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# Selective Nitration of Aromatic Compounds with Bismuth Subnitrate and Thionyl Chloride

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**Abstract:** Bismuth subnitrate/thionyl chloride have been found to be an efficient combination of reagents for nitration of a wide range of aromatic compounds in dichloromethane. Phenols, in particular, were easily mononitrated and dinitrated with the reagents by controlling the stoichiometry,

**Keywords:** Bismuth subnitrate; thionyl chloride; nitration; aromatic compounds; phenols.

## Introduction

Aromatic nitro compounds represent versatile intermediates for a wide range of industrial products, like pharmaceuticals, dyestuffs and explosives [1-4]. The introduction of a nitro group into an aromatic ring is commonly performed in strongly acidic polar media [5]. The problems associated with mixed nitric and sulfuric acids have prompted the search for alternative methods [6,7].

The use of metal nitrates in aromatic nitration has received particular attention, e.g.: $AgNO_3$ / $BF_3$ [8], $Cu(NO_3)_2$ / clay [9], ceric ammonium nitrate (CAN) / $H_2SO_4$ / $SiO_2$ [10], $Fe(NO_3)_3$ / clay [11], $VO(NO_3)_3$ [12] and some other metal nitrates / clay activated by acetic anhydride [13]. However, most of these nitrates require certain manipulations before use, in addition to their limited applications to reactive aromatics like phenols [14,15].

Bismuth (III) compounds have received particular attention as low toxicity reagents and catalysts for various organic transformations [16,17]. We hereby introduce a mild and selective method for aromatic nitration using bismuth subnitrate and thionyl chloride in dichloromethane.

**Results and Discussion**

Bismuth nitrate exists in three forms: bismuth (III) nitrate pentahydrate [Bi(NO$_3$)$_3$·5H$_2$O)][18]; bismuth oxynitrate [BiONO$_3$], and bismuth subnitrate basic [Bi$_5$O(OH)$_9$(NO$_3$)$_4$] [19]. Bismuth (III) nitrate pentahydrate supported on montmorillonite was used as a nitrating agent for active aromatics, such as phenol, anisole and polycyclic compounds [20]. The reagent requires special preparation and has limited use with reactive aromatic compounds.

The commercially available bismuth subnitrate, which is prepared by hydrolysis of trinitrate, is not toxic [21]. It is used to treat gastric disorders [22]. To the best of our knowledge, it has not been used as a nitrating agent.

Bismuth subnitrate is inactive, on its own, towards aromatic nuclei in organic solvents. Thus, several catalysts to activate the subnitrate were considered. Thionyl chloride was reported to produce thionyl chloride nitrate [ClSO(ONO$_2$)] and thionyl nitrate [OS(ONO$_2$)$_2$] when treated with silver nitrate. Both nitrate species have failed in nuclear nitration of aromatic compounds. Only phenols reacted with both species to give o-nitrated products (Scheme 1) [23].

**Scheme 1**

$$SOCl_2 \; + \; AgNO_3 \; \xrightarrow{\text{THF}} \; ClSO(ONO_2) \; \xrightarrow{\text{PhOH}} \; PhONO_2$$

When bismuth subnitrate (0.25 equiv.) was added to a solution of the aromatic substrate and thionyl chloride in dichloromethane at room temperature, a pale yellow color began to develop and the nitration process started to take place (Scheme 2). The results are summarized in Tables 1-3.
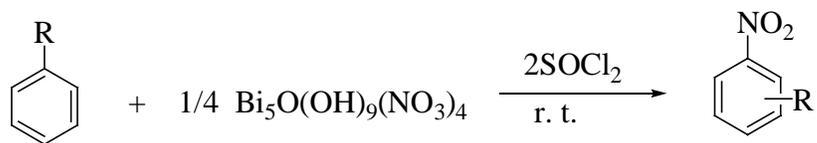
**Scheme 2**

**Table 1.** Nitration of Some Aromatic Compounds with Bismuth Subnitrate

| Entry | Substrate | Product | Sub:NO$_3$ ratio | Time h | Yield% |
|-------|-----------|---------|------------------|--------|--------|
| 1. | benzene | nitrobenzene | 1 : 1 | 6 | 87 |
| 2. | toluene | 2-nitrotoluene | 1 : 1 | 3 | 62 |
|    |          | 4- nitrotoluene |     |   | 27 |
| 3. | m-xylene | 4- nitro-m-xylene | 1 : 1 | 3 | 74 |
| 4. | mesitylene | 2-nitromesitylene | 1 : 1 | 2 | 84 |
| 5. | acetanilide | 2-nitroacetanilide | 1 : 1 | 3 | 16 |
|    |          | 4-nitroacetanilide |     |   | 52 |
| 6. | anisole | 2-nitroanisole | 1 : 1 | 2 | 12 |
|    |         | 4-nitroanisole |     |   | 76 |
| 7. | 4-bromoanisole | 4-bromo-2-nitroanisole | 1 : 1 | 6 | 75 |
| 8. | 2-chloroanisole | 2-chloro-4-nitroanisole | 1 : 1 | 5 | 74 |
| 9. | bromobenzene | 2-bromonitrobenzene | 1 : 1 | 9 | 18 |
|    |              | 4- bromonitrobenzene |     |   | 60 |
| 10. | chlorobenzene | 2-chloronitrobenzene | 1 : 1 | 9 | 27 |
|    |               | 4- chloronitrobenzene |     |   | 49 |

**Table 2.** Nitration of Polycyclic Aromatics with Bismuth Subnitrate

| Entry | Substrate | Product | Sub:NO$_3$ ratio | Time h | Yield % |
|-------|-----------|---------|------------------|--------|---------|
| 1. | naphthalene | 1-nitronaphthalene | 1 : 1 | 2 | 68 |
| 2. | 2-methylnaphthalene | 1-nitro-2-methyl naphthalene | 1 : 1 | 2 | 76 |
| 3. | acenaphthene | 5-nitroacenaphthene | 1 : 1 | 2 | 72 |
| 4. | biphenylene | 2-nitrobiphenylene | 1 : 1 | 1 | 81 |
| 5. | fluorene | 2-nitrofluorene | 1 : 1 | 2 | 74 |
| 6. | phenanthrene | 9-nitrophenanthrene | 1 : 1 | 2 | 64 |
| 7. | pyrene | 1-nitropyrene | 1 : 1 | 1 | 75 |
| 8. | biphenyl | 4-nitrobiphenyl | 1 : 1 | 1 | 73 |

**Table 3.** Nitration of Phenols with Bismuth Subnitrate

| Entry | Substrate | Product | Sub:NO$_3$ ratio | Time h | Yield % |
|-------|-----------|---------|------------------|--------|---------|
| 1. | phenol | 2-nitrophenol | 1 : 1 | 0.5 | 42 |
|  |  | 4- nitrophenol |  |  | 46 |
| 2. | phenol | 2,4-dinitrophenol | 1 : 2 | 2 | 72 |
|  |  | 2,6- dinitrophenol |  |  | 14 |
| 3. | o-cresol | 2-methyl-4-nitrophenol | 1 : 1 | 0.5 | 56 |
|  |  | 2-methyl-6-nitrophenol |  |  | 28 |
| 4. | o-cresol | 4,6-dinitro-2-methylphenol | 1 : 2 | 2 | 83 |
| 5. | p- cresol | 4-methyl-2-nitrophenol | 1 : 1 | 0.5 | 86 |
| 6. | p- cresol | 2,6-dinitro-4-methylphenol | 1 : 2 | 1 | 82 |
| 7. | 2-bromophenol | 2-bromo-4-nitrophenol | 1 : 1 | 1 | 52 |
|  |  | 2-bromo-6-nitrophenol |  |  | 22 |
| 8. | 2- bromophenol | 2-bromo-4,6-dinitrophenol | 1 : 2 | 3 | 70 |
| 9. | 4-chlorophenol | 4-chloro-2-nitrophenol | 1 : 1 | 1 | 78 |
| 10. | 4- chlorophenol | 4-chloro-2,6-dinitrophenol | 1 : 2 | 3 | 72 |
| 11. | salicyldehyde | 4-nitrosalicyldehyde | 1 : 1 | 3 | 63 |
| 12. | 4-nitrophenol | 2,4-dinitrophenol | 1 : 1 | 3 | 78 |

Benzene and methylbenzenes were nitrated in excellent yield with bismuth subnitrate. The reaction was selective, and no dinitro or side-chain substitution products were detected. The reaction rate of methylbenzenes increased with the increasing number of methyl groups. Polycyclic aromatic hydrocarbons can be efficiently mononitrated in good yields. Biphenylene, in particular, afforded 2-nitrobiphenylene as the only product in high yield (Scheme 3). The tricyclic hydrocarbon has been reported to undergo an addition reaction in acidic media because of the strained four-membered ring [24], although isolation of 2-nitro and 2,6-dinitrobiphenylene in low yield was also reported [25].

**Scheme 3**



81%
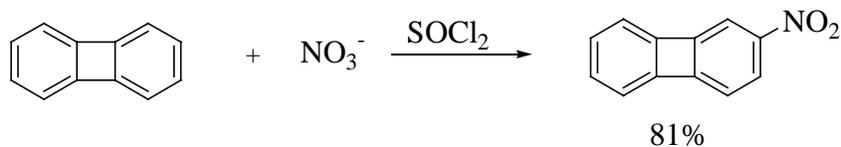
With regards to phenols, the present procedure has several advantages over some other reported methods, which suffer usually from drawbacks like overreactivity, oxidation ability of the reagents, strongly acidic media, toxicity of the metal cations and tedious work up [26]. The reagents can

selectively mononitrate phenols with different functional groups, regardless of their activity, to give *ortho* and *para* derivatives. Dinitration is also possible with phenol, cresols and halophenols using the appropriate proportions of the reagents. On the other hand, when the same procedure was applied to phenol using $Bi(NO_3)_3$, $Cu(NO_3)_2$, or $AgNO_3$, and thionyl chloride a mixture of mono and dinitro-phenols was isolated. Moderately reactive aromatic compounds, i.e. anisole and acetanilide react with the reagents to give mainly *para-* derivatives in high yields. Haloanisoles can be also nitrated in good yields. Despite their reduced activity, halobenzenes also react with the reagents. The reaction is slower but gives the corresponding *ortho-* and *para-*nitro derivatives in good yields.

No mechanistic work has been carried out. However, it is established that thionyl chloride reacts with metal nitrate in THF to give thionyl chloride nitrate [23]. We believe that the nitrate may disproportionate in the more polar dichloromethane to give sulfur dioxide and nitryl chloride ($NO_2Cl$), which might be the nitrating species. Our speculation is based on observed slow evolution of $SO_2$ at room temperature (Scheme 4).

<p align="center">**Scheme 4**</p>

$$ClSO(ONO_2) \xrightarrow[\text{r. t.}]{CH_2Cl_2} NO_2Cl \;+\; SO_2$$
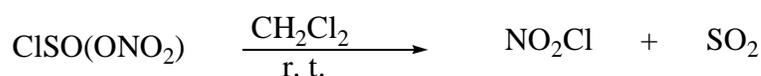
## Experimental

### *General*

Substrates used were of laboratory reagent grade. Bismuth subnitrate was obtained from Alfa Aesar. Thionyl chloride was purified by fractional distillation from quinoline. Product mixtures were analyzed by TLC and GLC. The products were identified by comparison of their NMR, IR spectra, TLC and physical data with those of authentic samples.

### *Typical procedure*

A round-bottomed flask (100mL) fitted with a condenser was charged with the aromatic substrate (5mmol), dry dichloromethane (50mL) and thionyl chloride (1.20g, 10mmol). The mixture was stirred and bismuth subnitrate 80% (2.20g, 1.25mmol) was added. After vigorous stirring at room temperature for the specified reaction time, the mixture was filtered to remove the inorganic materials. The filtrate was washed with dilute HCl and water to remove any traces of bismuth(iii) salts and dried ($Na_2SO_4$). It was evaporated in *vacuo* to give the crude products, which were separated by column chromatography on silica gel eluting with chloroform-petroleum ether. In the case of nitrophenols, the filtrate was washed only with cold saturated sodium chloride solution, dried and evaporated in *vacuo* at room temperature.

## References

1. Olah, G.A.; Malhorta,R.; Narang, S.C. *Nitration Methods and Mechanisms*; VCH: New York, **1989**.
2. Becker, F. F. Banik, B.K. *Bioorg. Med. Chem.* **1998**, *50*, 2877.
3. Zollinger, H. *Color Chemistry: Properties and Applications of Organic Dyes, 2nd Edition*; John Wiley: New York, **1991**.
4. Meyer, R.; Kholar, J.; Homburg, A. *Explosives, 5th Edition*; John Wiley: New York, **2002**.
5. Ward, E.R. *Chem. Ber.* **1979**, *15*, 297.
6. Smith, M.B; March, J. *March's Advanced Organic Chemistry*, *5th Edition*; John Wiley: New York, **2001**; p. 696.
7. Ridd, J.H. *Acta Chem. Scand.* **1998**, *52*, 11.
8. Olah, G.A.; Fung, A.P.; Narang, S.C.; Olah, J.A. *J.Org. Chem.* **1981**, *46*, 3533.
9. Gigantee, B.; Prazeres, A.O.; Marcelo-Curto, M.J.; Cornelis, A.; Laszlo, P. *J. Org. Chem.* **1995**, *60*, 3445.
10. Mellor, J.M.; Mittoo, S.; Parkes, R; Millar, R.W. *Tetrahedron* **2000**, *56*, 8019.
11. Cornelis, A.; Laszlo, P. *J. Org. Chem.* **1983**, *48*, 4771.
12. Dove, M.F.A.; Manz, B.; Montgomery, G.; Pattenden, G.; Wood, S.A. *J. Chem. Soc., Perkin Trans. 1* **1998**, 1589.
13. Cornelis, A.; Delaude, L.; Gerstmans, A.; Laszlo, P. *Tetrahedron Lett.* **1988**, *29*, 5909.
14. Bisarya, S.C.; Joshi, S.K.; Holkar,A.G. *Synth. Commun.* **1993**, *23*, 1125.
15. Zolfigol, M.A.; Ghaemi, E.; Madrakian, E. *Molecules* **2001**, *6*, 614.
16. Leonard, N.M.; Wieland, L.C.; Mohan, R.S. *Tetrahedron* **2002**, *58*, 8373.
17. Suzuki, H.; Ikegami, T.; Matano, Y. *Synthesis* **1997**, *3*, 249.
18. Mellor, J.W. *Compr. Treat. Inorg. Theor. Chem.* **1929**, *9*, 705.
19. Rajah, C.A. *Dtsch. Apoth. Ztg.* **1935**, 1714.
20. Samajdar, S.; Becker, F.F.; Banic, B. K. *Tetrahedron Lett.* **2000**, *41*, 8017.
21. Sundvall, B., *Acta Chem. Scand (A),* **1979**, *33*, 219.
22. Hejazi, R., Amiji, M. *Int. J. Pharm.*, **2002**, *235*, 87.
23. Hakimelahi, G.H., Sharghi, H., Zarrinmayeh, H, Khalafi-Nezhad , A. *Helv. Chim. Acta*, **1984**, *67*, 906.
24. Barton, J.W.; Whitaker, K.E. *J. Chem. Soc. (C)* **1968**, 1663.
25. Baker, W.; Barton, J.W.; McOmie, J.F. *J. Chem.Soc*. **1958**, 2666.
26. Zolfigol, M.A.; Madrakian, E.;Ghaemi, E. *Molecules*, **2002**, *7*, 734.

*Sample availability*:  Not available