demonstrates the first construction of all carbon quaternary centers via the reductive coupling of unactivated tertiary alkyl halides with a second electrophile B - .[27,28] I fi C- α- . Fi , Cl_2 II .

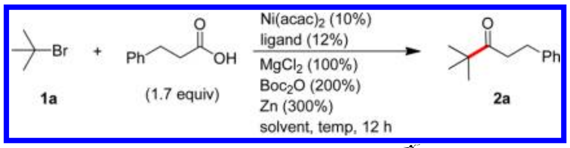
2. E A D D C

2.1. C *Tertiary* A A

A . tertiary tB B (1a) 1.7 3- B 2 / 1.5 Cl_2 (1).[29]

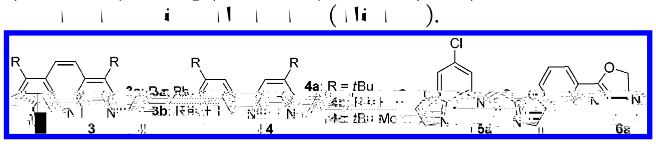
(8 13), 65% 19% 4b (9 14). D 2 E 1.5 0.85 79% (15). 25 30 °C 82% (16). (method A), 4a ffi (17). (method A, 1, 16) , tB -B 2a–f, 2g . tert- 7–15 (2). , 14 trans- (trans-4- /) cis- (cis-4- /).[29]

Table 1. Optimization for the Reaction of BuBr (1a) with 3-Phenylpropanoic Acid



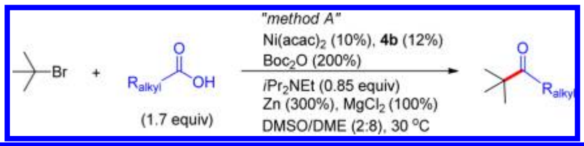
			2 E (%)	Cl_2 (%)	°C	(%)[b]
1	3a	HF	0	150	25	16
2	3b	HF	0	150	25	7
3	4a	HF	0	150	25	24
4	4a	D	0	150	25	25
5	4a	D E	0	150	25	34
6	4a	D /D E = 8:2	0	150	25	44
7	4a	D /D E = 2:8	0	150	25	36
8	4a	D /D E = 2:8	150	150	25	47
9	4b	D /D E = 2:8	150	150	25	19
10	4c	D /D E = 2:8	150	150	25	46
11	5a	D /D E = 2:8	150	150	25	<10
12	6a	D /D E = 2:8	150	150	25	<10
13	4a	D /D E = 2:8	150	100	25	39
14	4b	D /D E = 2:8	150	100	25	65
15	4b	D /D E = 2:8	85	100	25	79
16	**4b**	**DMSO/DME = 2:8**	**85**	**100**	**30**	**82**
17	4a	D /D E = 2:8	85	100	30	39

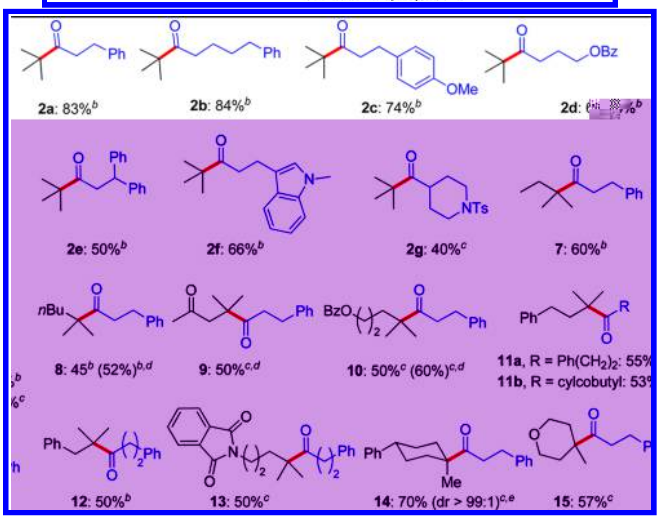
[a] C : tB B (0.3 , 100 %), (170 %), ( )$_2$ (10 %), (12 %), B 2 (200 %), (300 %), Cl_2 (100 %), (1 L). [b]GC ( ).



( )$_2$, 4a 2a 24% HF, 3a 3b (1, 1–3). ff 4a , D E D (4–5). D /D E 8/2 (/) 2/8 (6 7), 1.5 2 E 47% (8). , . ., 4b–c, 5a, 6a (9–12). I , Cl_2 1.5 1 4a

Table 2. Coupling of Unactivated -Alkyl Bromides with Acids





[a] C (A): tert- B (0.3 , 100 %), (170 %), ( )$_2$ (10 %), 4b (12 %), Cl_2 (100 %), 2 E (85 %), B 2 (200 %), (300 %), D /D E (0.2:0.8, / , 1 L). [b]I t- (B 2) FA. [c]I . [d]15 % ( )$_2$ 15 % 4b . [e] 14 GC (= 19:1); iff 14 - iff (I).

2.2. C *Tertiary* A A A .

method A (1, 16), (1.7) (3- -3-) 1b 11c, ; , tert- . A 3- (0.85) 1b 11a 60% , 11c (1). I , 1b 4- -1- (16a)

10%

, 1b

16a (2).

ffi

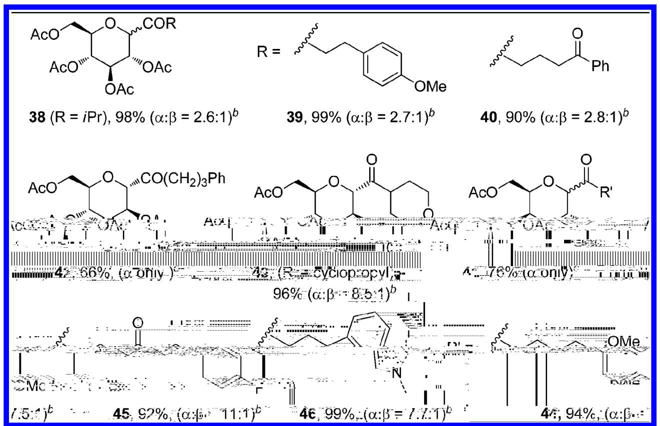
tertiary ,

secondary

tertiary .

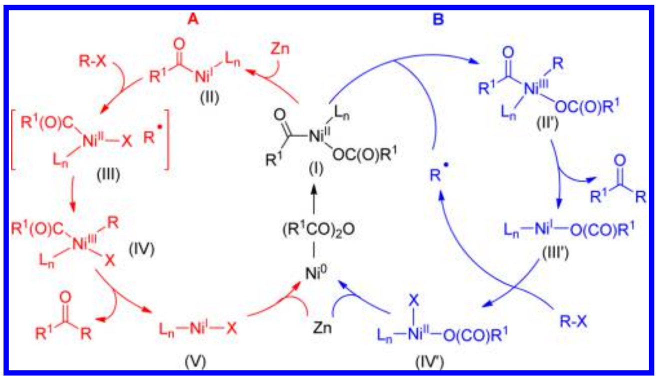
2.3. C *Primary* *Secondary*

Table 5. Examples of -Acyl Glycosides Using Methods B and C1



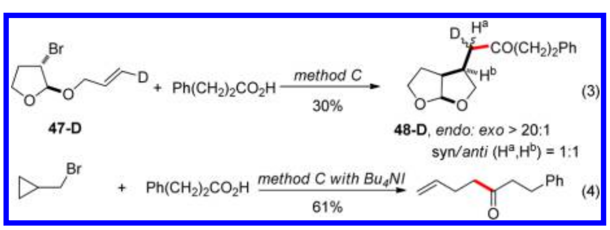
aI (α/β) 1H). b C1: C F/CH3C = 1:4. B.

Scheme 1. Double Oxidative Addition (Cycle A) And Radical Chain Mechanism (Cycle B)



I, H ' K , ' (1, B).[35] I (III′) II (IV′). I III′ I 1C( )– III(C( ))– (V′), I- .

2.5.2. *Radical Process.* fi 47-D 3- endo-48-D 1:1 syn/anti H /H (3), / 3- (4).[36]



2.5.3. *Radical Chain versus Double Oxidative Addition Mechanism.* (C D)2 4a (i C)2 (n C)2 E2 I-a (Fi 2) I-b

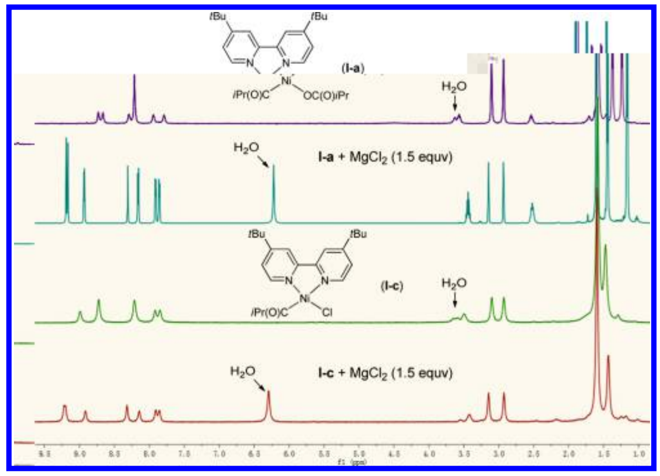
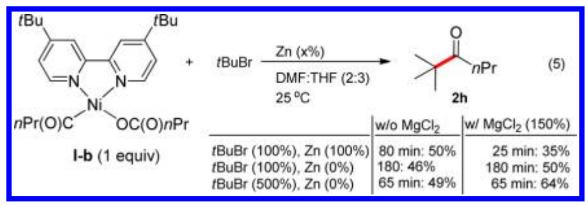


Figure 2. 1H I-a i F ( ) Cl_2, I-c ( ) Cl_2.

(5),[32,37] F , Cl_2,



tB B I-b i / E 180 2h 46% (I Fi 7). 5 tB B, 2h 50% 65 .[29] I-a 16a (I 4),

I (B, 1), I.[35] C A I I . I-b tB B (5). I B (1), I-b tB B II (I ') I 0. G

A Cl_2 I-b tB B ff (5). I Cl_2 (3- -3-) (1b) (CH2)2C 2H, 11a .

fi Cl_2, I-a (II) 3 F (I Fi 2).[29] ~80% ~100% I-a F F/ HF (2:3, /) 1 , (I Fi 3 4).[29] 1H iff Cl_2 I-a F (Fi 2).[29,38] Cl^-/ C( ) C( )– $(L_n)Cl$

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(I-c) 29,39 2+ Cl$_2$ I-c C Cl L$_n$ (0) ^{1}H I-a/ Cl$_2$ (Fi 2).[37,40] I-c I-a Cl$_2$ (I Fi 5), I-a/ Cl$_2$. H 2+ Cl$_2$ L$_n$- B$_2$ (L$_n$ = 4a) Cl$_2$, L$_n$- B$_2$ 3 (I Fi 6).[29,40] ff 2+ . B 1 Cl$_2$ tB B 3- 2a (1). E Cl$_2$ I-b D I-b 1 ; 1.5 Cl$_2$ 29 ff 2+

iff A B, 6- -1- 3- . A H ' K 35 , A (, III) 49/50 , (, I) 49/50 . Fi 3 ( )$_2$ 2.5% 15%, 49/50 B.

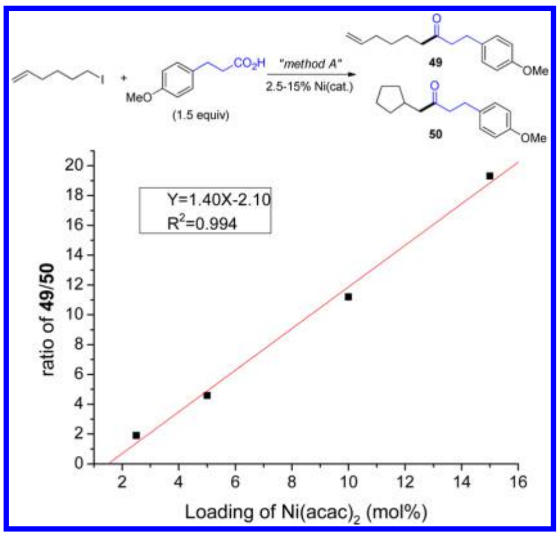

Figure 3. D (49/50) . E 4

B, . F , IV' 0 Cl$_2$. 38

3. C C

I , tertiary . A α- C Cl$_2$ II (., I-a), II B,

■ A C A ED C E

D
I ://

■ A F A

C A
@ . .
A C
†

fi

■ AC ED E

D . (ICI ;) . D . H D (I A C) . Fi C (. 21172140 21372151), A I Hi L (D) E C .

■ EFE E CE

(1) C tertiary C : ( ) , J.; , H.; B , . A.; K , H.; K , Angew. Chem., Int. Ed. **2007**, 46, 2086. ( ) , .; , L. A.; H , L. Angew. Chem., Int. Ed. **2012**, 51, 9110. ( ) , C.- .; , .; , J.; , J.-H.; L , .- .; C , H.-H.; , L. J. Am. Chem. Soc. **2012**, 134, 11124. C : ( ) I , .; , H.; , . .; K , H.; K , J. Am. Chem. Soc. **2013**, 135, 9604.

(2) C tertiary : ( ) L , C.; D , .; , C.; G , F. Chem.—Eur. J. **2011**, 17, 6052. ( ) J , A.; , C.- .; B , . . J. Am. Chem. Soc. **2011**, 133, 8478.

(3) C tertiary : ( ) G , . K.; J , .; H , .; , . Org. Lett. **2012**, 14, 1066. ( ) , H.; , H.; , H.; , K. Org. Lett. **2008**, 10, 969. ( ) , .; A , .; , K.; , H.; , H.; , K. Chem.—Asian J. **2010**, 5, 1487. ( ) , .; , H.; , K. Angew. Chem., Int. Ed. **2002**, 41, 4137.

(4) C tert- A -9BB : , . L.; F , G. C. J. Am. Chem. Soc. **2013**, 135, 624.

(5) ( ) i, . C.; F, G. C. Angew. Chem., Int. Ed. **2008**, 47, 9334.
( ) H, C.; B , . L. J. Am. Chem. Soc. **2009**, 131, 7532.
( ) , .; H, B.; G i, A.; , K.; H, E.;

Chem. **1981**, 21, 451. ( ) Fi , .; , D.; K , .; , J.; , B. J. Organomet. Chem. **1993**, 447, 131.

(33) B C i(I) (15).

(34) [illegible] : ( ) , . B.; B , E.; G -I , .; , D. J. Angew. Chem., Int. Ed. **2007**, 46, 8790. ( ) J , G. D.; , J. L.; F , C.; A , . .; H , . E.; H , A. D.; B , . J.; K , .; D , . J.; , .; , D. A. J. Am. Chem. Soc. **2006**, 128, 13175.

(35) ( ) B , J.; , J.; , . D.; H , . J. Am. Chem. Soc. **2013**, 135, 12004. ( ) Bi , .; , D. J. J. Am. Chem. Soc. **2013**, 135, 16192. ( ) , .; , D. J. J. Am. Chem. Soc. **2014**, 136, 48. ( ) , J. C.; , D. .; , G. A. Science **2014**, 345, 433. ( ) , .; A , D. .; C , L.; , J. A.; D , A. G.; , D. . C. Science **2014**, 345, 437. : ( ) , D.; F , G. C. J. Am. Chem. Soc. **2014**, 136, 16588–16593.

(36) ( ) G -B .; F , G. C. J. Am. Chem. Soc. **2006**, 128, 5360. ( ) , D. A.; , .; F , G. C. J. Am. Chem. Soc. **2005**, 127, 510. ( ) , .; , .; , H.; G , H. Org. Lett. **2011**, 13, 2138. ( ) , H.; , C.; , .; D , .; G , H. Chem. Sci. **2013**, 4, 4022. ( ) C , . E.; L , K. J.; F , G. C.; , J. C. Science **2012**, 338, 647.

(37) A - , **I-a** (**I-a**]) [1]H, [13]C IC (I).

(38) C Cl$_2$, . ., Cl, : Ji , L.; Li , C.; Li , J.; H , F.; L , .; B , A. .; H , J. A. K.; , . B.; L , A. J. Am. Chem. Soc. **2009**, 131, 16656.

(39) , - i(II)–Cl HF , : , A. C.; . D.; , D. J. Organometallics **2014**, 33, 5874.

(40) Cl$_2$: C , L. C.; , . G. Angew. Chem., Int. Ed. **2014**, 53, 4386.