The Reaction of Arylthallium(III) Compounds with Metal Nitrite. Synthesis of Nitroarenes.[1]

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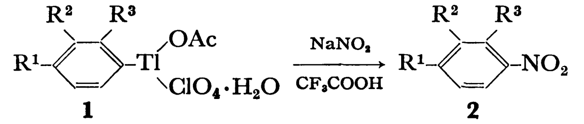
Arylthallium(III) compounds react smoothly with various metal nitrites such as $NaNO_2$, KNO_2, and $AgNO_2$ in trifluoroacetic acid to give nitroarenes in good yields. It has been clarified that the reaction proceeds through substitution of thallium moiety by nitroso group at the (*ipso*) position where thallium was attached previously to aromatic ring to give nitrosoarenes, followed by their oxidation to nitroarenes.

Recently Davies and Thomas reported a facile nitrodethallation of arylthallium(III) compounds by nitrogen dioxide which can be used for selective introduction of a nitro group into aromatic substrates.[2] In the course of our studies on the substitution of thallium moiety in arylthallium(III) compounds by halogen or pseudohalogen[3] we found that a similar nitrodethallation also occurred readily by use of metal nitrite through a different reaction scheme from that by nitrogen dioxide. This reaction may be useful as an alternative method for selective nitration of arenes.

Results and Discussion

When a mixture of *p*-tolylthallium(III) compound (**1**, R^1=Me, R^2=R^3=H) and sodium nitrite was stirred in trifluoroacetic acid at room temperature for 3 h, *p*-nitrotoluene (**2**, R^1=Me, R^2=R^3=H) was obtained almost quantitatively (Scheme 1). No formation of *m*- and *o*-nitrotoluene shows that the replacement of thallium moiety by NO_2 occurred at the position where thallium was attached previously to aromatic ring. The reaction also took place in other organic acids such as chloroacetic acid and acetic acid, but it was slower and the yield of *p*-nitrotoluene was lower than that in trifluoroacetic acid, a side-product sometimes being formed. Almost no reaction occurred in organic solvents such as pyridine, dioxane, DMF, and acetonitrile even at refluxing temperature in which halogeno- and pseudohalogenodethallation proceeded smoothly.[3] It was found that the yield of *p*-nitrotoluene is affected by concentrations of both **1** and $NaNO_2$ in trifluoroacetic acid, lower concentration being preferable for higher yield of *p*-nitrotoluene. Other metal nitrites such as $AgNO_2$ and KNO_2 were also effective for this reaction. Typical results are summarized in Table 1.



1 **2** (1)

Application of the reaction to other **1** such as *o*- and *m*-xylyl- and *p*-anisylthallium(III) compounds also afforded readily almost quantitative yield of **2**. In the case of phenyl- and chlorophenylthallium(III) compounds, however, the yield of **2** was low and considerable amounts of nitrosoarene and resinous products were formed. When potassium dichromate was added in

TABLE 2. RESULTS OF NITRODETHALLATION OF **1**[a]

1			(mmol)	$NaNO_2$ (mmol)	CF_3CO_2H (ml)	**2** Yield (%)[b]
R^1	R^2	R^3				
Me	H	H	2	6	15	97
Me	Me	H	2	6	15	99
Me	H	Me	2	6	15	100
MeO	H	H	2	6	15	92[c]
H	H	H	1	3	15	25[d]
H	H	H	1	3	15	60[e]
H Cl	H	Cl[f] H	2	6	15	16[f,g]
H Cl	H	Cl[f] H	1	2	15	51[e,f]

a) At 25 °C for 3 h. b) Based on **1**. c) At 25 °C for 10 min. d) PhNO 27%. e) $K_2Cr_2O_7$ (1 mmol) was added. f) *o*:*p*=20:80. g) ClC_6H_4NO 11%.

TABLE 1. EFFECTS OF SOLVENT, CONCENTRATION OF REACTANTS, AND METAL NITRITE IN NITRODETHALLATION OF **1** (R^1=Me, R^2=R^3=H)

1 (R^1=Me, R^2=R^3=H) (mmol)	MNO_2 (mmol)		Solvent (ml)		Temp (°C)	Time (h)	**2** (R^1=Me, R^2=R^3=H) Yield (%)[a]
2	$NaNO_2$	6	CF_3CO_2H	15	25	3	97
2	$NaNO_2$	12	CF_3CO_2H	15	25	3	51
4	$NaNO_2$	12	CF_3CO_2H	15	25	3	76
5	$NaNO_2$	15	$ClCH_2CO_2H$	25	100	10	54
5	$NaNO_2$	15	CH_3CO_2H	25	25	5	0
5	$NaNO_2$	15	CH_3CO_2H	25	100	5	55[b]
2	$AgNO_2$	6	CF_3CO_2H	15	25	3	87
2	KNO_2	6	CF_3CO_2H	15	25	3	89

a) Based on **1**. b) Other product; *p*-tolyl acetate 9%.

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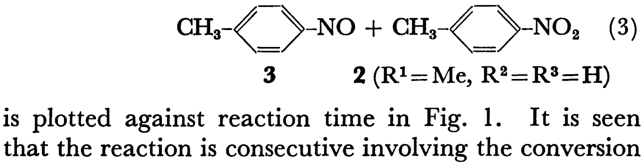
these reaction systems, the yield of **2** increased, no nitrosoarene being detected. The results are given in Table 2. The nitrodethallation procedure is applicable even without the isolation of intermediate arylthallium(III) compounds. As an example, nitroarenes could be obtained (*in situ* nitrodethallation) when the reaction was carried out at 25 °C for 3 h by adding sodium nitrite to trifluoroacetic acid solution of arylthallium(III) compound prepared by the method[4] of McKillop *et al.* The yields and isomer ratios of some nitroarenes are as follows ($K_2Cr_2O_7$ was also added in the case of halobenzene): toluene (87%, *o*: *m*: *p*=13: 1: 86), *t*-butylbenzene (92%, *o*: *m*: *p*=2: 6: 92), *o*-xylene (90%, 3-: 4-=7: 93), *m*-xylene (100%, only 4-), mesitylene (27%), biphenyl (mononitro- 47%, dinitro-53%), chlorobenzene (50%, *o*: *p*=19: 81) and bromobenzene (34%, *o*: *p*=19: 81). These isomer ratios should reflect those of intermediate arylthallium(III) compounds.

Metal nitrite reacts with various organic and inorganic acids to give nitrous acid (HNO_2). This gives NO^+ or N_2O_3 in acidic media, the latter being known as a carrier of nitrosyl ion (Scheme 2).[5a,b)]

$$\begin{gathered} NaNO_2 + CF_3COOH \rightleftarrows HNO_2 + CF_3CO_2Na \\ 2HNO_2 \rightleftarrows N_2O_3 + H_2O \\ HNO_2 + H^+ \rightleftarrows NO^+ + H_2O \end{gathered} \qquad (2)$$

The presence of nitrosyl ion in trifluoroacetic acid has been shown by cryoscopic experiments and spectral data.[6] From these facts and the reported data for electrophilic nitrosodethallation of arylthallium(III) compounds with nitrosyl chloride (NOCl),[7] nitrosoarenes should be expected as the intermediates in our case. In fact, nitrosoarenes were detected in the reaction products in the cases of phenyl- and chlorophenylthallium(III) compounds. For the sake of clarification we investigated the reaction products and their yields in the nitrodethallation of **1** (R^1=Me, R^2=R^3=H). It was found that when the reaction is stopped in a very short time, *p*-nitrosotoluene (**3**) is mainly formed together with a small amount of *p*-nitrotoluene (Scheme 3). The yield of each product is plotted against reaction time in Fig. 1.



1 (R^1=Me, R^2=R^3=H)

3 **2** (R^1=Me, R^2=R^3=H)

It is seen that the reaction is consecutive involving the conversion of **3** into **2** (R^1=Me, R^2=R^3=H). In order to know how **3** can be converted into **2** (R^1=Me, R^2=R^3=H), the oxidation of **3** prepared separately by the reported method[8] to **2** (R^1=Me, R^2=R^3=H) was examined under various conditions (Table 3). The oxidation of **3** to **2** (R^1=Me, R^2=R^3=H) was rather slow in trifluoroacetic acid containing sodium nitrite, but the addition of thallium(III) salt and perchloric acid, both of which are expected to be formed in the reaction shown in Scheme 3, enhanced the rate remarkably.

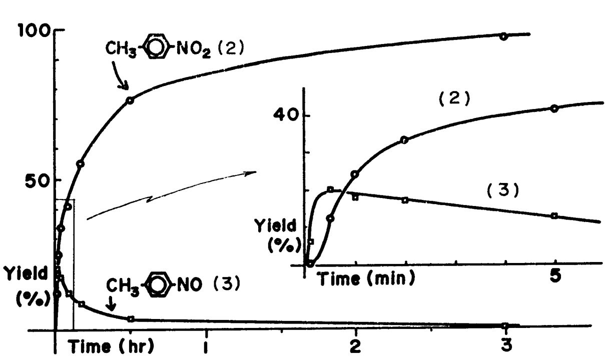


Fig. 1. Effect of reaction time on product and yield in the reaction of Scheme 3. Reaction conditions; **1** 2 mmol, $NaNO_2$ 6 mmol, CF_3CO_2H 15 ml, at 25 °C.

When **1** (R^1=MeO, R^2=R^3=H) was used as an additive, a very good yield of **2** (R^1=MeO, R^2=R^3=H) was obtained, **3** being partly oxidized to **2** (R^1=Me, R^2=R^3=H). This result shows that **1** and/or some species derived from **1** has a strong oxidizing ability and also that the oxidation of *p*-nitrosoanisole to the corresponding nitro compound is faster than that of **3**.

The yield of **2** from **1** (R^1=R^2=R^3=H and R^1 or R^3=Cl or H, R^2=H) was low, while the addition of $K_2Cr_2O_7$ increased it. When the reaction was stopped in a short time in the cases without $K_2Cr_2O_7$, the main product was nitrosoarene. As an example, from **1** (R^1=R^2=R^3=H) nitrosobenzene was obtained in 37% and 51% yield for 2 min and 10 min reaction, respectively, together with a small amount of nitrobenzene (<1.3%), and from **1** (R^1 or R^3=Cl or H, R^2=H) only chloronitrosobenzene was obtained in 14% yield for 2 min reaction (under the conditions shown in Fig. 1). At first glance it seems that the addition of $K_2Cr_2O_7$ helps the oxidation of nitroso compounds. However, it was clarified that the oxidation of nitrosobenzene to nitrobenzene was slow and a lot of nitrosobenzene was lost to unidentified compounds under various conditions (Table 3) or even in the presence of $K_2Cr_2O_7$ (See Experimental). Therefore the reason for effectiveness of the potassium salt in these cases seems to be attributed to other factors, *i.e.*, oxidation of C–Tl bond by $K_2Cr_2O_7$ followed by NO_2^- attack, a similar scheme having been proposed in the cases of arylpalladium(II) compounds,[9]

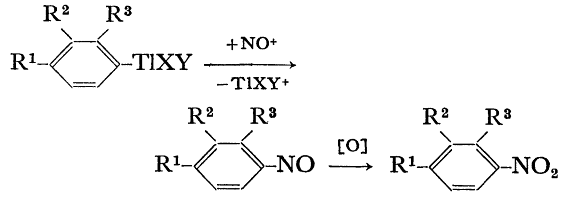
Table 3. Results of the oxidation of *p*-nitrosotoluene to *p*-nitrotoluene[a)]

3 (mmol)	$NaNO_2$ (mmol)	Additive (mmol)	Time (min)	**2** (R^1=Me, R^2=R^3=H) Yield (%)
2	6	—	10	0.4
2	6	—	180	90
2	6	$Tl(OAc)_3$ 2	10	25
2	6	70% $HClO_4$ 2	10	50
2	6	$Tl(OAc)_3$ 2, 70% $HClO_4$ 2	10	96
2	6	**1** (R^1=MeO, R^2=R^3=H) 2	10	48[b)]

a) CF_3CO_2H 15 ml, at 25 °C. b) *p*-$MeOC_6H_4NO_2$ (89%) was also formed.

In order to confirm the mechanistic difference of nitrodethallation by metal nitrite from that by nitrogen dioxide,2) nitrodethallation of **1** (R^1=Me, R^2=R^3=H) with nitrogen dioxide was carried out in trifluoroacetic acid at 25 °C, the reaction being stopped after 2 min. Only *p*-nitrotoluene was detected as the product (54% yield), no *p*-nitrosotoluene being formed (Compare with Fig. 1).

From the results it can be concluded that nitrodethallation of **1** with metal nitrite proceeds through electrophilic substitution of thallium moiety by NO^+ to give nitroso compounds followed by facile oxidation to nitro compounds (Scheme 4).



(4)

Experimental

GLC analyses were carried out on a Shimadzu 5APTF apparatus using PEG 6000 (25%)-Chromosorb W (1 m) and Apiezon L (30%)-Celite (1 m) columns (N_2 as a carrier gas).

Materials. Arylthallium(III) acetate perchlorate monohydrate10) and bistrifluoroacetates4) were prepared by reported methods. Commercial sodium nitrite was used without further purification. Nitrogen dioxide was prepared by the method of Brook.11) Commercial organic solvents and substances of guaranteed grade were used. All the nitro compounds and nitrosobenzene were available either commercially or from previous studies in our laboratory. *p*-Nitrosotoluene was synthesized by the reduction of *p*-nitrotoluene to *p*-tolylhydroxylamine followed by oxidation using sodium dichromate.8)

Reaction of 1 with Sodium Nitrite in Trifluoroacetic Acid (Tables 1 and 2). The following shows a typical experimental procedure. To a white suspension of **1** (R^1=Me, R^2=R^3=H) (0.94 g, 2 mmol) in trifluoroacetic acid (15 ml) was added solid sodium nitrite (0.41 g, 6 mmol) at 25 °C in one portion. The color of the mixture immediately turned dark-brown. The mixture was stirred at 25 °C for 3 h, during which period evolution of a small amount of brown fume was observed. The resulting yellow heterogeneous mixture was poured into water (100 ml) and the products were extracted with benzene. The extract was washed with aq. $NaHCO_3$ and dried over $MgSO_4$. The solvent was removed at atmospheric pressure. GLC analysis of the residue showed the presence of **2** (R^1=Me, R^2=R^3=H) (1.94 mmol, 97%) as the sole product.

When the reaction was stopped in a short time (10 s—0.5 h), variable amount of **3** was detected in GLC together with 2 (R^1=Me, R^2=R^3=H) (See Fig. 1).

Reaction of 1 (R^1=Me, R^2=R^3=H) with Nitrogen Dioxide in Trifluoroacetic Acid. To a solution of nitrogen dioxide11) (1.5 ml, 50 mmol) in trifluoroacetic acid (15 ml) was added solid **1** (R^1=Me, R^2=R^3=H) (0.94 g, 2 mmol) at 25 °C in one portion and the resulting mixture was stirred for 2 min followed by addition of 100 ml of water to stop the reaction. After the usual work-up procedure, GLC analysis of the organic residue showed the presence of **2** (R^1=Me, R^2=R^3=H) (1.1 mmol, 54%) and none of **3**.

Oxidation of p-*Nitrosotoluene (3) to* p-*Nitrotoluene [2 (R^1=Me, R^2=R^3=H)] (Table 3).* To a stirred solution of $Tl(OAc)_3$ (0.76 g, 2 mmol) and 70% $HClO_4$ (0.29 g, 2 mmol) in trifluoroacetic acid (15 ml) was added solid sodium nitrite (0.41 g, 6 mmol) at 25 °C to give a brown suspension. To this suspension was added **3** (2.39 g, 2 mmol) and the solution was stirred for 10 min. After the usual work-up procedure, GLC analysis of the organic residue showed the presence of **2** (R^1=Me, R^2=R^3=H) (1.94 mmol) and unreacted **3** (0.06 mmol). This indicates that 96% of **3** was oxidized.

Oxidation of Nitrosobenzene to Nitrobenzene [2 R^1=R^2=R^3=H)]. To a green solution of nitrosobenzene (0.10 g, 1 mmol) in trifluoroacetic acid (15 ml) were added solid sodium nitrite (0.14 g, 2 mmol) and $Tl(OAc)_3$ (0.38 g, 1 mmol) in one portion and the resulting dark brown mixture was stirred at 25 °C for 3 h. Water (*ca.* 100 ml) was then added to give a dark brown tarry compound which was filtered. The filtrate was extracted with benzene. GLC analysis of the benzene extract showed the presence of nitrobenzene (0.11 mmol) and nitrosobenzene (0.13 mmol), indicating that 11% of the starting material was oxidized to nitrobenzene, 13% of it was recovered unreacted, and 76% of it was transformed to unidentified compounds. When a similar treatment was carried out with the addition of $K_2Cr_2O_7$ (0.29 g, 1 mmol), 16% of the starting material was oxidized to nitrobenzene and 18% of it was recovered unreacted.

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