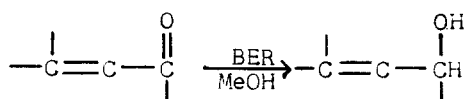BOROHYDRIDE REDUCING AGENT DERIVED FROM ANION EXCHANGE RESIN :

SELECTIVE REDUCTION OF α, β-UNSATURATED CARBONYL COMPOUNDS[1].

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ABSTRACT : Borohydride exchange resin (BER) exhibited selectivity in the
          reduction of α, β-unsaturated carbonyl compounds to the
          corresponding unsaturated alcohols.

It has been found that reagents supported on insoluble polymers have
acquired popularity in the last ten to fifteen years and have already found
wide applications in various fields, particularly for solving problems in
organic synthesis[2]. Among these, the borohydride exchange resin (BER) was
first reported in 1977 by Gibson and Baily[3a] and has been used in solvent
purification, generation of volatile metal hydrides and reduction of metal
ions and some aldehydes[3b]. The BER exhibited a high chemoselectivity not
only between aldehydes and ketones but also between ketones[4]. Now, we wish
to report that BER shows selectivity in the reduction of α, β-unsaturated
carbonyl compounds to the corresponding unsaturated alcohols in high yields.

$$-\overset{|}{C}=\overset{|}{C}-\overset{\overset{O}{\parallel}}{C} \xrightarrow[\text{MeOH}]{\text{BER}} -\overset{|}{C}=\overset{|}{C}-\overset{\overset{OH}{|}}{C}H$$

The reduction of a conjugated double bond is a substantial competing
process in the sodium borohydride reduction of both cyclic and acyclic
ketones[5a-5c]. Examination of the literature revealed several similar
reports[6a-6f] of conjugated ketone double bond reduction. Selective reduction
of α, β-unsaturated carbonyl compounds without disturbing the carbon-carbon
double bond is a frequent synthetic problem. In recent years various reagents
have been developed for such selective reductions[7a-7d] but they have several
disadvantages such as complex reaction workup, low yields etc. The selective
reduction of α, β-unsaturated aldehydes and ketones to the corresponding un-
saturated alcohols with BER is summarised in Table 1 and is found to be more
efficient than with the above reagents.

TABLE 1 : Reduction of α, β-Unsaturated Carbonyl Compounds with
Borohydride Exchange Resin to Corresponding Unsaturated
Alcohols at 25°C

Entry	Carbonyl compounds[a]	BER reagent[b] gm/mmol of substrate	Solvent	Time (hr)	Yield[c,d] %
1	Cinnamaldehyde	0.5	Methanol	1.50	99.0
2	Cinnamaldehyde	1.0	Methanol	0.25	99.0
3	Cinnamaldehyde	0.5	Benzene	60.00	99.0
4	Cinnamaldehyde	0.5	Ether	48.00	99.0
5	Cinnamaldehyde	0.5	Ethanol	3.00	99.0
6	Benzal acetone	1.0'	Methanol	4.00	90.0
7	Benzal acetophenone	1.0	Methanol	28.00	89.0
8	Benzal acetyl acetone	1.0	Methanol	4.00	93.0
9	Dibenzal acetone	1.0	Methanol	4.00	90.0
10	Citral	1.0	Methanol	3.00	90.0
11	Crotonaldehyde	0.5	Methanol[f] + H_2O	0.25	85.0
12	Cinnamaldehyde	0.5[e]	Methanol	0.50	99.0

a) One mmol substrate in 20 ml methanol.
b) BER prepared from Amberlite IRA-400.
c) Purity checked by GLC AIMIL DUAL column gas chromatograph
   model 5500 series on carbowax 10 % chromosorb-W-column.
d) Products characterised by IR and H^1 NMR.
e) BER prepared from Amberlyst A-26.
f) One mmol substrate in 10 ml methanol + 10 ml water.

As shown in Table 1 the reaction rate seems to be dependent on the BER
to the substrate ratio (entries 1 and 2), however, the yields generally
remain unaffected. The reduction may be performed in aprotic solvents such as
ether or benzene without significant variation in yields although longer
reaction times are required (entries 3 and 4). The rate of reduction is
much faster in methanol than in ethanol (entries 1 and 5). The reaction
rates also seem to be dependent on the structure of the substrate as BER
reduces the α, β-unsaturated aldehydes much faster than ketones (entries 1 and
6 to 10). The reduction of a unhindered ketone, benzal acetone, is much
faster than benzal acetophenone (entries 6 and 7) and this could be explained
on the basis of a steric effect. Under equivalent conditions BER prepared

from Amberlyst A-26 is much more reactive than BER prepared from Amberlite IRA-400 (entries 1 and 12). The rates of reduction with BER are found to be slower than $NaBH_4$ adsorbed on alumina suggesting greater selectivity of BER[8].

The BER has significant advantages over other hydride systems. Thus, simple separation of the reagent by filtration or decantation gives the solution of a pure product essentially free from a boron moiety[9]. The resin could be used repeatedly, since it can be regenerated to its initial activity by treating with a solution of $NaBH_4$.

A general procedure for the preparation of BER is as follows : 20 g of wet chloride-form resin (Amberlite IRA-400 anion exchange resin) was slurry packed with 100 ml sintered glass funnel, mounted on a filtering flask. Then, 200 ml of aqueous $NaBH_4$ solution (0.5 M) was slowly passed through the resin over a period of 60 minutes. The resulting resin was washed with distilled water thoroughly until free from excess of $NaBH_4$. The borohydride exchange resin was then dried in vacuo at $65^{\circ}C$ for 2 hours. The dried resin was analysed for borohydride content by hydrogen evolution on acidification with 0.8 N HCl and the average capacity of BER was found to be 2.5 mmol of BH_4^- per gram. The dried resin was stored under nitrogen at room temperature and the hydride content was found to be constant over 6 weeks.

A general procedure for the reduction of α, β-unsaturated carbonyl compounds : A solution of a carbonyl compound (1 mmol) in methanol (20 ml) was added to the BER (0.5 g) with constant stirring. After completion of the reaction the resin was removed by filtration and distillation of the solvent furnished the corresponding alcohol in high yield. The products were characterised by NMR and IR and the purity was checked by GC.

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1. This work in part is accepted for presentation at the Second International Conference on "Polymer Supported Reactions in Organic Chemistry" at Lancaster (U.K.), 2 to 5 July (1984).

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9. After the reduction with BER reagent the ethanol solution of the
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