Monatsh Chem (2010) 141:1089–1091
DOI 10.1007/s00706-010-0381-6

ORIGINAL PAPER

Concise preparation of azenes by oxidation of aromatic amines with molecular oxygen in subcritical water

Nermin Simsek Kus

Received: 8 December 2009 / Accepted: 7 August 2010 / Published online: 1 September 2010

Abstract Reaction of organic substrates with molecular oxygen, the most abundant and accessible oxidant, has always been an attractive method for preparation of target molecules. In terms of green chemistry, non-metal-catalyzed oxidation of organic substrates is very attractive. This paper describes a general procedure for synthesis of azenes by oxidation of primary aromatic amines with molecular oxygen ($^3O_2$) in subcritical water. The reactions afforded the corresponding azenes in moderate to good yield.

Keywords Primary aromatic amines · Oxidation · Molecular oxygen · Azene · Subcritical water

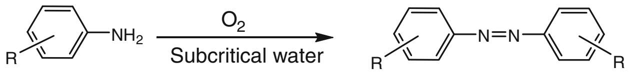
Introduction

There has been great interest in the chemistry of diazenes (azo compounds) since the discovery that they act as potential modulators of drug resistance to cisplatin for certain types of tumors [1–3]. Although several procedures for synthesis of azenes have been reported in the literature [4–10], two main procedures have always been attractive. The first is oxidation of primary aromatic amines to azenes with sodium periodate catalyzed by manganese(III) Schiff base complexes [11], while the second is utilization of heterogeneous permanganate oxidation [12]. The use of a common oxidant is not an environmentally friendly method, since an equivalent amount of waste is produced. Use of molecular oxygen as an oxidant is advantageous due to the fact that it is relatively cheap, environmentally benign, soluble in subcritical water, and readily available. The only byproduct is water, which makes molecular oxygen undoubtedly appealing for synthetic applications. Fortunately, molecular oxygen does not require activation for oxidation in subcritical water. In view of the environmental reasons, an efficient and environmentally benign procedure for preparation of azenes is highly desirable. The present work describes an environmentally benign procedure for synthesis of azenes, employing molecular oxygen as an oxidant in subcritical water as a reaction medium (Scheme 1). Use of subcritical water as a medium for chemical reactions has recently received a great deal of attention [13–16]. In contrast to many other solvents, water provides a medium for solution chemistry but also often participates in elementary chemical events on a molecular scale. Water also offers practical advantages over organic solvents. It is cheap, readily available, nontoxic, and nonflammable.

Results and discussion

This paper describes a simple and general procedure that can be used for oxidation of primary aromatic amines to azo derivatives with different amounts of molecular oxygen in subcritical water. The reaction conditions were compatible with functional groups such as –Br, –Cl, –CN, $-CH_3$, $-OCH_3$, $-OC_2H_5$, and $-NO_2$ present in the substrates. The yields of substrates bearing $-CH_3$, $-OCH_3$, and $-OC_2H_5$ were excellent as compared with some other methods (Table 1). The yield of the product was significantly increased in the case of electron-donating groups. However, arylamines with electron-withdrawing substituents such as –CN and $-NO_2$ recorded the lowest yield of azoxy compounds, with a large bulk of the starting material remaining

N. S. Kus (✉)
Department of Chemistry, Mersin University,
33343 Mersin, Turkey
e-mail: simner@mersin.edu.tr



Scheme 1

Table 1 Oxidation of primary aromatic amines to azo derivatives with molecular oxygen (110 °C, 2.1 kPa O_2 pressure)

Entry	R	Time (h)	M.p. (Lit. M.p.) (°C)	Ref.	Yield (%)
1	H	3	70–71 (68–71)	[12]	80
2	4-Br	4	203–204 (203–205)	[12]	65
3	4-Cl	4	190 (189)	[12]	59
4	4-NO_2	5	222–224 (222–223)	[12]	55
5	4-CH_3	3	143–145 (144–145)	[12]	95
6	4-OCH_3	4	164 (165)	[12]	85
7	4-OC_2H_5	6	128 (130–131)	[12]	85
8	4-CN	4	235 (230–231)	[18]	45
9	2-Cl	4	137 (136)	[19]	65
10	2-CH_3	3	56 (54)	[12]	95
11	2-OCH_3	3	152 (143–145)	[12]	85
12	2-CN	6	59 (57–58)	[4]	53
13	2-OC_2H_5	4	130 (130–132)	[20]	85

Isolated yields based on starting aromatic amine. Products identified by comparison of physical and spectroscopic properties [melting points, mass spectra, infrared spectra, and nuclear magnetic resonance (NMR) spectra] with literature values

as uncharacterized tar. Oxidation of arylamines with electron-withdrawing substituents such as –Br and –Cl resulted in formation of corresponding oxide products in 50–60% yield because of the unreacted starting materials. As the reaction went on, an increase in the time led to decomposition of the starting materials.

The amount of oxygen dissolved in water at atmospheric pressure was determined according to Henry's Law [17] (1.296×10^{-3} mol O_2/kg of H_2O at 25 °C). The amount of oxygen was regulated by the oxygen pressure [17]. All oxidations were performed by adding 50 cm^3 water, one molar equivalent of substrate, and two molar equivalents of oxygen. Moreover, increase of oxygen pressure beginning from 0.53 until 2.1 kPa increased the yields, but increase over 2.1 kPa resulted in decomposition of the starting materials.

All products were characterized by comparison of their thin-layer chromatography (TLC), melting points, and infrared (IR) and ^{1}H nuclear magnetic resonance (NMR) spectra with those of authentic samples. The IR spectra of all the products showed bands between 1,630 and 1,575 cm^{-1}, ascribed to the azo compound, and no absorption bands were observed for the substrate NH_2 group (between 3,500 and 3,300 cm^{-1}). This result clearly indicates complete conversion of amino derivatives to their corresponding azo compounds. Furthermore, the disappearance of a broad singlet between $\delta = 4.5$ and 6.5 ppm owing to the NH_2 protons in the ^{1}H NMR spectra confirmed the products.

Use of molecular oxygen is a selective and convenient method for transformation of primary aromatic amines to corresponding diazenes. This environmentally friendly method avoids use of materials such as chromic acid, Schiff base complexes, and permanganate, which should allow application in organic synthesis. This cheap method uses only water as a solvent and the procedure is simple and mild, with environmentally friendly reaction conditions and good yields.

In conclusion, I developed a practical procedure for oxidation of primary aromatic amines to their corresponding diazene compounds, in subcritical water with molecular oxygen. This simple, economical, and environmentally friendly method is useful for transformation of primary aromatic amines to corresponding diazenes.

Experimental

All chemical reagents were commercially purchased from standard chemical suppliers. The starting materials were purified (distilled or crystallized) before use. ^{1}H NMR spectra were recorded on a Bruker 400 MHz spectrometer, and infrared spectra were obtained as film on NaCl plates for liquids and KBr pellets for solids on a Win First® Satellite Model infrared recording spectrophotometer. All column chromatography was performed on silica gel (60 mesh, Merck).

General procedure for the oxidation reaction

Oxidation reactions were carried out at 110 °C in a 200-cm^3 stainless-steel reactor. A glass vessel was inserted into the reactor, and the oxidation occurred without contact with the stainless-steel reactor surface to avoid the catalytic effect of steel and corrosion. The stainless-steel reactor, containing 50 cm^3 water and the substrate (5 mmol), was heated to the desired temperature (110 °C) from the bottom by means of a hotplate and surrounded by heat-resistant material to prevent loss of heat. All the valves of the reactor were tightly closed during preheating. Then, the desired oxygen pressure (2.1 kPa) was applied to the vessel through a stainless-steel tube directly into the liquid phase. After the reaction was complete, the mixture was cooled to room temperature and filtered, and the residue was washed with $CHCl_3$ (3×40 cm^3). After drying over $MgSO_4$, the solvents were evaporated in vacuum and the products were purified by column chromatography on silica gel (60 mesh, Merck, with 50 cm glass column, eluent: CCl_4–Et_2O). The products were characterized by ^{1}H NMR, ^{13}C NMR, and IR spectroscopy.

Acknowledgments I am grateful to Mersin University Research Council and TUBITAK (the Scientific and Technological Research Council of Turkey) for supporting this work (grant no. TBAG-2144-102T043).

References

1. Ittel SD, Ibers JA (1975) Inorg Chem 14:1183
2. Osmak M, Bordukalo T, Ambriovic Ristov A, Jernej B, Kosmrlj J, Polanc S (2000) Neoplasma 47:390
3. Čimbora-Zovko T, Bombek S, Košmrlj J, Kovačić L, Polanc S, Katalinić A, Osmak M (2004) Drug Dev Res 61:95
4. Mirkhanı V, Tangestaninejad S, Moghadam M, Karimian Z (2003) J Chem Res (S) 12:792
5. Habibi MH, Tangestaninejad S, Mirkhani V (1998) J Chem Res (S) 648
6. Habibi MH, Tangestaninejad S, Mirkhani V (1998) Asian Chem Lett 2:107
7. Dutta DK (2006) Synth Commun 36:1903
8. Sanz R, Escribano J, Fernandez Y, Aguado R, Pedrosa MR, Arnaiz FJ (2005) Synlett 9:1389
9. Inui H, Irisawa M, Oishi S (2005) Chem Lett 34:478
10. Hedayatullah M, Thevenet F, Denivelle L (1977) Tetrahedron Lett 18:1595
11. Mirkhani V, Tangestaninejad S, Moghadam M, Moghbel M (2004) Bioorg Chem 2:4673
12. Barman DC, Saikia P, Prajapati D, Sandhu JS (2002) Synth Commun 32:3407
13. Kayan B, Özen R, Gizir AM, Simsek Kus N (2005) Org Prep Proced Int 37:83
14. Ozen R, Simsek Kus N (2006) Monatsh Chem 137:1597
15. Holliday RL, Jong BYM, Kolis JW (1998) J Supercrit Fluids 12:255
16. Katritzky AR, Allin SM, Siksin M (1996) Acc Chem Res 29:399
17. Tromans D (2000) Ind Eng Chem Res 39:805
18. Farhadi S, Zaringhadam P, Sahamieh RZ (2007) Acta Chim Slov 54:647
19. Wang XY, Wang YL, Li JP, Sun LF, Zhang ZY, Wang X, Wang Y, Li J, Wang C, Duan Z, Zhang Z (1999) Chin Chem Lett 10:533
20. Srinivasa GR, Abiraj K, Channe Gowda D (2003) Synth Comm 33:4221