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(±)-Camphor sulfonic acid assisted IBX based oxidation of 1° and 2° alcohols

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Introduction

Oxidation of alcohols is a very common reaction in organic synthesis. Oxidation of alcohol results carbonyl compounds like aldehyde, ketone, carboxylic acid [1]. Carbonyl compounds are the key synthons in synthetic organic chemistry i. e., these are the starting material for the development of drugs, antibiotics and agrochemicals, ring systems etc. Several efforts have been made to oxidize alcohols [2].

In recent decade, interest in the hypervalent iodine chemistry has grown at a rapid pace due to the environmental benign, mild and highly selective oxidizing nature of these reagents [3,4]. Among these, IBX (*o*-iodoxybenzoic acid) is one of the fashionable hypervalent iodine(v) reagent, which may be ascribe to its remarkable reactivity and commercial availability [4,5]. The insolubility of IBX in common organic solvents except DMSO, and explosive nature at high temperature are the main challenges with this reagent [6]. Since after Dess-Martin periodinane [7], a number of modified IBXs [8] and solid supported IBX [9] have been prepared to overcome these problems. However, typical synthetic procedures and high cost limits the use of these modified IBXs [8]. In contrast, to avoid the structural modifications and enhance the efficiency of IBX few additives like oxone [10] acetic acid [11] trifluoroacetic acid [12] *p*-toluenesulfonic acid [13] triflic acid or trifluoromethanesulfonic acid [14] β-cyclodextrin [15] have been used. Several reports also demonstrate that IBX is a powerful oxidant when used in ionic liquids [16] or solvents like EtOAc [17] acetone or MeCN at elevated temperature [18]. IBX-OTs was reported as a powerful oxidant in dichloromethane for the oxidation of alcohols. Recently an IBX based new reagent (IBX-ditriflate) was synthesized which transform C—H into C-OH (Fig. 1) [14]. In our earlier report we have used triflic acid in combination with IBX to oxidise alcohols but instability of TfOH at room temperature [14], difficult handling and safety concerns compel us to develop more easy and convenient method for the same. Therefore, herein we have established a more convenient methodology.

Result and discussion

Optimization of reaction condition

Initially 4-nitrobenzyl alcohol was oxidized using IBX as an oxidant in DCM at room temperature. No isolable product formation was observed even after 12 hrs. Surprisingly addition of one equivalent of (±)-Camphor sulfonic acid monohydrate leads to the formation of a new spot on the TLC which was relatively less polar than alcohol. Preliminary investigation (visualization with 2, 4-DNP solution) indicates the progress in oxidation and this promoted us to establish this methodology. The solvent screening results indicated that the binary solvent system (DCM:1,4-dioxane ratio; 1:1) was the most appropriate solvent for this reaction. Further we screened the oxidant IBX and (±)-CSA monohydrate and combination of 1.2 equivalent of IBX with respect to alcohol and 15–20 mol% of (±)-CSA monohydrate (see SI, Tables 1 and 2) was found to be optimum combination for this conversion. After optimizing the reaction condition, a verity of 1° and 2° alcohols were screened.

Under optimized reaction condition verity of benzyl alcohols (Fig. 1) were oxidized. The oxidation of nitro substituted benzyl alcohols shows that the 4-nitro benzyl alcohol oxidized faster with higher yield with respect to 2-nitro benzyl alcohol, it indicates the retardation of oxidation due to steric effect of nitro group at 2nd position. The 4-fluoro, 4-chloro and 4-bromo benzyl alcohols were oxidised and shows almost similar results. The oxidation of 4-cyano benzyl alcohol was little messy with relatively poor yield. Piperonal was obtained quickly from the oxidation of piperonyl alcohol. 4-Methoxy benzyl alcohols were oxidized successfully with high yield. The oxidation of primary and secondary alcohols, attached with heterocyclic rings are quite challenging and less explored with IBX oxidation too. Here in we have oxidised few such class of alcohols in easy manner.

Different secondary alcohols were successfully oxidized using (±)-camphor sulfonic acid/IBX as catalytic system. The methyl, hydroxy, and bromo 1-phenylethan-1-ol were oxidised into corresponding acetophenones. The 2,3-dihydro-*1H*-inden-1-ol was oxidised under these reaction condition with quantitative yield. To investigate the selectivity in oxidation, the 2,3-dihydro-1*H*-indene-1,3-diol was subjected to oxidation under this reaction condition, the mixed product of 1-indanone and 1,3-indandione

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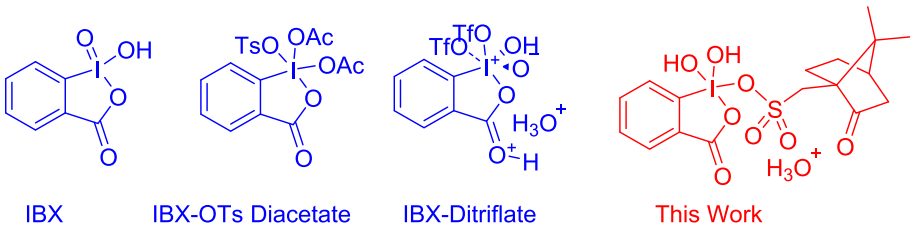
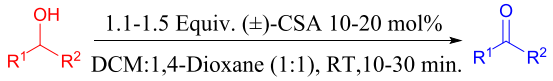


Fig. 1. IBX based oxidants.



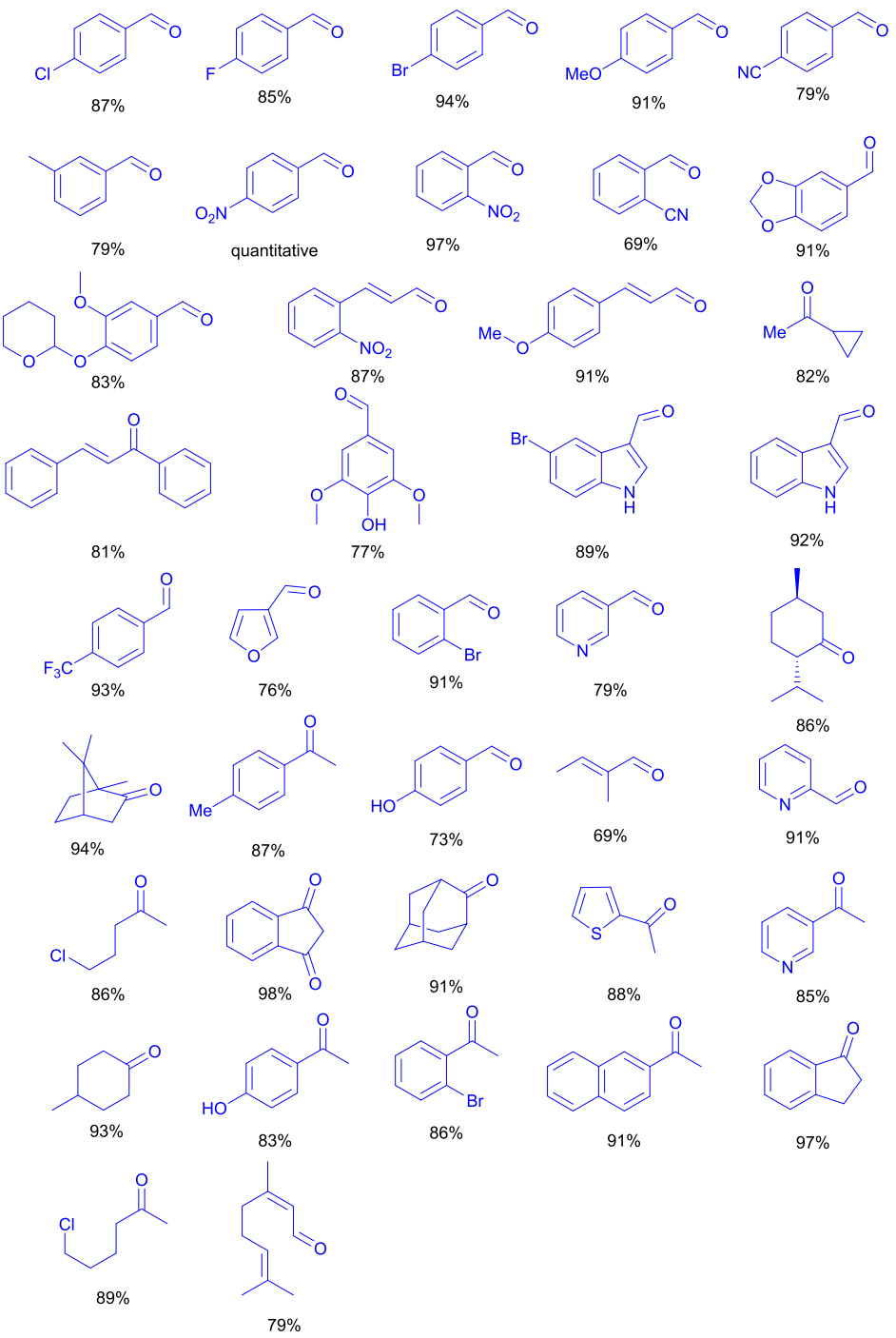


Fig. 2. Oxidation of different primary and secondary alcohols.

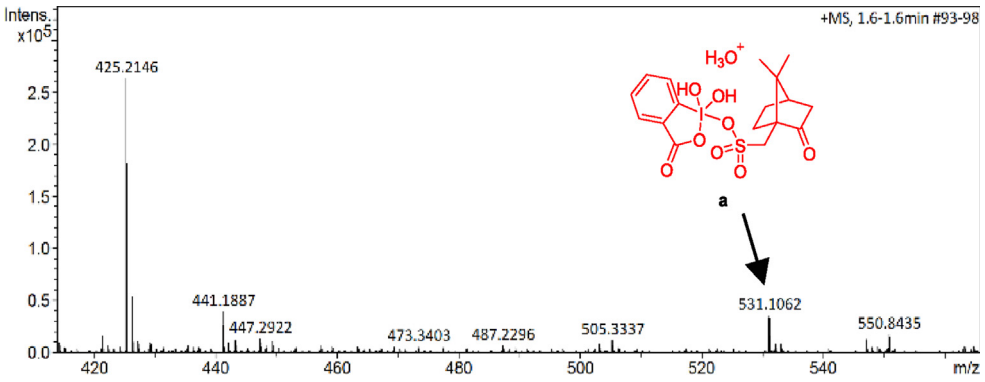


Fig. 3. Mass spectrometry of reaction mixture.

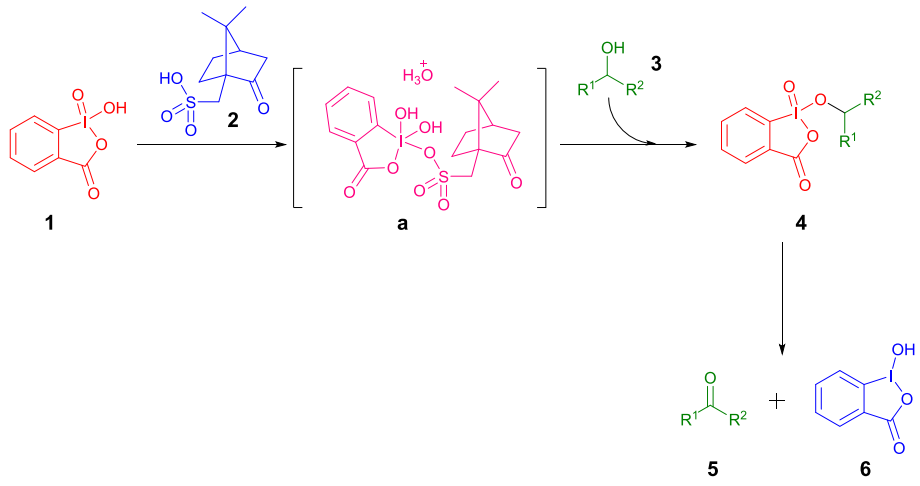


Fig. 4. Plausible mechanism of oxidation.

were obtained. This indicates no partial oxidation; the complete oxidation consumed 2.3 equivalent of IBX with 15 mol% (±)-CSA. Benzyl allyl alcohol produced chalcone in quantitative yield. Further this method was employed to oxidise aliphatic primary and secondary alcohols (Fig. 2). Sometimes oxidation of the aliphatic alcohols is more challenging due to poor yield and difficulty in isolation of the products. Few simple alcohols *viz* cyclopropylethan-1-ol, 4-methylcyclohexanol, 5-chloropentan-2-one and 6-chloropentan-2-one were oxidised and isolated with high yield. Geraniol was oxidised into geranial with 79% of isolated yield. The norborneol is a bulky substrate, which was oxidised successfully with 94% yield.

Admantan-2-one was obtained from the oxidation of admantane-2-ol with a very good yield. The (*E*)-2-methylbut-2-en-1-ol was kept under oxidation and isolated yield was 69%. 4-Hydroxy benzyl alcohol was oxidized under this newly developed methodology, the only hydroxy group at benzylic position was oxidised i.e., 4-hydroxybenzaldehyde was isolated as oxidized product. The oxidation of trans-menthol in acidic medium may produce the racemic mixture, so to check the applicability of this method we have kept the trans-menthol under this oxidation condition and found that the isolated product was single stereoisomer, which was confirmed by ^{1}H, ^{13}C and CD spectra (see SI).

To understand the advantage of IBX-(±)-CSA based oxidant in the oxidation of alcohols, two separate reactions were performed (a) oxidation of 4-nitrobenzyl alcohol with IBX and (b) oxidation of 4-nitrobenzyl alcohol with IBX-(±)-CSA at room temperature. ^{1}H NMR spectra of both the reaction was recorded. It was found that the reaction in which the (±)-CSA was not used, 2.6% of 4-nitro benzaldehyde was formed (see SI, ^{1}H NMR, Figs. 1 and 2), while in case of IBX-(±)-CSA based oxidation, 92.3% of 4-nitrobenzaldehyde was formed. The experiment concludes that the newly develop methodology is far efficient over oxidation by IBX itself only.

In order to understand the possible cause of trigger in oxidizing power of IBX in common organic solvent at room temperature, we performed an experiment and recorded the mass spectrum of the mixture of IBX and (±)-CSA. The appearance of m/z = 531.1062 in mass spectrum clearly indicate the formation of $C_{17}H_{24}IO_9S$, which can be represented best as 'a' (Fig. 3).

On the basis of mass spectrum data, the plausible mechanism of the oxidation is given in Fig. 4. First of all, (±)-CSA monohydrate **(2)** reacts with IBX **(1)** to give a highly reactive oxidant with formula $C_{17}H_{24}IO_9S$ **(a)** (confirmed by HRMS, see SI). The *in-situ* generated oxidant **(a)** undergoes ligand exchange with alcohol **(3)** and produce **(4),** which undergoes decomposes into carbonyl compound **(5)** and IBA **(6)**.

Conclusions

In conclusion, we have developed a practical and efficient methodology for the oxidation of primary and secondary alcohols which includes aliphatic, aromatic, heterocycles with differently substituted functional groups. This method is beneficial in terms of easy reaction condition, cheap reagents, highly efficient and quick purification.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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Experimental Section

Under nitrogen atmosphere, 1.1-1.5 mmol IBX and 10 to 20 mol % (±)-CSA monohydrate was added in round bottom flask already charged with magnetic bar and 2 mL DCM:1,4-Dioxane. Stirred the mixture for 10 minutes at room temperature and added the solution of alcohol dropwise for 5 minutes. Stirred the solution at room temperature till complete consumption of alcohol. Strip off the solvent and dilute the reaction mass with DCM. Filter the suspension through sintered funnel and wash the residue properly with DCM. This residue (white powdered solid, reduced part of IBX) was successfully used for preparation of IBX. Concentrate the filtrate on rotovap and purify the product by column chromatography.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tetlet.2021.153298.

References

[1] G. Tojo, M. I. Fernandez, 2006, Springer US, ISBN 978-0-387-23607-0.
[2] (a) T. Mallat, A. Baiker, Chem. Rev. 104 (2004) 3037–3058;
(b) M.S. Sigman, D.R. Jensen, Acc. Chem. Res. 39 (2006) 221–229;
(c) M.J. Schultz, M.S. Sigman, Tetrahedron 62 (2006) 8227–8241;
(d) W. Kroutil, H. Mang, K. Edegger, K. Faber, Adv. Synth. Catal. 346 (2004) 125–142.
[3] (a) Hypervalent Iodine Chemistry: Modern Developments in Organic Synthesis, ed. T. Wirth, 2003; (b) V. V. Zhdankin, Hypervalent Iodine Chemistry: Preparation, Structure, and Synthetic Applications of Polyvalent Iodine Compounds; Academic Press: John Wiley & Sons, 2013, 145– 307; (c) R. M. Moriarty, O. Prakash, Hypervalent Iodine in Organic Chemistry: Chemical Transformations; Wiley-Blackwell, 2008; (d) V. V. Zhdankin, P. J. Stang, Chem. Rev. 108 (2008) 5299; (e) Viktor V. Zhdankin ARKIVOC 2009 (i) 1-62; (f) M. S. Yusubov, D. Yu. Svitich, M. S. Larkina, V. V. Zhdankin, ARKIVOC, 2013, i, 364.
[4] A. Yoshimura, V.V. Zhdankin, Chem. Rev. 116 (2016) 3328–3435.
[5] (a) C. Hartmann, V. Meyer, Chem. Ber. 26 (1893) 1727–1732;
(b) V. Satam, A. Harad, R. Rajule, H. Pati, Tetrahedron 66 (2010) 7659–7706;
(c) A. Duschek, S.F. Kirsch, Angew. Chem. Int. Ed. 50 (2011) 1524–1552;
(d) V.V. Zhdankin, J. Org. Chem. 76 (2011) 1185–1197;
(e) Fateh V. Singh, T. Wirth, Chem. - Asian J. 9 (2014) 950–971;
(f) T.K. Achar, S. Maiti, P. Mal, RSC Adv. 4 (2014) 12834–12839.
[6] (a) M. Frigerio, M. Santagostino, S. Sputore, Giovanni Palmisano, J. Org. Chem. 60 (1995) 7273–7276;
(b) M. Frigerio, M. Santagostino, Tetrahedron Lett. 35 (1994) 8019–8022;
(c) K.C. Nicolaou, C.J.N. Mathison, T. Montagnon, J. Am. Chem. Soc. 126 (2004) 5192–5201.
[7] D.B. Dess, J.C. Martin, J. Org. Chem. 48 (1983) 4155–4156.
[8] (a) D.B. Dess, J.C. Martin, J. Am. Chem. Soc. 113 (1991) 7277–7287;
(b) D. Macikenas, E. Skrzypczak-Jankun, J.D. Protasiewicz, Angew. Chem. Int. Ed. 39 (2000) 2007–2010;
(c) G. Sorg, A. Mengei, G. Jung, J. Rademann, Angew. Chem. Int. Ed. 40 (2001) 4395–4397;
(d) A.P. Thottumkara, T.K. Vinod, Tetrahedron Lett. 43 (2002) 569–572;
(e) V.V. Zhdankin, A.Y. Koposov, B.C. Netzel, N.V. Yashin, B.P. Rempel, M.J. Ferguson, R.R. Tykwinski, Angew. Chem. Int. Ed. 42 (2003) 2194–2196;
(f) W.-J. Chung, D.-K. Kim, Y.-S. Lee, Tetrahedron Lett. 44 (2003) 9251–9254;
(g) U. Ladziata, A.Y. Koposov, K.Y. Lo, J. Willging, V.N. Nemykin, V.V. Zhdankin, Angew. Chem. Int. Ed. 44 (2005) 7127–7131;
(h) B.V. Meprathu, M.W. Justik, J.D. Protasiewicz, Tetrahedron Lett. 46 (2005) 5187–5190;
(i) A.Y. Koposov, D.N. Litvinov, V.V. Zhdankin, M.J. Ferguson, R. McDonald, R.R. Tykwinski, Eur. J. Org. Chem. (2006) 4791–4795;
(j) R.D. Richardson, J.M. Zayed, S. Altermann, D. Smith, T. Wirth, Angew. Chem., Int. Ed. 46 (2007) 6529–6532;
(k) L.-Q. Cui, Z.-L. Dong, K. Liu, C. Zhang, Org. Lett. 13 (2011) 6488–6491;
(l) J.N. Moorthy, K. Senapati, K.N. Parida, S. Jhulki, K. Sooraj, N.N. Nair, J. Org. Chem. 76 (2011) 9593–9601;
(m) S. Seth, S. Jhulki, J.N. Moorthy, Eur. J. Org. Chem. (2013) 2445–2452;
(n) J.N. Moorthy, K. Senapati, K.N. Parida, J. Org. Chem. 75 (2010) 8416–8421.
[9] (a) M. Mülbaier, A. Giannis, Angew. Chem., Int. Ed. 40 (2001) 4393–4394;
(b) A. Ozanne, L. Pouységu, D. Depernet, B. Francüois, S. Quideau, Org. Lett. 5 (2003) 2903–2906.
[10] A.P. Thottumkara, M.S. Bowsher, T.K. Vinod, Org. Lett. 7 (2005) 2933–2936.
[11] C.-K. Lin, T.-J. Lu, Tetrahedron 66 (2010) 9688–9693.
[12] J.N. Moorthy, N. Singhal, K. Senapati, Org. Biomol. Chem. 5 (2007) 767–771.
[13] M.S. Yusubov, D.Y. Svitich, A. Yoshimura, V.N. Nemykin, V.V. Zhdankin, Chem. Commun. 49 (2013) 11269–11271.
[14] (a) M. S. Yusubov, N. S. Soldatova, P. S. Postnikov, R. R. Valiev, A. Yoshimura, T. Wirth, V. N. Nemykin, V. V. Zhdankin, Chem. Commun. 55 (2019) 7760-7763; (b) K. Kumar, P. Kumar, P. Joshi, D. S. Rawat, Tetrahedron Lett. 61 (2020) 151749 (Featured in Org. Chem. Highlights: Oxidation (https://www.organic-chemistry.org/Highlights/2021/25January.shtm).
[15] K. Surendra, N.S. Krishnaveni, M.A. Reddy, Y.V.D. Nageswar, K.R. Rao, J. Org. Chem. 68 (2003) 2058–2059.
[16] (a) G. Karthikeyan, P.T. Perumal, Synlett (2003) 2249–2251;
(b) Z. Liu, Z.C. Chen, Q.G. Zheng, Org. Lett. 5 (2003) 3321–3323;
(c) J.S. Yadav, B.V.S. Reddy, A.K. Basak, A.V. Narsaiah, Tetrahedron 60 (2004) 2131–2135.
[17] Samuel L. Bartlett, Christopher M. Beaudry, J. Org. Chem. 76 (2011) 9852–9855.
[18] Jesse D. More, Nathaniel S. Finney, Org. Lett. 4 (2002) 3001–3003.