HNO$_3$/N,N-Diethylethanaminium-2-(Sulfooxy)Ethyl Sulfate as an Efficient System for the Regioselective of Aromatic Compounds

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ABSTRACT: *N,N-diethylethanaminium-2-(sulfooxy) ethyl sulfate was synthesized and used as an efficient, green, and recyclable catalyst and solvent for the nitration of aromatic compounds by nitric acid at 80^{o}C.*

KEY WORDS: *Acidic ionic liquid, Nitration, Aromatic compounds, Nitric acid.*

INTRODUCTION

Replacement of hydrogen by the nitro group is one of the most important reactions in the whole of organic chemistry, particularly in the aromatic series. It is affected not merely by nitric acid in various concentrations or in mixtures of solvents, but also by a number of other reagents. The most common reagent is the mixture of nitric and sulfuric acid known as nitrating acid [1-2].

Dilute nitric acid is used in special cases such as for the very easily nitratable phenols and for aliphatic hydrocarbons. There are, however, narrow limits to the use of dilute nitric acid, since in general its nitrating action becomes appreciable only at high temperatures where oxidizing side reactions become preponderant [3-4].

Concentrated nitric acid allows nitration to be carried out at lower temperatures and tendency to the undesired oxidation; however, it is being constantly diluted by the water formed, so that attainment of satisfactory yields requires extremely large excesses of the nitrating agent, and this severely limits its utility. To overcome this difficulty nitration was carried out in the presence of concentrated sulfuric acid. The sulfuric acid in a nitrating mixture not only serves to bind the water, but is also important in maintaining a sufficient concentration of the nitryl cations [5] that are actual nitrating agent. This contributes to the considerable suppression of oxidative side reactions. On the other hand, mixed acid can not be used when the compound to be nitrated is attacked by sulfuric acid, e. *g.*, when it is sulfonated thereby.

Also, nitration reaction has been investigated over much solid acid catalyst such as zeolite beta-1 [6], K 10 montmorillonite [7], mordenite [8], nafion-H [9], silica sulfuric acid [10], wet SiO$_2$ [11], benzyltriphenylphosphonium peroxodisulfate [12], 1-butyl-3-methylimidazolium hydrogen sulfate [13].

The present work relates to ionic liquids, which can serve as both of catalyst and solvent. Thus, much attention has recently been attracted in organic syntheses to ionic liquids. Ionic liquids may have affinity for particular substance and may have a function as catalyst.

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Thus, ionic liquids may be used as reaction solvents and furthermore may also be used for the purpose of increasing the process efficiency, for example, in separation of substance. Since the use of ionic liquids has become widespread, a large number of reactions previously developed in organic solvents have been attempted in these new solvents. Hydroformylation reaction [14-16], hydrogenation [17,118], Friedel-Crafts reaction [19-21], epoxidation [22,23], Miziroki-Heck reaction [24,25]. Suzuki-Miyaura cross-coupling reaction [26,27], and Diels-Alder reaction [28,29] are investigated in ionic liquids.

While considering ionic liquids as reaction media and their use in industrial processes, one major concern is cost. The cost of the ionic liquid would be directly dependent on the price of the cations and anions that are used for their production [30]. Thus, the currently popular ionic liquids incorporating expensive cations such as alkyl methyl imidazolium and dialkyl imidazolium are likely to remain expensive. This indicates that there is a need to develop and explore simple and cost-effective ionic liquids [31].

EXPERIMENTAL SECTION

All nitro products are known compounds and characterized by comparison of their physical and spectroscopic data with those of authentic samples. All chemicals were purchased from Alderich.

The ^{1}H NMR spectra were recorded on a Varian FT-80 spectrometer. Infrared spectra were taken on a Philips PU 9624 FTIR spectrophotometer. Gas chromatography was recorded on a Philips PU 4500 chromatograph. Thin layer chromatography was performed on silica gel (Macerey-Nagel Co., Plygram Sil G/uv 254).

Ethan-1,2-diyl bis (hydrogen sulfate) 1

To 12.4g ethylene glycol (o.2 mol) 46.6g chlorosulfonic acid (0.4 mol) was added drop wise with good cooling (0 to 5^{o}C). After drying in vacuum for 20 min, 43 g (97%) of product were isolated as a pure oily liquid. ^{1}H NMR (300 MHz, D_2O): δ = 3.40-3.45 (m, 2H), 3.01-3.26 (pentet, 2 H), ppm; Ana. Calcd (%) for $C_2H_6O_8S_2$ (222.19): C, 10.81; H, 6.05; O, 57.6; S, 28.86; found: C, 10.42; H, 5.71; S, 28.36.

N,N-diethylethanaminium-2-(sulfooxy) ethyl sulfate 2

Triethylamine (5.1g, 0.05 mol) in dichloromethane (10 mL) was added during 10 min to a rapidly stirred solution of ethan-1,2-diyl bis (hydrogen sulfate) **1**(11.1 g, 0.05 mol) in dichloromethane (20 mL) that is cooled in ice bath. Stirring is continued for 15 min, upper layer was separated. After drying in vacuum for 20 min, 15.8 g (98%) **2** were obtained as a yellowish oily product. ^{1}H NMR (300 MHz, D_2O): δ = 3.5 (s, 4H), 3.0 (q, 6H), 1.1 (t, 9H) ppm; Anal. Calcd (%) for $C_8H_{21}NO_8S_2$ (323.39): c, 29.71; H, 6.55; N, 4.33; O, 39.58; S, 19.83; found: C, 29.36; H, 4.18; S, 19.24.

Typical procedure (Preparation of nitrotoluene)

Nitric acid 65% (9.7 g, 0.1 mol) was added to a solution ionic liquid (16.15 g, 0.05 mol) and toluene (4.6 g, 0.05 mol). The reaction mixture was stirred at 80^{o}C. Upon completion of the reaction (monitored by TLC, GC, see Table 1), the reaction mixture was extracted with ether (3x20 ml). Combined organic layer were dried over Na_2SO_4, the solvent was removed by evaporation to afford the crude product. The crude product was purified by column chromatography over silica gel. For recovery of ionic liquid, the aqueous layer of extraction was dried in vacuum for 1h at 70^{o}C (95%).

RESULTS AND DISCUSSION

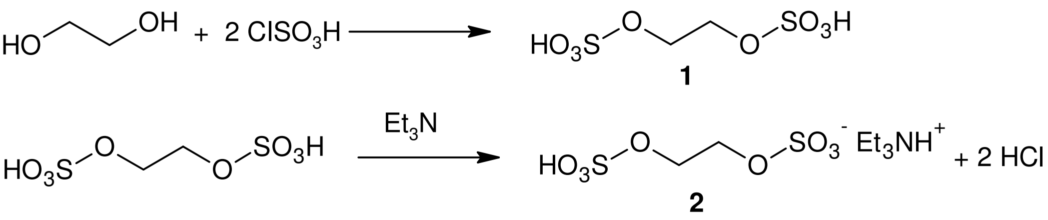
Our work is mainly devoted to find new procedure for nitration of aromatics using inexpensive and green reagent. We report herein a simple and convenient procedure for nitration of aromatic compounds by nitric acid using N,N-diethylethanaminium-2-(sulfooxy)ethyl sulfate 2 at 80^{o}C to the corresponding nitro derivatives. Ionic liquid 2 was obtained as yellow liquid in the synthetic procedure reported here. It represents a new acidic ionic liquid and was easily available from ethan-1,2-diyl bis (hydrogen sulfate) 1 and triethylamine under mild reaction conditions (Scheme 1). It can dissolve in water, ethanol, dichloromethane, dimethylsulfoxide, and is insoluble in diethyl ether and hexane. Acidic ionic liquid acts not merely as acid catalyst and solvent but also have water-binding properties.

We have found that the nitration of toluene as a model compound with one equivalent of 2 and two equivalents of nitric acid at 90^{o}C for 5 h to give the corresponding mono-nitrotoluene. Toluene is mono-nitrated to give 85:14 para:ortho ratio in 85% yield and nitration of benzoic acid yields a significant portion of

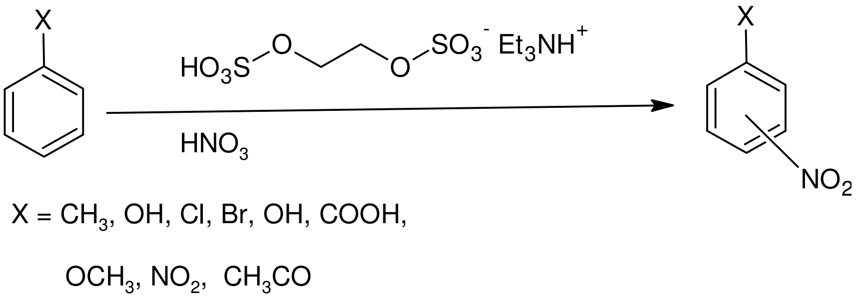
Table 1: Nitration of aromatic compounds with nitric acid in ionic liquid 2.

Entry	Substrate	Temp.	Time	Yield[a]	Ratio[b]			
		(°C)	(min)	(%)	para	ortho	meth	di-
1	phenol	25	30	92	75	21	-	4
2	4-methylphenol	25	30	93	-	94	-	6
3	anisole	25	50	78	80	17	-	3
4	4-chlorophenol	25	50	88	-	98	-	2
5	toluene	90	300	85	85	14	-	1
6	bromobenzene	90	300	76	92	8	-	-
7	chlrobenzene	90	300	73	91	9	-	-
8	acetophenone	90	420	60	-	-	100	-
9	benzoic acid	90	420	68	5	-	95	-
10	nitrobenzene	90	600	58	-	-	100	-
11	aniline	90	600	-	-	-	-	-

a) Based on aromatic compound. B) Ratio was determined by GC.



Scheme 1: Preparation of ionic liquid.



Scheme 2: Preparation of nitro compounds.

m-nitrobenzoic acid alongside the para-nitro-isomer. The use of 2, 4 or 6 equivalents of nitric acid had no effect on the overall yield. Deactivated aromatic substituted (such as benzoic acid, entry 9) could be nitrated only once under this condition, while activated aromatic substituted (such as phenol, entry 1) produced dinitro compound.

Having established the reaction condition, various aromatic compounds were subjected to react and the results are summarized in Table 1. As evident, aromatic compounds having electron donating group readily underwent nitration in excellent yields. Also, deactivated aromatic compounds underwent nitration in good yields, however, with a relatively longer time.

The solvent catalyst is generated by heating at 70°C for 1 h under reduced pressure. It is advisable to devote a batch of the solvent-catalyst to one type or reaction. In this manner, after 6 cycles the same batch of ionic liquid was found to catalyze the nitration reaction of phenol in 87% yield. First reaction was done with mixture of 0.2 mole nitric acid 65%, 0.1 mole ionic liquid, and 0.1 mole phenol at room temperature for 30 min. Nitrated phenol (92%) and recovered ionic liquid (0.098 mole) were obtained. In the next reaction, recovered ionic liquid (0.098 mole) was mixed with nitric acid 65% (0.196 mole) and phenol (0.098 mole) at room temperature for 30 min. Nitrated phenol (92%) and recovered ionic liquid (0.096 mole) were obtained. In the similar way, four reactions were done. The yield of nitrated phenol for each reaction was 90%, 89%, 89%, and 87% and mole of recovered ionic liquid was respectively 0.094, 0.092, 0.09.

CONCLUSIONS

In conclusion, nitric acid promoted by ionic liquid **2** can acts as a versatile system for nitration of a variety of aromatic compounds. Compound **2** acts as acid catalyst and solvent for nitration of aromatic compounds. The use of inexpensive and relatively non-toxic catalyst is another advantage of this method.

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REFERENCES

[1] Olah G.A., Malhotra R., Narang S.C., "Nitration Methods and Mechanism", VCH, New York, pp. 5-15 (1989).

[2] Schofield K., "Aromatic Nitration", Cambridge University Press, Cambridge (1980).

[3] Gigante B., Prazeres A.O., Marcelo-Cutro M.J., Cornelis A., Laszlo P., Mild and Selective Nitration by Claycop, *J. Org. Chem.*, **60**, 3445 (1995).

[4] Sun H.B., Hua R., Yin Y., Highly Efficient Nitration of Phenolic Compounds in Solid Phase or Solution Using $Bi(NO_3)_3.5H_2O$, *J. Org. Chem.*, **70**, p. 9071 (2005).

[5] Ingold C.K., "Structure and Mechanism in Organic Chemistry" Cornell University Press, Ithaca, New York (1953).

[6] Choudary B.M., Sateesh M., Kantam M.L., Rao K.K., Ram Prasad K.V., Raghavan K.V., Sarma J.A.R.P., Selective Nitration of Aromatic Compounds by Solid Acid Catalysts, *Chem. Commun.*, p. 25 (2000).

[7] Delaude L., Laszlo P., Smith K., Heightened Selectivity in Aromatic Nitrations and Chlorinations by the Use of Solid Suppotrs and Catalysts, *Chem. Res.*, **26**, p. 607 (1993).

[8] Smith K., Fry K., Butters M., Nay B., Para-Selective Mononitration of Alkylbenzenes under Mild Conditions by Use of Benzoyl Nitrate in the Presence of a Zeolite Catalyst, *Tetrahedron Lett.*, **30**, p. 5333 (1989).

[9] Olah G.A., Malhotra R., Narang S.C., Aromatic Substitution. 43. Perfluorinated Resinsulfonic Acid Catalyzed Nitration of aromatics, *J. Org. Chem.*, **43**, p. 4628 (1978).

[10] Zolfigol M.A., Madrakian E., Ghaemi E., Silica Sulfuric Acid/ $NaNO_2$ as a Novel Heterogeneous System for the Nitration of Phenols Under Mild Conditions, *Molecules*, **7**, p. 734 (2002).

[11] Zolfigol M.A., Madrakian E., Ghaemi E., Trichloroisocyanuric Acid/$NaNO_2$ Wet SiO_2 as an Efficient System for the Selective Dinitration of Phenols under Solvent-free Conditions, *Synlett*, **15**, p. 2222 (2003).

[12] Tajic H., Zolfigol M.A., Akkadi J., Eslami Q., Nitration of Some Aromatic Compounds by Sodium Nitrate in the Presnce of Benzyltriphenylphosphonium Peroxodisulfate, *Synth. Commun.*, **37**, p. 2771 (2007).

[13] Tajic H., Niknam R., Parsa F., Using Acidic Ionic Liquid 1-Butyl-3-methylimidazolium Hydrogen Sulfate in Selective Nitration of Phenols under Mild Conditions, *J. Iran. Chem. Soc.*, **6**, p. 159 (2009).

[14] Parshall G.W., Catalysis in Molten Salt Media, *J. Am. Chem. Soc.*, **94**, p. 8716 (1972).

[15] Wasserscheild P., Waffenschmidt H., Ionic Liquids in Regioselective Platinium-Catalysed Hydroformylation, *J. Mol. Catal. A: Chem.*, **164**, p. 61 (2000).

[16] Knifton J.F., Syngas Reactions: Part XI. The Ruthenium Melt Catalyzed Oxonation of Internal Olefins, *J. Mol. Catal.*, **43**, p. 65 (1987).

[17] Chauvin Y., Mussmann L., Olivier H., A Novel Class of Versatile Solvents for Two-Phase Catalysis: Hydrogenation, Isomerization, and Hydroformylation of Alkenes catalyzed by Rhodium Complexes in Liquid 1,3-Dialkylimidazolium Salts, *Angew. Chem. Int. Ed. Engl.*, **34**, p. 2698 (1995).

[18] Monteiro A.L., Zinn F.K., De Souza R.F., Dupont J., Asymmetric Hydrogenation of 2-Arylacrylic Acids Catalyzed by Immobilized Ru-BINAP Complex in 1-*n*-Butyl-3-Methylimidazolium Tetrafluoroborate Molten Salt, *Tetrahedron Asymmetry*, **8**, p. 177 (1997).

[19] Boon J.A., Levisky J.A., Pflug J.L., Wilkes J.S., Fridel-Crafts Reactions in Ambient-Temperature Molten Salts, *J. Org. Chem.*, **51**, p. 480 (1986).

[20] DeCastro C., Sauvage E., Valkenberg M.H., Holderch W.F., Immobilized Ionic Liquids as Lewis Acid Ctalysts for the Alkylation Of Aromatic Compounds with Dodecene, *J. Catal.*, **196**, p. 86 (2000).

[21] Ross J., Xiao J., Fridel-Crafts Alkylation Acylation Reactions Using Metal Triflates in Ionic Liquid, *Green Chem.*, **4**, p. 129 (2002).

[22] Owens G.S., Durazo A., Abu-Omar M.M., Kinetics of MTO-Catalyzed Olefin Epoxidation in Ambient Temperature Ionic Liquids: UV/Vis and NMR Study, *Chem. Eur. J.*, **8**, p. 3053 (2002).

[23] Owens G.S., Abu-Omar M.M., Methyltrioxorhenium-Catalyzed Epoxidations in Ionic Liquids, *Chem. Commun.*, 1165 (2000).

[24] Kaufmann D.E., Nouroozian M., Henze H., Molten Salts as Effective Medium for Palladium Catalyzed C-C Coupling Reactions, *Synlett*, **8**, p. 1091 (1996).

[25] Herrmann W.A., Bohm V.P.W., Heck Reaction Catalyzed by Phospha-Palladacycles in Non-Aqueous Ionic Liquids, *J. Organomet. Chem.*, **572**, p. 141 (1999).

[26] McNulty J., Capretta A., Wilson J., Dyck J., Adjabeng G., Robertson A., Suzuki Cross-Coupling Reactions of Aryl Halides in Phosphonium Salt Ionic Liquid Under Mild Conditions, *Chem. Commun.*, 1986 (2002).

[27] Zou G., Wang Z., Zhu J., Tang J., He M., Developing an Ionic Medium for Ligandless-Palladium-Catalysed Suzuki and Heck Couplings, *J. Mol. Catal. A: Chem.*, **206**, p. 193 (2003).

[28] Lee C.W., Diels-Alder Reactions in Chloroaluminate Ionic Liquids: Acceleration and Selectivity Enhancement, *Tetrahedron Lett.*, **40**, p. 2461 (1999).

[29] Fischer T., Sethi A., Welton T., Woolf J., Diels-Alder Reactions in Room-Temperature Ionic Liquids, *Tetrahedron Lett.*, **40**, p. 793 (1999).

[30] Wasserscheild P., Welton T., "Ionic Liquid in Synthesis", Wiley-VCH, (2004).

[31] Sharma Y.O., Degani M.S., Green and Mild Protocol for Hetero-Michael Addition of Sulfur and Nitrogen Nucleophiles in Ionic Liquid, *Journal of Molecular Catalysis A: Chemical*, **277**, p. 215 (2007).