Supported Reagents in Facile and Selective Two-phase Additions to C=C Double Bonds

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Inorganic-solid-supported KSCN, NaN_3, and KOAc mixed with iodine and an alkene in $CHCl_3$ gave products by a facile two-phase addition.

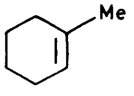
Although a variety of solid-supported inorganic salts have been studied for oxidation–reduction,[1,2] substitution,[1,2] elimination, and ring opening reactions,[1,3] their application to addition reactions has been limited. We now report a novel solid–liquid two-phase addition reaction to alkenes which utilises the benefits of supported reagents, such as high reagent activity, good selectivity, and ease of work-up. The two-phase addition consists of the attack of an electrophile in solution followed by attack of a nucleophile at the solid–liquid interface. Thus inorganic-solid-supported thiocyanate, azide, and acetate salts (KSCN, NaN_3, KOAc) mixed with an alkene and iodine in solution conveniently give vicinal substituted iodoalkanes in moderate or excellent yield, with good regioselectivity.

Table 1 gives yields of addition products using the various solid-supported salts in alkene/I_2/$CHCl_3$ systems. Some of the advantages of using the supported reagent system may be seen by comparing the iodothiocyanation of cyclohexene (runs 1—3) with previously reported results using phase transfer conditions (P.T.C.). Woodgate *et al.*[4] obtained a mixture of iodothiocyanatocyclohexane (30%) and iodoisothiocyanatocyclohexane (13%) after 2 h at 20 °C using a KSCN/H_2O/I_2/$CHCl_3$ system with Adogen 464 P.T.C. reagent. Reaction with KSCN/I_2/$CHCl_3$ alone gave only an 11% yield of a

Table 1. Two-phase addition to C=C double bonds.[a]

Run	Substrate	Reagent[b]	Temp. /°C	Time /h	Product[c]	% Yield (g.l.c.)
1	Cyclohexene	$KSCN{-}CaF_2$	r.t.[d]	2	*trans*-1-Iodo-2-thiocyanatocyclohexane	96
2	,,	$KSCN{-}SiO_2$	r.t.	2	,,	82
3	,,	$KSCN{-}Al_2O_3$	r.t.	2	,,	86
4	$PhCH{=}CH_2$	,,	20	6	$PhCH(SCN)CH_2I$	79
5	$PhCMe{=}CH_2$	,,	r.t.	30	$PhC(Me)(SCN)CH_2I$	68
					$PhC(Me)(SCN)CH_2SCN$	9
6	,,	$KSCN{-}SiO_2$	r.t.	30	$PhC(Me)(SCN)CH_2I$	43
					$PHC(Me)(SCN)CH_2SCN$	15
7	(**1**)	$KSCN{-}CaF_2$	r.t.	72	(**2**)	63
8	Cyclohexene	$NaN_3{-}CaF_2$	r.t.	48	*trans*-1-Azido-2-iodocyclohexane	44
9	,,	$NaN_3{-}Al_2O_3$	r.t.	48	,,	74
10	$PhCH{=}CH_2$	,,	20	7	$PhCH(N_3)CH_2I$	76
11	Cyclohexene	$KOAc{-}Al_2O_3$	55	42	*trans*-1-Acetoxy-2-iodocyclohexane	70
12	$PhCH{=}CH_2$	,,	55	48	$PhCH(OAc)CH_2I$	75

[a] Reaction with I_2 (1.5 mmol), supported salt (1.5 mmol), alkene (0.625 mmol), in 5 ml of ethanol-free $CHCl_3$. Work-up with aq. $Na_2S_2O_3$ wash, CH_2Cl_2 extraction, drying ($MgSO_4$), and solvent evaporation. [b] Prepared by rotary evaporation of an aqueous solution of the salt mixed with the support, followed by drying; loading was 0.5 mmol g^{-1} for CaF_2, 2 mmol g^{-1} for alumina (Merck 90 N), and 3 mmol g^{-1} for silica (Merck 60). [c] Identified by ^1H n.m.r. and i.r. spectroscopy and/or g.c.–mass spectrometry. [d] r.t. = room temperature.



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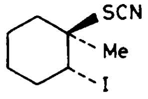

(2)

mixture of isomers.[4] In contrast, i.r. and ^{13}C n.m.r. analysis of the products obtained using the supported KSCN showed that the thiocyanate was produced selectively. We have recently shown that KSCN is activated for substitution on a variety of high-surface-area inorganic solids,[5] and the present results (runs 1—7) also show the high reactivity and selectivity of the reagents. The non-surface-hydroxylated CaF_2 support gave very high yield and easy recoverability of the adduct.

Azide anion addition to cyclohexyliodonium ion gave a higher yield with the alumina supported reagent rather than the calcium fluoride supported one. This presumably reflects the greater dispersion and activation of NaN_3 on the hydroxylated high surface area of alumina. The easier recoverability of products from the calcium fluoride support is of less importance.

The two-phase addition was also successful with an anion of much lower nucleophilicity; thus iodoacetoxylation of cyclohexene was achieved in high yield (run 11). The same reaction with Adogen 464 gave just 9% of iodoacetate and there was virtually no conversion without a P.T.C. reagent ($KOAc/I_2/CHCl_3$).[4] Our result is similar to that employing an 18-crown-6/$KOAc/CHCl_3/I_2$ system.[4]

We believe that our results show a potentially valuable new application of supported reagents, extending their value in organic synthesis.

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