

N,N'-Dibromo-*N,N'*-1,2-ethanediylbis(benzenesulphonamide) (BNBBS): a Safe, Neutral and Efficient Reagent for the Oxidation of Primary and Secondary Alcohols to Corresponding Carbonyl Compounds under Mild Conditions

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ABSTRACT

Efficient oxidation of various types of structurally diverse alcohols to the corresponding carbonyl compounds can be carried out with *N,N'*-dibromo-*N,N'*-1,2-ethanediylbis(benzenesulphonamide) in good to high yield of products in CH₂Cl₂ at room temperature. Primary (aliphatic, benzylic and allylic) alcohols are oxidized with no over-oxidation to carboxylic acids.

KEYWORDS

Oxidation, alcohols, carbonyl compounds, *N,N'*-dibromo-*N,N'*-1,2-ethanediylbis(benzenesulphonamide).

1. Introduction

The selective oxidation of primary and secondary alcohols to the corresponding carbonyl compounds is a key transformation in modern organic synthesis.¹ Apart from conventional stoichiometric oxidants, notably chromium (VI) and manganese reagents, which produce copious amounts of heavy metal waste,^{2,3} the use of molecular oxygen with a variety of metal catalysts has been reported in the literature,^{4–11} in pursuit of the development of eco-friendly synthetic methodologies. However, these procedures suffer from one or more drawbacks, such as the use of expensive metal catalysts like ruthenium and palladium, oxidation of only activated alcohols such as benzylic and allylic alcohols, the need for a sacrificial aldehyde, and severe reaction conditions, for example, high temperature or pressure, leaving scope for further improvements in the catalytic oxidation of alcohols to corresponding carbonyl compounds.

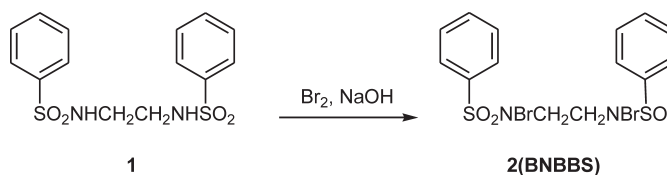
Favourable attributes of an alcohol oxidation procedure include high conversions, the absence of side products, the use of available, inexpensive, non-toxic reagents, and mild conditions. On the basis of our knowledge of the literature on the oxidation of alcohols to carbonyl compounds using *N*-bromosuccinimide (NBS), we found this reaction needs to use co-reagents such as heavy metals or acidic or alkaline conditions.^{12–14} Recently we reported that *N,N'*-dibromo-*N,N'*-1,2-ethanediylbis(benzenesulphonamide) (BNBBS)¹⁵ in the presence of (CH₃)₂S in CH₂Cl₂ at –15 °C is an efficient reagent for the oxidation of primary and secondary alcohols to aldehydes and ketones. However the major disadvantages with these *N*-halo reagents (NBS, BNBBS) are the requirement for special conditions and long reaction times. These observations encouraged us to investigate the ability of another protocol for the efficient and highly rapid conversion of various types of alcohols to their corresponding carbonyl compounds under mild conditions.

2. Results and Discussion

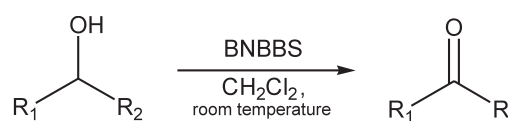
A large group of substances generically called *N*-halo reagents is widely used in fine organic synthesis and in the chemistry of natural compounds.¹⁶ In a continuation of our interest in the application of *N*-halo compounds in organic synthesis,¹⁷ very recently we used *N,N'*-dibromo-*N,N'*-1,2-ethanediylbis(benzenesulphonamide) (BNBBS) (**2**) as a catalyst for the tetrahydropyranlation of alcohols.^{17c} Here we report a convenient methodology for the oxidation of alcohols to the corresponding carbonyl compounds in good to high yields with BNBBS which overcomes the disadvantages associated with oxidative methods developed so far. BNBBS is prepared similarly to other *N*-halo reagents from *N,N'*-1,2-ethanediylbis(benzenesulphonamide) (**1**) by the action of molecular bromine in alkaline medium (Scheme 1).

Various types of alcohols were converted to corresponding carbonyl compounds in the presence of BNBBS in dichloromethane at room temperature (Scheme 2).

The oxidation of various types of structurally diverse alcohols



Scheme 1

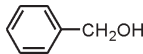
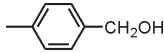
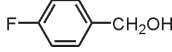
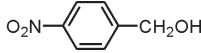
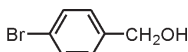
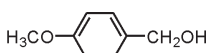
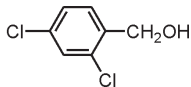
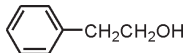
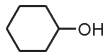
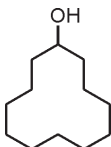
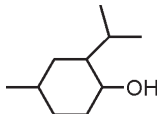
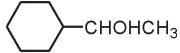


R₁, R₂ = H, benzylic, linear, cyclic, aryl

Scheme 2

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Table 1 Oxidation of alcohols with BNBBS in dichloromethane at room temperature.

Entry	ROH	Molar ratio Substrate/BNBBS	Time/h	Yield/% ^{a,b}	M.p./°C	Lit. m.p./°C ^{23–25}
1		1:1.5	1	90	234–236	237
2		1:1.5	0.58	97	229–231	233
3		1:1.5	0.75	95	258–260	260–261
4		1:1.5	4.41	93	317–319	320
5		1:1.5	1.75	85	275–277	278
6		1:1.5	0.76	92	250–252	253
7		1:1.5	0.41	98	70–72	72 ^c
8	PhCH(OH)Ph	1:1.5	5.33	95	246	248–249
9	CH ₃ (CH ₂) ₆ CH ₂ OH	1:1.5	3.25	86	104–106	106
10		1:1.5	6.08	91	118–120	120
11	CH ₃ CH(OH)(CH ₂) ₄ CH ₃	1:1.5	1	87	87–89	89
12		1:1.5	1.75	90	158–160	161
13		1:1.5	1	95	57	59 ^d
14		1:1.5	2.33	90	137–140	140–142
15		1:1.5	1.50	87	138–139	140–141

^a All products were characterized by comparison of their spectral data (¹H NMR and IR spectra) and the melting points of their 2,4-dinitrophenylhydrazone derivatives with those of authentic samples.

^b Isolated yields as mass of their 2,4-dinitrophenylhydrazone derivatives.

^c Melting point of 2,4-dichlorobenzaldehyde.

^d Melting point of cyclododecanone.

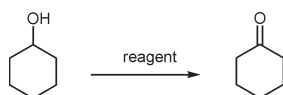
was carried out under optimized conditions, and the results are shown in Table 1.

It is notable that side reactions such as oxidations of carbon-hydrogen bonds to alcohols, over-oxidation of aldehydes and bromination of aromatic rings, were not observed.

In order to illustrate the activity of BNBBS, we compared our results obtained for the oxidation of cyclohexanol with oxidizing reagents, including halogen-based oxidants, as shown in

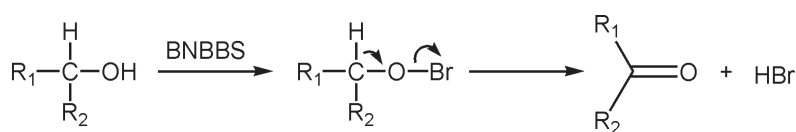
Table 2. The advantages or the characteristic aspects of the described method in this communication in comparison with other previously reported *N*-halo reagents are:

- There is no need to use a co-reagent such as heavy metals,^{14,15,18–21} therefore it has good economic and environmental properties.
- This method proceeds under 'neutral' conditions without requiring the assistance of acids or bases.¹⁵

Table 2 Comparison of the activity of this procedure with various methods including halogen-based oxidants for oxidation of cyclohexanol.

Entry	Catalyst	Conditions	Time/h	Yield/%	Ref.
1	BNBBS	CH ₂ Cl ₂ , room temperature	1.75	90	This work
2	BNBTS	CH ₂ Cl ₂ , (CH ₃) ₂ S, Et ₃ N, -15 °C	3	90	15
3	DABCO-Br ₂	CH ₂ Cl ₂ , room temperature	3.5	84	18
4	NCS, TEMPO, TBACl	CH ₂ Cl ₂ , room temperature	–	–	19
5	Bis(quinuclidine) bromine, AgBF ₄	CH ₂ Cl ₂ , room temperature	0.5	102	20
6	NBS, Bu ₄ NI	CH ₃ CN, MW(150 W) ^a	–	N.R	21
7	NBS, Co	CH ₃ CN, reflux	1.50	80	14

^aMW(150 W) = microwave treatment at 150 watts.

**Scheme 3**

(iii) Special temperature conditions such as reflux¹⁴ or low¹⁵ temperature are avoided.

The other advantages of BNBBS are that it is inexpensive, it has no moisture sensitivity, and no special efforts are required for its preparation.

At this stage the precise role of BNBBS to produce high yields in relatively short reaction times is not clear and the actual role of this reagent should be further studied in detail. On the basis of previously reported mechanisms for applying *N*-haloimides for the oxidation of alcohols,²² the primary or secondary alcohol forms a hypobromite which readily loses hydrogen bromide to form the carbonyl product (Scheme 3).

3. Conclusion

The procedure reported here is simple and allows for the oxidation of alcohols to carbonyl compounds under very mild and neutral conditions. The method seems to be as convenient for selective oxidation of both primary and secondary alcohols to carbonyl compounds without over-oxidation to carboxylic acids and can be used as a valid alternative oxidation method by avoiding the use of toxic reagents. Furthermore, BNBBS is an efficient, non-metallic, air- and water-stable oxidant and other work in our laboratory is directed towards broadening the scope and applications of this novel and efficient oxidant.

4. Experimental

General Procedure for Oxidation of Alcohols with BNBBS

BNBBS (1.5 mmol) was added to a mixture of alcohols (1 mmol) in CH₂Cl₂ (10 mL) and the mixture was stirred at room temperature for the specified time (Table 1). The progress of reaction was monitored by TLC (eluent: n-hexane/acetone 10:1). Upon completion of the reaction, solvent was removed under vacuum and n-hexane (20 mL) was added to the residual mixture. Insoluble reagent was removed by filtration. Evaporation of the n-hexane under reduced pressure gave the corresponding carbonyl compounds in 85–98% yields isolated as their 2,4-dinitrophenylhydrazone derivatives, which were recrystallized from ethanol.

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