

Halogenation Using Quaternary Ammonium Polyhalides XXVIII¹⁾. Effect of Substituents on Brominating Ability of Quaternary Ammonium Tribromides

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Abstract

Several substituted benzyltrimethylammonium tribromides (BTMA Br₃) and phenyltrimethylammonium tribromide (PTMA Br₃) were prepared to compare their brominating ability with the mother compounds BTMA Br₃ and PTMA Br₃. Consequently, it turned out that electron donating substituent such as *p*-methyl group increased the brominating ability of the tribromides and electron attracting substituent such as *p*-nitro group decreased its ability of the tribromides.

1. Introduction

We have already shown that bezyltrimethylammonium tribromide (BTMA Br₃)(**1a**) is used in the place of liquid bromine and is more effective brominating agent than bromine owing to its solid character, stability and nontoxicity²⁾. During the course of our further investigation on the bromination of aromatic compounds with these quaternary ammonium tribromides, we now tried to compare the brominating effect of substituted **1a** and substituted phenyltrimethylammonium tribromide with mother compounds **1a** and phenyltrimethylammonium tribromide (**2a**). In this case, as electron donating and electron attracting substituents, *p*-methyl and *p*-nitro groups were chosen, respectively. Thus, *p*-methylbenzyltrimethylammonium tribromide (*p*-CH₃-BTMA Br₃)(**1b**), *p*-nitrobenzyltrimethylammonium tribromide (*p*-NO₂-BTMA Br₃)(**1c**), *p*-methylphenyltrimethylammonium tribromide (*p*-CH₃-PTMA Br₃)(**2b**), and *p*-nitrophenyltrimethylammonium tribromide (*p*-NO₂-PTMA Br₃)(**2c**) were prepared, and investigated their bathochromic effects and brominating abilities. In this paper, we wish to report on the above results.

2. Results and Discussion

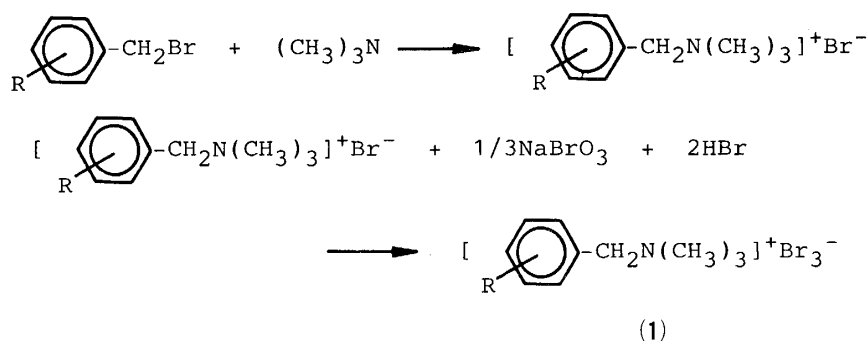
2.1 Preparation of Quaternary Ammonium Tribromides

2.1.1 Preparation of *p*-Substituted Benzyltrimethylammonium Tribromides

Compound **1b** was prepared from the reaction of *p*-methylbenzyltrimethylammonium tribromide, which was obtained from *p*-methylbenzyl bromide and trimethylamine,

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with sodium bromate (1/3 mol) and hydrobromic acid (2 mol) as shown in Scheme 1 (R = *p*-CH₃).



Scheme 1

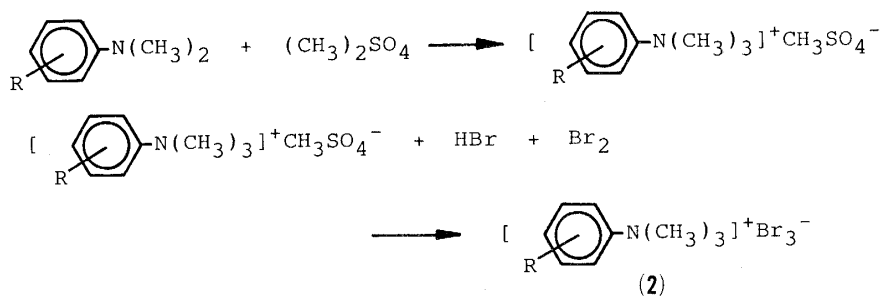
Compound **1c** was prepared in a similar manner using *p*-nitrobenzylbromide as starting material (Scheme 1, R = *p*-NO₂). The yield and analytical data of these compounds **1** are summarized together with **1a** in Table 1.

Table 1 The yields and analytical data of quaternary ammonium tribromides **1** and **2**

Comps	Yield	Found			Calcd.		
		C(%)	H(%)	N(%)	C(%)	H(%)	N(%)
1 and 2	%						
1a ⁴⁾	78	30.69	4.11	3.76	30.80	4.14	3.59
1b	92	32.74	4.31	2.92	32.70	4.49	3.47
1c	93	27.91	3.22	5.92	27.61	3.48	6.44
2a ³⁾	75	—	—	—	—	—	—
2b	95	30.90	4.01	3.09	30.80	4.14	3.59
2c	89	25.69	3.22	6.36	25.68	3.11	6.66

2.1.2 Preparation of *p*-Substituted Phenyltrimethylammonium Tribromides

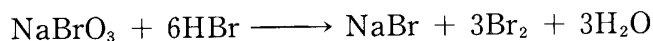
Compound **2a** was prepared from the reaction of phenyltrimethylammonium sul-



Scheme 2

fomethylate, which was obtained from *N,N*-dimethylaniline and dimethylsulfuric acid, with equiv of hydrobromic acid and bromine³⁾ (Scheme 2, R=H).

Compounds **2b** (Scheme 2, R=*p*-CH₃) and **2c** (Scheme 2, R=*p*-NO₂) were prepared in a similar manner as above. Still, bromine was also generatede *in situ* from sodium bromate and hydrobromic acid.



The yields and analytical data of those compounds **2** are summarized in Table 1. Furthermore, attempts to prepare 2,4-dinitrophenyltrimethylammonium tribromide and 4-methoxyphenyltrimethylammonium tribromide were unsuccessful.

Table 2 Physical properties of the tribromides

Compds.	Mp(°C)	Color	Solubility in CH ₂ Cl ₂ at r.t.
1a ³⁾	100-101	orange red	readily soluble
1b	90-92	orange	highly soluble
1c	126-127	orange yellow	slightly soluble
2a ³⁾	116-117	orange yellow	readily soluble
2b	107-109	golden yellow	highly soluble
2c	152-153	deep yellow	almost insoluble

2.2 Comparison of Some physical properties of the Tribromides

Some physical properties of the obtained tribromides are shown in Table 2. As shown in Table 2, the order of bathochromic effects of these tribromides is as follows;



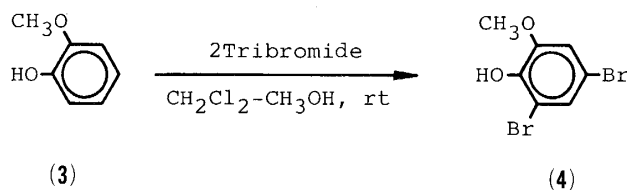
That is, substituents such as *p*-CH₃ and *p*-NO₂ did scarcely influence for the bathochromic effects of these tribromides. However, it turned out that *p*-CH₃ group increased the solubility of tribromides in solvent and *p*-NO₂ group decreased it.

2.3 Comparison of Brominating Ability of the Tribromides

In order to compare brominating ability of the prepared substituted BTMA Br₃(**1b**, **1c**) and PTMA Br₃(**2b**, **2c**) with the mother compounds (**1a**, **2a**), we chose 2-methoxyphenol (**3**) as substrate, because this compound **3** is moderately active for the electrophilic substitution and its bromination product is easily to handle.

The reaction of **3** with 2-equiv of those tribromides in CH₂Cl₂-CH₃OH at room temperature gave 4,6-dibromo-2-methoxyphenol (**4**), respectively. The results are summarized in Table 3.

As shown in Table 3, the order of brominating abilities of these tribromides for **3** is as follows;

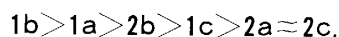


Scheme 3

Table 3 Bromination of 2-methoxyphenol (**3**) with quaternary ammonium tribromides in CH_2Cl_2 - CH_3OH at room temperature

Run	Reagent	Reagent 3	Reaction time hour	Yield ^{a)} of 4 (%)
1	1a	2.1	1	90
2	1b	2.1	0.5	89
3	1b	2.1	1	98
4	1c	2.1	1	27
5	1c	2.1	5	33
6	2b	2.1	1	82
7	2a	2.1	5	- ^{b)}
8	2c	2.1	5	- ^{c)}

a) Yield of isolated product. b) Product was obtained as a mixture of **4** and **3**, and product ratio was determined by its $^1\text{H-NMR}$ spectrum as $4/3=1.2/1$. c) Product was obtained as a mixture of **4** and **3**, and product ratio was as follows: $4/3=1.1/1$.



Thus, *p*- CH_3 substituent on benzyl or phenyl group did remarkably increase the brominating ability of the tribromide, and *p*- NO_2 substituent did considerably decrease it. It can therefore be presumed that *p*- CH_3 substituent labilizes the tribromide and *p*- NO_2 substituent stabilizes the tribromide. Actually, as shown in Table 2, *p*- CH_3 substituted tribromide shows the lowest melting point and *p*- NO_2 substituted tribromides shows the highest melting point.

3. Experimental

3.1 Synthesis of *p*-Methylbenzyltrimethylammonium Tribromide (**1b**):

To a solution of *p*-methylbenzyl bromide (5.0 g, 0.027 mol) in methanol (30 ml) was added trimethylamine (30% aq) (5.33 g, 0.027 mol) under stirring. After the reaction mixture was stirred for 3h at room temperature, the solvent was distilled. The obtained residue was washed with acetone (20 ml) and dried to give *p*-methylbenzyltrimethylammonium bromide as hygroscopic colorless crystals; yield 6.05

g (92%); mp 200-201°C; ¹H NMR (D₂O) δ =2.40(3H, s, CH₃), 3.10(9H, s, N(CH₃)₃), 4.44(2H, s, CH₂), 7.40(4H, s, C₆H₄).

To a solution of the bromide (2.0 g, 8.19 mmol) and sodium bromate (0.42 g, 2.78 mmol) in water (10 ml) was added hydrobromic acid (47% aq)(2 ml, 16.7 mmol) under stirring at room temperature. After the reaction mixture was stirred for 1h, a precipitated solid was filtered, dried, and recrystallized from methanol-hydrobromic acid (47% aq)(5:1)(10 ml) to give **1b** as orange crystals; yield 3.3g (92%); mp 90-92 °C. Analytical data was shown in Table 1.

3.2 Synthesis of *p*-Nitrobenzyltrimethylammonium Tribromide (**1c**):

Trimethylamine (30% aq)(4.56 g, 0.231 mol) was added to a solution of *p*-nitrobenzyl bromide (5.0 g, 0.0231 mol) in methanol (25 ml) under stirring. After the reaction mixture was stirred for 1h at room temperature, the solvent was distilled. The residue obtained was washed with acetone (20 ml) and dried to give *p*-nitrobenzyltrimethylammonium bromide as hygroscopic colorless crystals; yield 5.92 g (93%); mp 228-229°C; ¹H NMR (D₂O) δ =3.28(9H, s, N(CH₃)₃), 4.70(2H, s, CH₂), 7.88-7.98(2H, d, 2- and 6-H), 8.39-8.48(2H, d, 3- and 5-H).

To a solution of the bromide (1.0 g, 3.63 mmol) and sodium bromate (0.19 g, 1.26 mmol) in water (10 ml) was added dropwise hydrobromic acid (47% aq)(0.9 g, 7.52 mmol) under stirring at room temperature. After the reaction mixture was stirred for 1h, a precipitated solid was filtered, dried, and recrystallized from methanol-hydrobromic acid (47% aq)(5:1)(10 ml) to give **1c** as orange yellow crystal; yield 1.52 g (93%); mp 126-127°C. Analytical result was shown in Table 1.

3.3 Synthesis of *p*-Methylphenyl trimethylammonium Tribromide (**2b**):

To a solution of *N,N*-dimethyl-*p*-toluidine (9.36 g, 0.069 mol) in toluene (20 ml) was added dropwise dimethylsulfuric acid (8.74 g, 0.027 mol) under stirring. After the reaction mixture was stirred for 3h at room temperature, the obtained solid was filtered and washed with toluene (20 ml) and then with ether (20 ml). Thus, *p*-methylphenyltrimethylammonium sulfomethylate was obtained as hygroscopic colorless crystals; yield 17.3g (95%); ¹H NMR (D₂O) δ =2.40(3H, s, CH₃), 3.70(9H, s, N(CH₃)₃), 3.80(3H, s, CH₃SO₄), 7.44-7.90(4H, br.s, C₆H₄).

To a solution of the sulfomethylate (3.0 g, 11.5 mmol) and sodium bromate (0.58 g, 3.84 mmol) in ice water (15 ml) was added dropwise hydrobromic acid (47% aq)(4.2 ml, 0.035 mol) under stirring. After the reaction mixture was stirred for 1h at room temperature, a precipitated solid was filtered, dried, and recrystallized from methanol-hydrobromic acid (47% aq)(5:1)(10 ml) to give **2b** as golden yellow crystals; yield 4.17 g (95%); mp 107-109°C. Analytical result was shown in Table 1.

3.4 Synthesis of *p*-Nitrophenyltrimethylammonium Tribromide (**2c**):

Dimethylsulfuric acid (3.0 ml, 0.034 mol) was added dropwise to a solution of *N,N*-dimethyl-*p*-nitroaniline (3.33 g, 0.024 mol) in toluene (50 ml) under stirring. The reaction mixture was refluxed for 6h and then cooled to room temperature. The solid obtained was filtered and washed with toluene (10 ml) and with benzene (50 ml) and then with acetone (10 ml). Thus, *p*-nitrophenyltrimethylammonium sulfomethylate was

obtained as hygroscopic light yellow crystals; yield 6.21 g (89%); mp 217-219°C; ¹H NMR (D₂O) δ=3.66(9H, s, N(CH₃)₃), 8.10(2H, d, 2- and 6-H), 8.28(2H, d, 3- and 5-H).

To a solution of the sulfomethylate (1.60 g, 5.5 mmol) and hydrobromic acid (47% aq) (1 ml) in water (5 ml) was added dropwise bromine (0.94 g, 5.9 mmol) under stirring. After the reaction mixture was stirred for 6h at room temperature, a solid obtained was filtered, dried, and recrystallized from methanol-hydrobromic acid (47% aq)(5:1) (10 ml) to give **2c** as deep yellow crystals; yield 1.80 g (89%); mp 152-153°C. Analytical result was shown in Table 1.

3.5 Bromination of 2-Methoxyphenol (3) with p-Methylbenzyltrimethylammonium Tribromide (1b). Typical Procedure of the Reaction of **3** with the Tribromides: The tribromide **1b** (0.665 g, 1.65 mmol) was added to a solution of **3** (0.094 g, 0.784 mmol) in dichloromethane-methanol (5:1)(14 ml) under stirring at room temperature. After the reaction mixture was stirred for 1h until a decoloration of orange solution took place, the solvent was distilled and the solid residue was extracted with ether (10 ml × 4). The ether layer was dried with MgSO₄ and evaporated in vacuo to give 4,6-dibromo-2-methoxyphenol as colorless crystals; yield 0.212 g (98%); mp 59-61°C (lit.⁵⁾, mp 64-65°C).

References

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