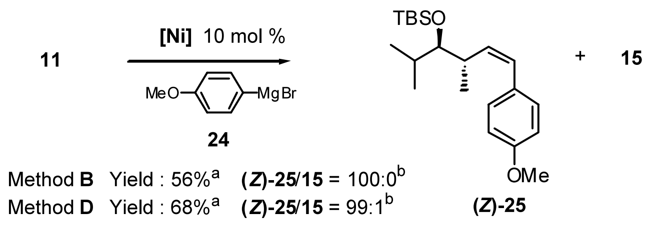
Scheme 3. Cross coupling reaction with phenylmagnesium bromide.

the homocoupling product **15** in a 68:12:20 ratio and a 95% yield.

Using [Ni(acac)$_2$ 10 mol%, DIBAL-H 20 mol%, PPh$_3$ 20 mol%, Et$_2$O, 0°C, 12 h, RMgX 5 equiv.] conditions (method **D**),[12] the reaction proceeded in 72% yield, and compound (*Z*)-**23** was isolated together with its (*E*)-**23** isomer and a few amount of the reduced derivative **14** in a (*Z*)-**23**/(*E*)-**23**/**15**/**14** = 72:25:0:3 selectivity. Formation of homocoupling product **15** was totally avoided in this case.

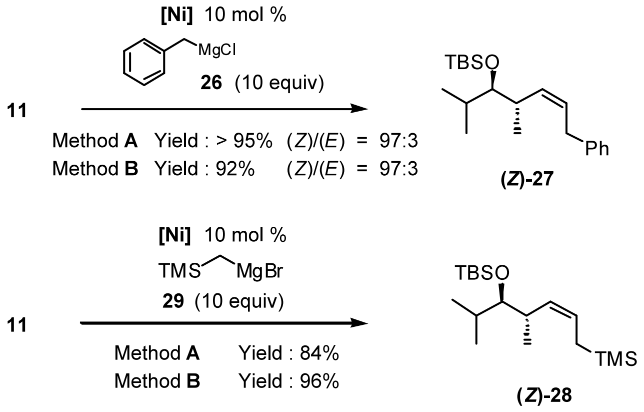
Interestingly, the coupling reaction of **11** and *p*-methoxyphenylmagnesium bromide **24** (Scheme 4), in presence of Ni(acac)$_2$ (**A** or **C** protocol) gave access to the (*Z*)-**25** derivative as a mixture with the homocoupling product **15**. Surprisingly method **B** conducted to compound (*Z*)-**25** in 56% yield and total stereocontrol. The best result was obtained with **D** conditions, compound (*Z*)-**25** was isolated in 68% yield, the homocoupling product **15** being produced in less than 1% yield (entry 4).

Another application of this Ni-catalysed reaction was also performed with benzylmagnesium chloride **26** (Scheme 5). Under **A** conditions, reaction proceeded in an excellent 95% yield and the vinyl adduct (*Z*)-**27** was cleanly produced with a high selectivity [(*Z*)/(*E*) = 97:3]. Employing **B** conditions, comparable yield and selectivity were observed [92% yield, (*Z*)/(*E*) = 97:3].



[a] Isolated yield. [b] GC/MS analysis.

Scheme 4. Cross coupling reaction with *p*-methoxyphenylmagnesium bromide.



Scheme 5. Cross coupling reaction with benzylmagnesium chloride and trimethylsilylmethylmagnesium bromide.

An interesting synthetic point of view was the transformation of the vinyl carbamate **11** into the allylsilane (*Z*)-**28** (Scheme 5) to promote a subsequent aldehyde allylation either in preparation of the extended chain or furan derivative.[13] As a satisfying result, coupling reaction between vinyl carbamate **11** and the trimethylsilylmethylmagnesium bromide **29**, either applying **A** or **B** conditions, gave the pure allylsilane (*Z*)-**28** in 84 and 96% yield, respectively.[14] Production of the two possible by-products, reduced compound **14** and homocoupling product **15**, was not observed in these cases.

In conclusion it was shown that a direct Ni-catalysed coupling reaction between the (*Z*)-vinyl (*N*,*N*-diisopropyl)carbamate **11**, and vinyl-, aryl-, benzyl- and trimethylsilylmethyl Grignard reagents led to the corresponding substituted (*Z*)-alkenyl derivatives in good yields and high stereoselectivities. These coupling reactions could be considered as a useful tool in organic synthesis[15] and applications are underway.

Acknowledgements

The CNRS, UCP and ESCOM are acknowledged for financial support.

References

1. (a) Hoppe, D. *Angew. Chem., Int. Ed. Engl.* **1984**, *23*, 932–948; (b) Hoppe, D.; Zschage, O. *Angew. Chem., Int. Ed. Engl.* **1989**, *28*, 69–71; (c) Zschage, O.; Hoppe, D. *Tetrahedron* **1992**, *48*, 8389–8392; (d) Hoppe, D.; Hense, T. *Angew. Chem., Int. Ed.* **1997**, *36*, 2282–2316.
2. (a) Paulsen, H.; Hoppe, D. *Tetrahedron* **1992**, *48*, 5667–5670; (b) Férézou, J.-P.; Julia, M.; Li, Y.; Liu, L. W.; Pancrazi, A. *Bull. Soc. Chim. Fr.* **1995**, *132*, 428–452; (c) Smith, N. D.; Kocienski, P. J.; Street, S. D. A. *Synthesis* **1996**, 652–666; (d) Berque, I.; Le Ménez, P.; Razon, P.; Anies, C.; Pancrazi, A.; Ardisson, J.; Neuman, A.; Prangé, T.; Brion, J.-D. *Synlett* **1988**, 1132–1134; (e) Berque, I.; Le Ménez, P.; Razon, P.; Pancrazi, A.; Ardisson, J.; Brion, J.-D. *Synlett* **1988**, 1135–1137; (f) Berque, I.; Le Ménez, P.; Razon, P.; Mahuteau, J.; Férézou, J.-P.; Pancrazi, A.; Ardisson, J.; Brion, J.-D. *J. Org. Chem.* **1999**, *64*, 373–381.
3. Hoppe, D.; Hanko, R.; Brönneke, A.; Lichtenberg, F.; van Hülsen, E. *Chem. Ber.* **1985**, *118*, 2822–2851.
4. (a) Pimm, A.; Kocienski, P.; Street, S. D. A. *Synlett* **1992**, 886–888. For a recent review, see: (b) Braun, M. *Angew. Chem., Int. Ed.* **1998**, *37*, 430–451.
5. (a) Kocienski, P.; Dixon, N. J. *Synlett* **1989**, 52–54; (b) Wadman, S.; Whitby, R.; Yeates, C.; Kocienski, P.; Cooper, K. *J. Chem. Soc., Chem. Commun.* **1987**, 241–243. For transformation of a (*Z*)- or (*E*)-crotyl diisopropylcarbamate into corresponding (*E*)-vinyl iodide derivative, see: (c) Liard, A.; Marek, I. *J. Org. Chem.* **2000**, *65*, 7218–7220.
6. Madec, D.; Pujol, S.; Henryon, V.; Férézou, J.-P. *Synlett* **1995**, 435–438.

7. (a) Wenkert, E.; Michelotti, E. L.; Swindell, C. S. *J. Am. Chem. Soc.* **1979**, *101*, 2246–2247; (b) Wenkert, E.; Michelotti, E. L.; Swindell, C. S.; Tingoli, M. *J. Org. Chem.* **1984**, *49*, 4894–4899.
8. (a) Hayashi, T.; Katsuro, Y.; Okamoto, Y.; Kumada, M. *Tetrahedron Lett.* **1981**, *22*, 4449–4452; (b) Sengupta, S.; Leite, M.; Raslan, D. S.; Quesnelle, C.; Snieckus, V. *J. Org. Chem.* **1992**, *57*, 4066–4068.
9. (a) Hayashi, T.; Katsuro, Y.; Kumada, M. *Tetrahedron Lett.* **1980**, *21*, 3915–3918; (b) Crouse, G. D.; Paquette, L. A. *J. Org. Chem.* **1981**, *46*, 4272–4274.
10. A first attempt conducted on compound **10**, with the free secondary hydroxy group, gave any cross coupling product.
11. General procedure for cross-coupling reactions: To a flame-dried flask, under argon, were added vinyl carbamate **11** (200 mg, 0.52 mmol) and Ni(acac)$_2$ (13 mg, 0.05 mmol, 0.1 equiv.) or [NiCl$_2$(dppp) catalyst (28 mg, 0.05 mmol, 0.1 equiv.)]. Freshly distilled diethyl ether (5 mL) or [toluene (5 mL)] was added, and the solution was degassed and flushing with argon. The mixture was cooled at −5°C and Grignard reagent (1.0 M solution in THF, 5 mL, 5.0 mmol, 10 equiv.) was added dropwise and stirred for 12 h at −5°C or [heated to reflux for 3 h]. Then the mixture was quenched by addition of a saturated aqueous NH$_4$Cl solution and extracted with diethyl ether. The organic layer was washed with brine, dried over magnesium sulfate, filtered and concentrated in vacuo. Purification was effected by chromatography on silica gel (cyclohexane).

   (*Z*)-**13**: ^{1}H NMR (270 MHz, CDCl$_3$) δ 6.55 (ddd, *J*= 16.8, 11.2, 10.1 Hz, 1H, H-7), 5.91 (dd, *J*=11.2, 10.9 Hz, 1H, H-6), 5.52 (dd, *J*=10.9, 9.9 Hz, 1H, H-5), 5.13 (dd, *J*=16.8, 2.0 Hz, 1H, Ha-8), 5.02 (dd, *J*=10.1, 2.0 Hz, 1H, Hb-8), 3.27 (dd, *J*=5.6, 3.3 Hz, 1H, H-3), 2.79 (dqd, *J*=9.9, 6.9, 3.3 Hz, 1H, H-4), 1.66 (heptd, *J*=6.9, 5.6 Hz, 1H, H-2), 0.94 (d, *J*=6.9 Hz, 3H, CH$_3$-4), 0.86 [s, 9H, CH$_3$, SiC(CH$_3$)$_3$], 0.83 (d, *J*=6.9 Hz, 3H, H$_3$-1 or CH$_3$-2), 0.81 (d, *J*=6.9 Hz, 3H, CH$_3$-2 or H3-1), 0.00 [s, 6H, CH$_3$, Si(CH$_3$)$_2$]. ^{13}C NMR (67.5 MHz, CDCl$_3$) δ 135.9 (CH, C-5), 132.8 (CH, C-7), 128.2 (CH, C-6), 116.9 (CH$_2$, C-8), 81.1 (CH, C-3), 35.7 (CH, C-4), 32.9 (CH, C-2), 26.3 [3CH$_3$, SiC($\underline{C}$H$_3$)$_3$], 19.7 (2CH$_3$, C-1 or CH$_3$-2 and CH$_3$-4), 18.9 (CH$_3$, CH$_3$-2 or C-1), 18.6 [C, Si$\underline{C}$(CH$_3$)$_3$], −3.6 [2CH$_3$, Si($\underline{C}$H$_3$)$_2$].
12. (a) Gunn, A.; Jarowicki, K.; Kocienski, P.; Lockhart, S. *Synthesis* **2001**, 331–338; (b) Sato, Y.; Takimoto, M.; Mori, M. *J. Am. Chem. Soc.* **2000**, *122*, 1624–1634.
13. Hoffmann, R. W.; Giesen, V.; Fuest, M. *Liebigs Ann. Chem.* **1993**, 629–639.
14. (*Z*)-**28**: ^{1}H NMR (270 MHz, CDCl$_3$) δ 5.33 (dd, *J*=10.8, 9.3 Hz, 1H, H-5), 5.29 (ddd, *J*=10.8, 8.0, 5.8 Hz, 1H, H-6), 3.27 (dd, *J*=5.3, 4.0 Hz, 1H, H-3), 2.59 (dqd, *J*=9.3, 7.1, 4.0 Hz, 1H, H-4), 1.72 (heptd, *J*=6.7, 5.3 Hz, 1H, H-2), 1.52 (dd, *J*=13.9, 8.0 Hz, 1H, H-7a), 1.36 (dd, *J*=13.9, 5.8 Hz, 1H, H-7b), 0.92 (d, *J*=7.1 Hz, 3H, CH$_3$-4), 0.90 [s, 9H, 3CH$_3$, SiC(CH$_3$)$_3$], 0.86 (d, *J*=6.7 Hz, 3H, H$_3$-1 or CH$_3$-2), 0.85 (d, *J*=6.7 Hz, 3H, CH$_3$-2 or H$_3$-1), 0.04 [s, 3H, CH$_3$, Si(CH$_3$)$_2$], 0.02 [s, 3H, CH$_3$, Si(CH$_3$)$_2$], 0.00 [s, 9H, 3CH$_3$, Si(CH$_3$)$_3$]. ^{13}C NMR (67.5 MHz, CDCl$_3$) δ 131.0 (CH, C-5), 124.2 (CH, C-6), 81.0 (CH, C-3), 35.2 (CH, C-4), 32.2 (CH, C-2), 26.2 [3CH$_3$, SiC($\underline{C}$H$_3$)$_3$], 20.5 (CH$_3$, C-1 or CH$_3$-2), 19.0 (CH$_3$, CH$_3$-4), 18.6 (CH$_3$, C-1 or CH$_3$-2), 18.6 (CH$_2$-7), 18.6 [C, Si$\underline{C}$(CH$_3$)$_3$], −1.5 [3CH$_3$, Si($\underline{C}$H$_3$)$_3$], −3.2 [CH$_3$, Si($\underline{C}$H$_3$)$_2$], −3.6 [CH$_3$, Si($\underline{C}$H$_3$)$_2$].
15. (*Z*)-Vinyl carbamate derivatives could be prepared in good yield and high stereoselectivity from allylic alcohols, see Ref. 6.