Application of Indium Ate Complexes to Synthetic Chemistry. Selective Conjugate Addition to Enones and Coupling with Allylic Halides

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Tetraorganoindium ate complexes, prepared by the addition of organolithium reagents to trialkylindium, reacted with α,β-unsaturated ketones in a 1,4-addition fashion; allylic indates derived from allylic indium sesquihalides coupled with allylic halides regio- and stereo-specifically to give high yields of head-to-tail 1,5-dienes.

Trivalent organoindium reagents were recently introduced to organic synthesis and were proved to be useful for organic transformations.[1] Although tetramethylindate was prepared and structurally elucidated as the first indium ate complex,[2] its chemical behaviour, in particular application to organic synthesis, has not been studied so far. This paper describes the preparation of a variety of indates and their reactions with electrophiles, of which the couplings with α,β-unsaturated ketones and allylic halides provide convenient methods for selective conjugate alkylation and regiospecific allyl–allyl coupling, respectively.

Table 1 Reaction of tetraorganoindates with α,β-unsaturated carbonyl compounds[a]

		Yield(%)[b]	
Indate	Carbonyl compound	1,4-Addition	1,2-Addition
Li[Bu$_4$In]	PhCH=CHCHO	0	100
Li[Bu$_4$In]	PhCH=CHCOMe	64	26
Li[Bu$_4$In]	Cyclohexen-2-one	76	0
Li[Me$_4$In]	Cyclohexen-2-one	55	0
Li[Bu$_3$(R)In][c]	Cyclohexen-2-one	67[d]	0
Li[Bu$_4$In]	Cyclohexen-2-one	66	0
Li[Bu$_4$In]	3-Ethoxycyclo-hexen-2-one	50[e]	0

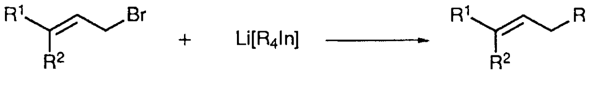
[a] Reactions were carried out with indate (*ca.* 1.3 equiv.) and carbonyl compound (1 equiv.) at room temp. for 2 h. [b] Isolated yield; all products gave satisfactory spectral and analytical data. [c] R = oct-1-ynyl. [d] Butylated product. [e] Yield of 3-butylcyclohexen-2-one.

Tetraorganoindates, prepared by the addition of organolithium reagent to trialkylindium, reacted with α, β-unsaturated carbonyl compounds to give 1,2- and/or 1,4-adducts (Table 1).[3] The 1,2- *vs.* 1,4-ratio largely depended on the substrate structure; with tetrabutylindate cinnamaldehyde gave the 1,2-adduct quantitatively, whereas unsaturated ketones, in particular cyclic enones, preferentially gave the 1,4-adducts. Tributyloct-1-ynylindate selectively butylated cyclohexen-2-one, the corresponding octynylated product was

Table 2 Allylation of tetraalkylindates[a]

Indate	Allylic bromide		
R	R^1	R^2	Yield (%)[b]
Bu	Pr	H	80
Bu	Ph	H	88
Bu	Ph	Ph	76
Bu	Me$_2$C=CH(CH$_2$)$_2$	Me	62
Bu	Me	Me$_2$C=CH(CH$_2$)$_2$	54
Me	Ph	H	78

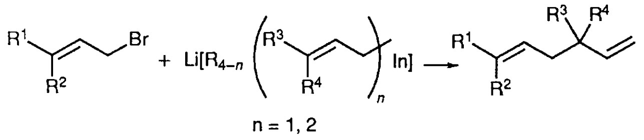
[a] Reactions were carried out with indate (*ca.* 1.2 equiv.) and allylic bromide (1 equiv.) at room temp. for 3 h. [b] Isolated yield; all products gave satisfactory spectral and analytical data.



Scheme 1

$$(\text{allyl})_3\text{In}_2\text{X}_3 \xrightarrow{5\,\text{RLi}} \text{Li}[\text{R}_3(\text{allyl})\text{In}] + \text{Li}[\text{R}_2(\text{allyl})_2\text{In}]$$

Scheme 2



Scheme 3

Table 3 Allylation of allylic indates[a]

Indate			Allylic bromide		
R	R^3	R^4	R^1	R^2	Yield (%)[b]
Me	H	H	Ph	H	86
Me	H	H	Ph	Ph	98
Bu	H	H	MP[c]	Me	78
Bu	H	H	Me	MP[c]	77
Me	Me	H	Ph	H	85
Me	Ph	H	Me	H	100
Me	Ph	H	MP[c]	Me	82
Me	Ph	H	Me	MP[c]	67
Me	Pr	H	Ph	H	76
Me	H	Pr	Ph	H	75
Me	MP[c]	Me	Ph	H	55

[a] Reactions were carried out with indate (*ca.* 1.3 equiv.) and allylic bromide (1 equiv.) at room temp. for 3 h. [b] Isolated yield; all products gave satisfactory spectral and analytical data. [c] MP = 4-methylpenten-3-yl.

not formed. Reaction of 3-ethoxycyclohexen-2-one with lithium tetrabutylindate gave 3-butylcyclohexen-2-one.

Regio- and stereo-specific alkyl–allyl and allyl–allyl couplings were realized *via* allylation of indates. Reaction of tetraalkylindates with allylic bromides went smoothly at room temperature (Table 2). The coupling occurred regiospecifically at the α-position of allylic bromides and the configuration of allylic double bond was completely preserved (Scheme 1). Allylic indates were readily prepared by the addition of five equivalents of alkyllithium to allylic indium sesquihalides[1a,f] (Scheme 2). The allylic indates thus prepared are presumably 1 : 1 mixtures of allyltrialkyl- and diallyldialkyl-indates. Allylation of these allylic indates also proceeded regio- and stereo-specifically; only the products coupled at the α-position of allylic bromides and γ-position of allylic indates were produced in good yields (Scheme 3, Table 3). The head-to-tail coupling of two allylic components[4] has hitherto been achieved with satisfactory selectivity *via* allylic boronates[5] and other organometallic reagents.[6] Nevertheless, our indate-based procedure is superior to the existing methods for several reasons: (*i*) a wide variety of allylic indates are easily accessible *via* allylic indium sesquihalides,[1a,f] (*ii*) the regio- and stereo-selectivity are excellent and (*iii*) the reactions can be done at room temperature.

Trialkylindium and allylic indium sesquihalide did not react with ketones and allylic halides,[1f] respectively. Ate-complex formation not only overcomes the low reactivity of the trivalent organoindium reagents but also brings about new reactions unique to indates. This should increase the utility of organoindium reagents in organic chemistry.

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References

1 (*a*) S. Araki, H. Ito and Y. Butsugan, *J. Org. Chem.*, 1988, **53**, 1831; (*b*) S. Araki, H. Ito and Y. Butsugan, *Synth. Commun.*, 1988, **18**, 453; (*c*) S. Araki, N. Katsumura, H. Ito and Y. Butsugan, *Tetrahedron Lett.*, 1989, **30**, 1581; (*d*) S. Araki, H. Ito, N. Katsumura and Y. Butsugan, *J. Organomet. Chem.*, 1989, **369**, 291; (*e*) S. Araki and Y. Butsugan, *J. Chem. Soc., Chem. Commun.*, 1989, 1286; (*f*) S. Araki, T. Shimizu, P. S. Johar, S.-J. Jin and Y. Butsugan, *J. Org. Chem.*, 1991, **56**, 2538.

2 K. Hoffmann and E. Weiss, *J. Organomet. Chem.*, 1972, **37**, 1; 1973, **50**, 17 and 25.

3 For reviews on 1,4-addition to α,β-unsaturated carbonyls, see: G. H. Posner, *Org. React.*, 1972, **19**, 1; F. R. Hartley, *The Use of Organometallic Compounds in Organic Synthesis*, Wiley, New York, 1987.

4 For reviews, see: G. Courtois and L. Miginiac, *J. Organomet. Chem.*, 1974, **69**, 1; R. M. Magid, *Tetrahedron*, 1980, **36**, 1901.

5 Y. Yamamoto, H. Yatagai and K. Maruyama, *J. Am. Chem. Soc.*, 1981, **103**, 1969.

6 R. Noyori, in *Transition Metal Organometallics in Organic Synthesis*, ed. H. Alper, Academic, New York, 1976, vol. 1, p. 83; Y. Yamamoto, H. Yatagai and K. Maruyama, *J. Org. Chem.*, 1984, **49**, 1096; K. Sekiya and E. Nakamura, *Tetrahedron Lett.*, 1988, **29**, 5155.