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Oxidative carbon–carbon bond cleavage reaction of 1,2-diamines and 1,2-amino alcohols under an oxygen atmosphere

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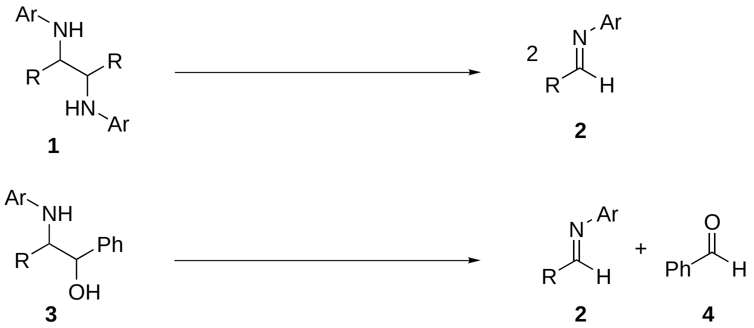
Abstract—Under an atmosphere of oxygen 1,2-diamines underwent clean oxidative cleavage in the presence of $BF_3{\cdot}OEt_2$ to give imines in good to excellent yields. 1,2-Amino alcohols were also cleaved under the same conditions to give imines and aldehydes in good yields. © 2001 Elsevier Science Ltd. All rights reserved.

Although oxidative cleavage of 1,2-diols constitutes one of the most important transformations which involve use of periodic acid,[1] lead tetraacetate,[2] activated MnO_2,[3] and pyridinium chlorochromate,[4] that of 1,2-diamines and/or amino alcohols has not been studied in detail. This may be due to lack of general methodologies for such transformations. Only limited examples involve use of dimethyldioxirane for cleavage of 1,2-diamines[5] and sodium periodate or periodic acid for 1,2-amino alcohols,[6] respectively. In connection with growing interests in the compounds containing 1,2-diamino and/ or amino alcohol moieties, selective transformation of such functionalities has received considerable preparative interests.[7,8]

We have been interested in the preparation of 1,2-diamines and 1,2-amino alcohols in a diastereo- and enantioselective manner, and have already disclosed asymmetric imino pinacol coupling,[9] stereoselective reduction of 1,2-diimines and 1,2-imino ketones,[10] and *N*-alkylation-coupling reaction.[11] During these investigations we have been interested in the selective oxidative cleavage of produced 1,2-diamines and 1,2-amino alcohols, since they sometimes underwent cleavage reactions upon standing in open air in the presence of a certain acid. This report describes a simple and ready method for the oxidative cleavage of 1,2-diamines and 1,2-amino alcohols to give the corresponding imines and aldehydes in high yields (Scheme 1).

The initial examination was carried out using *N*,*N*-diaryl-1,2-diphenylethane-1,2-diamine as substrate in the presence of various acids under an oxygen atmosphere, and the results are summarized in Table 1.[12]

The cleavage reaction of *N*,*N*-bis-(4-methoxyphenyl)-1,2-diphenylethane-1,2-diamine **1** (R = Ph, Ar = *p*-An) in the absence of acids gave the imine **2** in moderate yield even after 46 h (entry 1). While the use of protic



Scheme 1.

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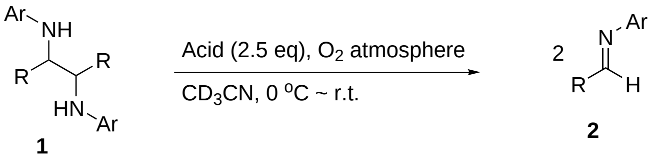
Table 1. Cleavage of 1,2-diamines[a]



Entry	R	Ar (*dl*:*meso*)	Acid	Time (h)	Yield[b] (%)
1	Ph	4-MeOC$_6$H$_4$ (50:50)	None	46	67
2	Ph	4-MeOC$_6$H$_4$ (50:50)	MsOH	18.5	25[c]
3	Ph	4-MeOC$_6$H$_4$ (50:50)	TsOH	1.5	21[d]
4	Ph	4-MeOC$_6$H$_4$ (50:50)	TMSOTf	2.5	77
5	Ph	4-MeOC$_6$H$_4$ (50:50)	AlCl$_3$	1.5	75
6	Ph	4-MeOC$_6$H$_4$ (50:50)	BF$_3$·Et$_2$O	134	43[e]
7	Ph	4-MeOC$_6$H$_4$ (50:50)	BF$_3$·Et$_2$O	1	93(67)[f]
8	Ph	4-MeOC$_6$H$_4$ (50:50)	BF$_3$·Et$_2$O	1	96[g]
9	Ph	Ph (73:27)	BF$_3$·Et$_2$O	91	69
10	Ph	2,4-(MeO)$_2$C$_6$H$_3$ (13:87)	BF$_3$·Et$_2$O	1	82
11	Ph	4-MeSC$_6$H$_4$ (64:36)	BF$_3$·Et$_2$O	1	87
12	Ph	4-MeC$_6$H$_4$ (55:45)	BF$_3$·Et$_2$O	1	70[h]
13	Ph	4-ClC$_6$H$_4$ (69:31)	BF$_3$·Et$_2$O	46	58[i]
14	Ph	4-CF$_3$C$_6$H$_4$ (50:50)	BF$_3$·Et$_2$O	144	23[j]
15	4-MeOC$_6$H$_4$	Ph (59:41)	BF$_3$·Et$_2$O	114	67
16	*c*-Hex	4-MeOC$_6$H$_4$ (100:0)	BF$_3$·Et$_2$O	165	63[k]
17	Et	4-MeOC$_6$H$_4$ (100:0)	BF$_3$·Et$_2$O	120	0[k,l]

[a] Reaction conditions; see Ref. 12.

[b] Determined by ^{1}H NMR using 1,1,2,2-tetrachloroethane as an internal standard.

[c] PhCHO was obtained in 46% yield.

[d] PhCHO was obtained in 53% yield.

[e] BF$_3$·Et$_2$O (2.0 equiv.) was used, and the reaction was run under an Ar atmosphere.

[f] Isolated yield in the parenthesis.

[g] In the presence of MS4A.

[h] The starting material was recovered in 20%.

[i] PhCHO was obtained in 33% yield.

[j] PhCHO was obtained in 65% yield.

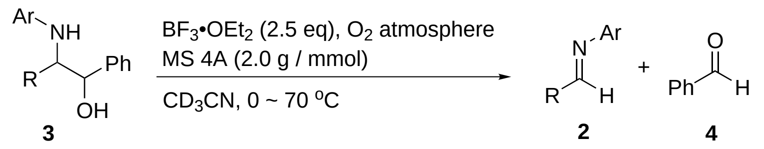
[k] The reaction was run at 0–70°C.

[l] The starting material was recovered unchanged.

acids such as methanesulfonic acid and *p*-toluenesulfonic acid gave the cleaved imines in low yields due to the hydrolysis of the produced imines (entries 2–3), that of trimethylsilyl trifluoromethanesulfonate or aluminum chloride effected the cleavage in moderate yields (entries 4–5). Among the Lewis acids screened the use of boron trifluoride etherate gave the imine in excellent yield (entry 7). The control experiment was carried out under an argon atmosphere instead of oxygen, and in this case, the imine was formed in low yield, (entry 6). This result indicates that although the oxygen present in the solvent effects the cleavage to some extent, the reaction conducted under an oxygen atmosphere is much effective. In the presence of molecular sieves 4 Å, a slight increase in the product yield was observed (entry 8). The cleavage reaction of 1,2-diamines with an electron-donating group on the nitrogen atom proceeded to give the imines in high yield in a short reaction time (entries 7, 8, 10–12), whereas in the case of 1,2-diamines possessing an electron-withdrawing group on the nitrogen atom and that of the *cyclo*-hexyl derivative, the reactions were relatively slow, giving the imines in moderate yields (entries 13, 14 and 16). However, the diethyl substituted substrate did not undergo oxidative cleavage, but gave only the recovered starting material (entry 17). Under the optimum conditions found for the oxidative cleavage of 1,2-diamines, a variety of 1,2-amino alcohols underwent a similar reaction, and the results are summarized in Table 2.[13]

Since in the absence of molecular sieves 4 Å, a considerable amount of carboxylic acid was formed as a by-product (entry 1), the oxidative cleavage of 1,2-amino alcohols were carried out in their presence. The amount of MS4A is important to suppress the formation of undesired carboxylic acid. While in the presence of MS4A (1.5 g/mmol), the aldehyde **4** was obtained in 87% yield with formation of a small amount of the carboxylic acid, the use of an increased amount of MS4A (2.0 g/mmol) gave only the imine **2** and the aldehyde **4** in excellent yields, respectively (entries 2 and 3). As in the cases with diamines, the reaction of 1,2-amino alcohols possessing an electron-donating group on the nitrogen atom proceeded to give the cleaved products in high yields in short reaction times (entries 3–5).

Table 2. Oxidative cleavage of 1,2-amino alcohols[a]



Entry	R	Ar (*syn*:*anti*)	Time (h)	**2** (%)[b]	**4** (%)[b]
1	Ph	4-MeOC$_6$H$_4$ (65:35)	1.0	73	22[c]
2	Ph	4-MeOC$_6$H$_4$ (65:35)	2.2	93	87[d]
3	Ph	2-MeOC$_6$H$_4$ (52:48)	3.5	98	99
4	Ph	4-MeSC$_6$H$_4$ (60:40)	3.5	89	93
5	Ph	Ph (54:46)	3.5	88	94
6	Ph	4-ClC$_6$H$_4$ (45:55)	5.0	56	80
7	*c*-Hex	4-MeOC$_6$H$_4$ (77:23)	2.0	51	60

[a] Reaction conditions; see Ref. 13.

[b] Determined by ^{1}H NMR using 1,1,2,2-tetrachloroethane as an internal standard.

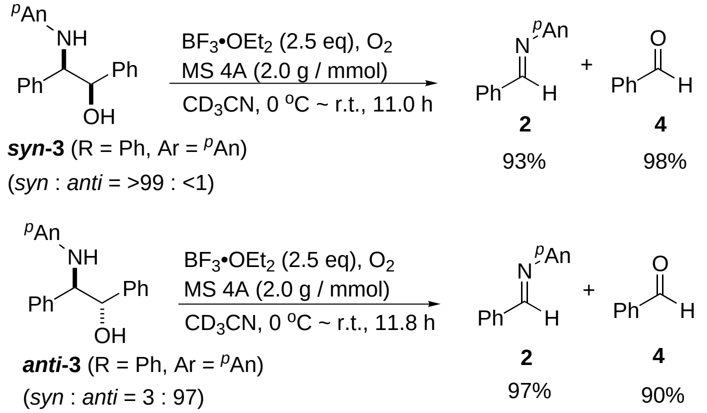
[c] PhCOOH was obtained in 43% yield when the reaction was carried out in the absence of MS4A.

[d] MS4A (1.5 g/mmol) was used.

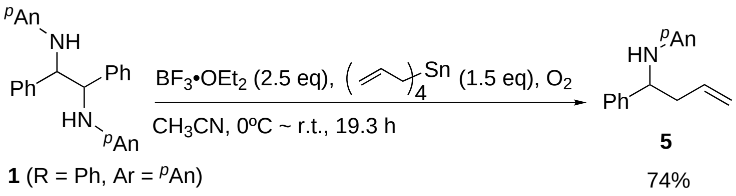
When oxidation reagents such as lead tetraacetate and periodates are used for the cleavage of 1,2-diols, the apparent necessity to form a cyclic ester, prior to the oxidative cleavage results in significant difference in the rates of cleavage of diastereoisomeric 1,2-diols.[14] Regarding the effect of the stereochemistry of the amino alcohols on present type of oxidative cleavage, the following *syn*- and *anti*-isomers were subjected to the reaction conditions, and the results are shown in Scheme 2.

Both diastereomers were cleaved smoothly in good yields, and there was not a significant difference in the rate of oxidation. The present reaction is used for further C–C bond forming reactions. The cleavage reaction in the presence of tetraallylstannan gave the allylated product **5** in 74% (Scheme 3), indicating that the present reaction may be used for the in situ generation of relatively unstable imines.

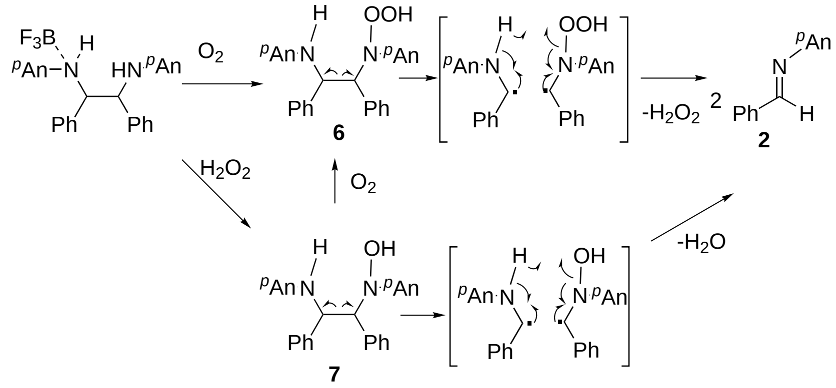
The present cleavage reaction may proceed via the following intermediates. First, the nitrogen atom of 1,2-diamine is coordinated with boron tirfluoride etherate, and subsequently attacked by molecular oxygen to form a hydroperoxyamine **6**. The C–C bond cleavage reaction proceeds to give the imine **2** and hydrogen peroxide, which in turn oxidizes the starting diamine as in the case with oxygen to form a hydroxyamine **7**. This



Scheme 2.



Scheme 3.



Scheme 4.

hydroxyamine **7** may collapse to the imine **2** and water, or may be oxidized to the hydroperoxyamine **6** (Scheme 4).

In conclusion, we have shown an oxidative cleavage of 1,2-diamines and 1,2-amino alcohols in high yields under very mild conditions. Since the cleaved products, imine and/or aldehyde, may be used for further reactions, the present reaction has a good potential for the use of 1,2-diamines or amino alcohols as masked diimines or imino carbonyl compounds.

Acknowledgements

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References

1. Jackson, E. L. *Org. React.* **1944**, *2*, 341–375.
2. Mosettiig, E. *Org. React.* **1954**, *8*, 225–229.
3. Ohloff, G.; Giersch, W. *Angew. Chem., Int. Ed Engl.* **1973**, *12*, 401–402.
4. Cisneros, A.; Fernandez, S.; Hernandez, J. E. *Synth. Commun.* **1982**, *12*, 833–838.
5. Gagnon, J. L.; Zajac, W. W., Jr. *Tetrahedron Lett.* **1995**, *36*, 1803–1804.
6. (a) House, H. O.; Berkowitz, W. F. *J. Org. Chem.* **1963**, *28*, 2271–2276; (b) Kovar, J. J.; Blaha, K. *Coll. Czech. Chem. Commun.* **1963**, *28*, 2199–2206.
7. Ogata, Y.; Sawaki, Y.; Shiroyama, M. *J. Org. Chem.* **1977**, *42*, 4061–4066.
8. Nagarkatti, J. P.; Ashley, K. R. *Tetrahedron Lett.* **1973**, *14*, 4599–4600.
9. Shimizu, M.; Iida, T.; Fujisawa, F. *Chem. Lett.* **1995**, 609–610.
10. (a) Shimizu, M.; Kamei, M.; Fujisawa, T. *Tetrahedron Lett.* **1995**, *36*, 8607–8610; (b) Shimizu, M.; Tsukamoto, K.; Fujisawa, T. *Tetrahedron Lett.* **1997**, *38*, 5193–5196; (c) Shimizu, M.; Fujisawa, T. *J. Synth. Org. Chem. Jpn.* **1998**, *56*, 672–680.
11. Shimizu, M.; Niwa, Y. *Tetrahedron Lett.* **2001**, *42*, 2829–2832.
12. A typical procedure is as follows: To a solution of 1,2-diamine (1.0 equiv.) in CD_3CN (0.1 mmol/ml) was added $BF_3{\cdot}OEt_2$ (2.5 equiv.) at 0°C under an oxygen atmosphere. After the disappearance of the 1,2-diamine on TLC, the product yield was determined by 500 MHz ^{1}H NMR.
13. Typical procedure for oxidative cleavage of 1,2-amino alcohols: To a solution of 1,2-amino alcohol (1.0 equiv.) and MS4A (2.0 g/mmol) in CD_3CN (0.1 mmol/ml) was added $BF_3{\cdot}OEt_2$ (2.5 equiv.) at 0°C under an oxygen atmosphere. After the disappearance of the 1,2-amino alcohol was monitored on TLC, the product yields were determined by 500 MHz ^{1}H NMR.
14. Buist, G. J.; Bunton, C. A.; Miles, J. H. *J. Chem. Soc.* **1959**, 743–748.