

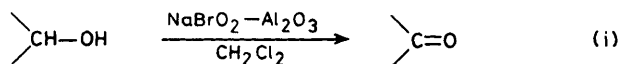
## Ready Oxidation of Alcohols to Carbonyl Compounds by Sodium Bromite in Methylene Dichloride in the Presence of Aluminium Oxide

Takashi Morimoto,\* Masao Hirano, Yumiko Aikawa, and Xiumin Zhang

Department of Industrial Chemistry, Faculty of Technology, Tokyo University of Agriculture and Technology, Koganei, Tokyo 184, Japan

Aliphatic secondary alcohols and aromatic alcohols were oxidized by sodium bromite in an inert solvent in the presence of aluminium oxide under mild conditions to give the corresponding carbonyl compounds in good yields.

Sodium bromite ( $\text{NaBrO}_2$ ) is intermediate in oxidation state between sodium hypobromite ( $\text{NaBrO}$ ) and sodium bromate ( $\text{NaBrO}_3$ ). Its aqueous solution has been used as a desizing agent for textiles.<sup>1</sup> Solid sodium bromite has been obtained as a trihydrate,<sup>2</sup> and has been used for the oxidation of alcohols,<sup>3</sup> alkenes,<sup>4</sup> and phenols,<sup>5</sup> and also for the *N*-bromination of amides<sup>6</sup> in water or acetic acid–water. However, the reagent has not been employed previously as an oxidant in a water-free solvent. We describe here the oxidation of aliphatic secondary alcohols and aromatic alcohols to carbonyl compounds by sodium bromite in methylene dichloride in the presence of aluminium oxide under mild conditions, with simple isolation of products [equation (i)].



Reagents supported on organic or inorganic carriers have recently been developed in order to simplify product isolation.<sup>7</sup> Such materials are prepared by evaporation of solvent from a mixture of oxidant and carrier in suspension, or by ion exchange of the oxidant prior to use. In the present reaction, the oxidant was simply mixed with alcohol and carrier in an inert organic solvent (benzene, acetonitrile, or methylene dichloride). Similar procedures have been reported in the use of an organic oxidant.<sup>8</sup>

### Results and Discussion

Sodium bromite trihydrate was mixed with aluminium oxide in methylene dichloride and the mixture was stirred. The suspended solid uniformly turned yellow, showing that the aluminium oxide had become covered with sodium bromite. When an alcohol was added to the resulting suspension, the colour was gradually discharged. Sometimes the suspension became orange for a short period during the reaction. G.l.c. analysis showed that the alcohol was converted into a carbonyl compound and that the oxidant was completely consumed when the yellow colour of the suspension had disappeared. Thus completion of the reaction could be judged visually. The same behaviour was observed in various other organic solvents, except for those sensitive to sodium bromite. Hexane, benzene, carbon tetrachloride, ether, and methylene dichloride were effective as solvents for the oxidation of alcohols and there was little difference in yields. Methylene dichloride was preferred for all the cases, since it is conveniently removed from the reaction mixture.

The reaction was carried out by mixing aluminium oxide, sodium bromite, and an alcohol in methylene dichloride. The mixture was stirred for a given time, and samples of the organic layer were removed at intervals and analysed by g.l.c. Plots of

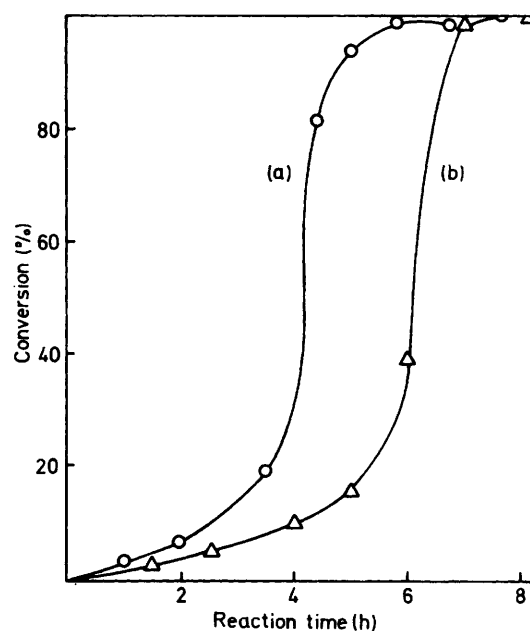


Figure. Conversion *vs.* reaction time in the oxidation of (a) diphenylmethanol and (b) 4-t-butylcyclohexanol by sodium bromite in methylene dichloride at room temperature

conversion *vs.* reaction time are shown in the Figure for the oxidations of 4-t-butylcyclohexanol and diphenylmethanol. The reaction was slow initially and then proceeded rapidly. At the final stage of the rapid reaction, the colour of the suspension removed completely. Subsequently the yield did not vary with reaction period, suggesting that the carbonyl compound underwent no further oxidation. The same behaviour was observed in the oxidation of benzyl alcohols to the corresponding benzaldehydes under argon even when an excess of sodium bromite was used. Indeed, control experiments showed that the tabulated ketones and aldehydes are stable to sodium bromite under the conditions used. These phenomena make the reaction easy to handle, since work-up can be carried out at any time after completion of the reaction.

The reaction was not accelerated at elevated temperature, perhaps owing to the instability of sodium bromite. Thus, the yield of carbonyl compound and the conversion of alcohol decreased gradually with temperature when the reaction was carried out above 30 °C. The reaction was therefore carried out routinely at room temperature without temperature control. Although the reaction period was dependent on the room temperature, almost all reactions were complete within 10–15 h.

**Table.** Oxidation of alcohols by sodium bromite in the presence of aluminium oxide in methylene dichloride<sup>a</sup>

Alcohol	Oxidant/ substrate	Yield (%) <sup>b</sup>
2-Methylcyclohexanol	1.5	89 <sup>c</sup>
3-Methylcyclohexanol	1.0	96
4-Methylcyclohexanol	1.0	96
Cyclohexanol	2.0	96
4-t-Butylcyclohexanol	1.0	98
Cyclododecanol	1.0	86 <sup>d</sup>
Menthol	1.5	79 <sup>d</sup>
(+)-Borneol	1.0	100
(±)-Isoborneol	1.0	98
Octan-2-ol	1.0	98
Benzyl alcohol	1.0	99
4-Methylbenzyl alcohol	1.0	95
4-Chlorobenzyl alcohol	1.0	92
4-Nitrobenzyl alcohol	1.0	80
1-Phenylethanol	2.0	99
Diphenylmethanol	1.5	99

<sup>a</sup> Reactions for 24 h at ambient temperature; *ca.* 0.5 g of substrate, 2 g of aluminium oxide, and 10 ml of methylene dichloride used in every run.

<sup>b</sup> Yields of isolated product. <sup>c</sup> Reaction for 32 h. <sup>d</sup> Product purified by flash chromatography.

The use of silica gel in place of aluminium oxide resulted in lower yields of carbonyl compounds. In the absence of aluminium oxide or silica gel, the oxidation did not proceed and almost all substrate was recovered showing that the surface of these solids plays an important role in the oxidation.

On the basis of the foregoing observations, oxidations of various alcohols by sodium bromite were conducted in methylene dichloride in the presence of aluminium oxide at room temperature. When benzyl alcohols were used as substrates, the reaction flask was flushed with argon because of the sensitivity of the products to autoxidation. The results are summarized in the Table. Oxidation of benzylic alcohols proceeded smoothly to give aldehydes or ketones in good yields. The effect of ring substituents on the yields was small: even *p*-nitro derivatives gave the corresponding benzaldehydes in fairly good yield. Aliphatic secondary alcohols were also smoothly oxidized to ketones in excellent yield. Some differences in reaction period result from differences in substrate reactivity, but 24 h reactions all gave satisfactory yields of carbonyl compounds except in the case of cyclohexanol. When the reaction was monitored by a suitable method,\* it was possible to stop the reaction earlier and to obtain the same results as those in the Table.

Aliphatic primary alcohols could be oxidized by this method to the corresponding carboxylic esters in low yields; the corresponding aldehydes were scarcely formed under the same conditions. A study of this reaction is under way in our laboratory.

The present reaction is clean and the procedures for isolation of the product are convenient. Insoluble sodium bromide and aluminium oxide can be separated by filtration, and the carbonyl compounds can be isolated by evaporation of the filtrate. G.l.c. analysis showed that the carbonyl compounds obtained were of high purity (over 95% in almost all cases).

\* When a stoichiometric amount or a small excess of sodium bromite was used, judgement of completion of the reaction from the colour change was not satisfactory: some unchanged alcohol sometimes still remained.

When purification of the product was necessary, because of low conversion or the formation of a by-product, the mixture could be chromatographed immediately after evaporation of the solution. Furthermore, when the conversion was low and a considerable amount of alcohol remained, more sodium bromite could be added to the mixture to complete the reaction.

A variety of supported reagents<sup>7</sup> have been used previously, including metallic oxidants on silica gel,<sup>9</sup> on aluminium oxide,<sup>8</sup> or on polymer.<sup>10</sup> The present system is a kind of supported oxidant, and is particularly useful since all the components are available commercially. The reaction system may be effective for both oxidation and bromination of various compounds, since sodium bromite is reported to be useful both as an oxidant<sup>3-5</sup> and as a bromination reagent<sup>6</sup> in a water-containing solvent. We have already found that the system is useful for the conversion of sulphides into sulphoxides and for the conversion of amides into urea derivatives.<sup>11</sup>

## Experimental

<sup>1</sup>H N.m.r. spectra were measured for solutions in CCl<sub>4</sub> with a JEOL PMX-60 spectrometer. I.r. spectra were recorded with a JASCO DS-403G spectrophotometer. G.l.c. was carried out with a Shimadzu GC-6A instrument (2 m glass column packed with 5% PEG-20M on Chromosorb WAW-DMCS) and on a Shimadzu GC-4C instrument (2 m glass column packed with 1.5% Silicone OV-17 on Chromosorb WAW-DMCS), with temperature programming.

Sodium bromite trihydrate was obtained from Nippon Silica Kogyo Co. Ltd., and was used without purification. The solvent and super-dried aluminium oxide (Woelm Pharma, Super I) were commercially available and were used without purification.

A typical procedure was as follows. To aluminium oxide (2 g) in methylene dichloride (10 ml) were added sodium bromite trihydrate (0.63 g, 3.3 mmol) and then 4-t-butylcyclohexanol (0.50 g, 3.2 mmol), with a small amount of the solvent. The mixture was stirred for 24 h at ambient temperature. The solution was filtered through sintered glass and the solid was thoroughly washed with the same solvent or diethyl ether (*ca.* 100 ml). Evaporation of the combined filtrate under reduced pressure gave 4-t-butylcyclohexanone (0.48 g, 98%) identified by n.m.r. and i.r. spectra. This compound was nearly 100% pure by g.l.c.

G.l.c. analysis sometimes showed that the product was contaminated with a trace of parent alcohol. In such cases the carbonyl compound was easily purified by flash chromatography.

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