We also thank Johnson Matthey for a loan of Pd and Rh compounds.

Supplementary Material Available: Spectral data (IR, ^{1}H NMR, and ^{13}C NMR) for **1a**, **1b**, **2b**, **3–7**, **8a**, **8b**, and **9–15** (6 pages). Ordering information is given on any current masthead page.

Trihalomethyl Cations[1]

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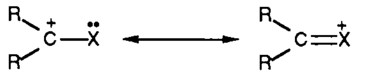
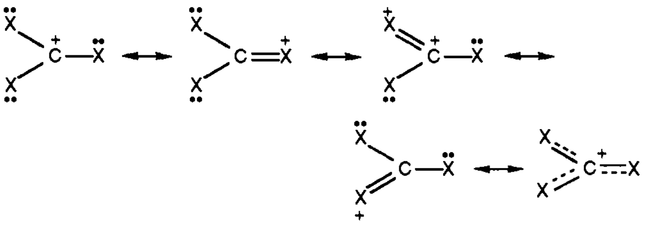
Although trialkyl,[2] halodialkyl,[3] and dihaloalkylmethyl[4] cations have been prepared and spectroscopically characterized under long-lived stable ion conditions in solution, the corresponding parent trihalomethyl cations have never been observed. Halogen atoms adjacent to a carbocationic center are inductively destablizing due to their high electronegativity. On the other hand, the nonbonded electron pairs on the halogen atom can stabilize the positive charge through back-donation (p–p interaction). The extent of stabilization is dependent on the electronegativity of the halogen atom and its size. Following the known electronegativity order F > Cl > Br > I,[5] fluorine should inductively destabilize the adjacent carbenium center the most. However, since fluorine is a small atom possessing 2p nonbonded electron pairs, the back-donation 2p–2p overlap is maximum, and in fact fluorine is an excellent stabilizer of adjacent positive charge. From previous studies[3] the order of the charge stabilizing effect of halogens on adjacent carbocationic centers has been found to be F > Cl > Br > I.



Consequently it was of interest to prepare stable trihalomethyl cations under superacid conditions and to probe the effect of three halogen atoms attached to carbocationic center. In principle the three halogen atoms should significantly stabilize the positive charge through back-donation involving several resonance structures. Such back-bonding resonance stabilization in guanidinum[6] and trihydroxycarbenium ions[7] is well-known.



Slow addition of a precooled solution of carbon tetrachloride in SO_2ClF to a stirred solution of 5-fold excess of SbF_5 in SO_2ClF maintained at −78 °C (dry/ice acetone bath) gave a clear colorless solution. The 50 MHz ^{13}C NMR spectrum of the solution obtained at −80 °C shows a single sharp resonance at δ^{13}C 236.3, deshielded from the progenitor signal by 139.6 ppm. The same

$$\underset{X = Cl, Br, I}{CX_4} \xrightarrow[-78\ ^\circ C]{nSbF_5/SO_2ClF} {}^+CX_3{}^-Sb_nF_{5n}X$$

ion (obtained from CCl_4) was also observed by the ionization with subsequent loss of SO_2 of trichloromethanesulfonyl chloride with SbF_5 under similar conditions. These data are indicative of the formation of the trichloromethyl cation.

$$CCl_3SO_2Cl \xrightarrow[-78\ ^\circ C]{nSbF_5/SO_2ClF} {}^+CCl_3{}^-Sb_nF_{5n}Cl + SO_2$$

To further confirm the observation of the trichloromethyl cation we also ionized trichloroacetyl chloride in SbF_5/SO_2ClF solution at −78 °C. Under the reaction conditions rapid CO gas evolution is observed with the formation of the identical trichloromethyl cation.

$$CCl_3COCl \xrightarrow[-78\ ^\circ C]{nSbF_5/SO_2ClF} {}^+CCl_3\ Sb_nF_{5n}Cl^- + CO\uparrow$$

In an attempt to observe the intermediate trichloroacetylium cation (CCl_3CO^+) we repeated the ionization experiment at −120 °C (ethanol/liquid N_2 slush bath). At this temperature trichloroacetyl chloride–SbF_5 undergoes rapid halogen exchange via the formed donor–acceptor complex. The complex showed two ^{13}C absorptions at δ^{13}C 194.8 (J_{C-F} = 120 Hz) and 92, with no discernible long-range fluorine coupling observed with the trichloromethyl carbon. Upon standing the complex even at this temperature decomposes to give the trichloromethyl cation.

$$CCl_3COCl + nSbF_5 \rightarrow CCl_3COF \rightarrow SbF_4Cl(Sb_{n-1}F_{5n-5})$$

The trichloromethyl cation is stable below −50 °C, above which it decomposes. Surprisingly, the $^+CCl_3$ ion coexists in the presence of excess carbon tetrachloride, and no evidence was obtained for the formation of bis(trichloromethyl)chloronium ion $(Cl_3C)_2Cl^+$. When a solution of the trichloromethyl cation was reacted with 3 equiv of benzene, the triphenylmethyl cation[8] was cleanly formed.

Carbon tetrabromide similarly ionizes in excess SbF_5/SO_2ClF solution at −78 °C giving the tribromomethyl cation. The ^{13}C NMR spectrum of the tribromomethyl cation shows a singlet at δ^{13}C 207. The extent of deshielding compared to its precursor carbon tetrabromide (δ^{13}C −28.5) is 235.5 ppm, consistent with the formation of tribromomethyl cation.

Even carbon tetraiodide undergoes clean ionization in SbF_5/SO_2ClF solution at −78 °C to give the triiodomethyl cation. The triiodomethyl cation exhibits a ^{13}C NMR chemical shift of 95 ppm, a deshielding of 387.3 compared to its progenitor carbon tetraiodide (δ^{13}C −292.3).[9]

All of our attempts to observe the trifluoromethyl cation were so far unsuccessful. Tetrafluoromethane (bp −128 °C) was found to be unreactive even in large excess SbF_5/SO_2ClF solution at −78 °C. Ionization of either trifluoroacetyl fluoride or trifluoromethanesulfonyl chloride with antimony pentafluoride, on the other hand, led to the formation of tetrafluoromethane. Further, trifluoroacetic acid in $FSO_3H{:}SbF_5$ (Magic Acid)/SO_2ClF solution gave the corresponding protonated acid, which was characterized by its ^{13}C NMR spectrum δ^{13}C 174.2 (J_{C-C-F} = 49.3 Hz), 112.4, (J_{C-F} = 283.7 Hz). Attempts to dehydrate the protonated acid to trifluoroacetyl cation (CF_3CO^+) and subsequently to trifluoromethyl cation (CF_3^+) were unsuccessful. When trifluoroacetyl chloride was reacted with benzene in the presence of $AlCl_3$ catalyst, besides trifluoroacetophenone the Friedel–Crafts trifluoroacetylation product, triphenylmethyl chloride was formed.[10] This is indicative of in situ decarbonylation of the trifluoroacetyl cation to the trifluoromethyl cation which

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Table I. Comparison of ^{13}C NMR Chemical Shifts[a] of Trihalomethyl Cations[b] and the Corresponding Trihalomethanes[c]

trihalomethyl cation	$\delta^{13}C$	trihalomethane	$\delta^{13}C$	$\Delta\delta^{13}C$
$^+CCl_3$	236.3	$HCCl_3$	77.7	158.6
$^+CBr_3$	207	$HCBr_3$	+12.3	194.7
$^+CI_3$	95	HCI_3	−139.7	234.7

[a] Chemical shifts in ppm from external tetramethylsilane signal. [b] In SbF_5/SO_2ClF solution at −80 °C. [c] Data taken from ref 9.

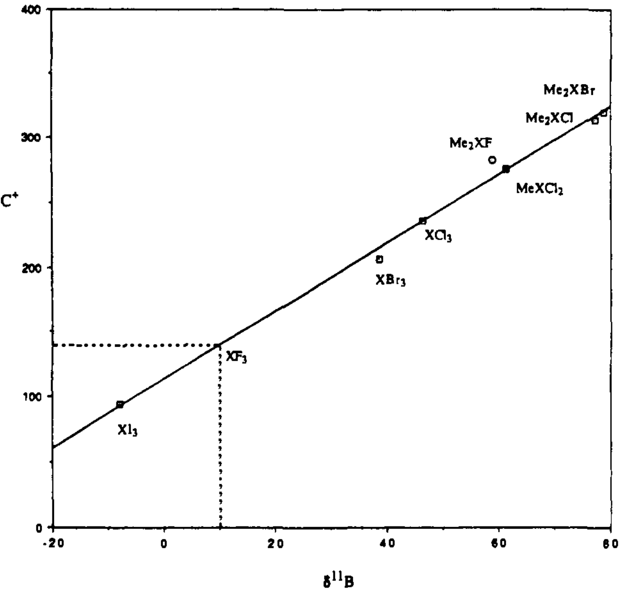

Figure 1. A plot of ^{13}C NMR chemical shifts of halomethyl cations vs ^{11}B NMR chemical shifts of isoelectronic isostructural haloboranes.

then reacts with benzene to give benzotrifluoride. Benzotrifluoride on subsequent reaction with benzene and aluminum trichloride gives triphenylmethyl chloride.

In the gas phase the CF_3^+ ion is stable and is an abundant species, specially in the mass spectra[11] of organofluorine compounds. However, in solution the great strength of the C–F bond in CF_4 (ca. 140 kcal/mol) leads to rapid quenching of CF_3^+ to CF_4 even in low nucleophilicity fluorinated superacid media.

We have compared the ^{13}C NMR chemical shifts of the trihalomethyl cations to those of the respective trihalomethanes and found a consistent trend (see Table I). The $\Delta\delta^{13}C$ chemical shift differences[12] are 158.6, 194.7, and 234.7 for the trichloro-, tribromo-, and triiodomethyl derivatives, respectively. This trend is in agreement with the positive charge stabilization (increased back-bonding) order of Cl > Br > I. The ^{13}C shifts of trihalomethyl cations correlate well with the electronegativities of the halogen atoms.[14]

The ^{13}C NMR chemical shifts of the trihalomethyl cations and related reported methyl substituted mono- and dihalocarbenium ions[3] also correlate well with the ^{11}B NMR chemical shifts of the corresponding isostructural, isoelectronic boron halides[13] (see Figure 1). An excellent linear relationship is obtained with a correlation coefficient of unity.[15] From this plot, with the known ^{11}B NMR chemical shift of BF_3 (10.4 ppm) we can estimate the corresponding ^{13}C NMR shift of the yet unknown trifluoromethyl cation as to be 140 ppm which is only 31.2 ppm more deshielded than trifluoromethane at $\delta^{13}C$ 118.8. This indicates substantial stabilization of the trifluoromethyl cation by fluorine back-bonding. Experimental verification, however, must await preparation of the still elusive CF_3^+ ion under long-lived conditions.

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[14] Correlation with Pauling's electronegativities of the halogens were excellent ($r^2 = 1$). From this correlation the ^{13}C NMR shift of $^+CF_3$ is estimated to be ≈150 ppm.

[15] The equation from the plot is $\delta^{13}C = 112.4272 + 2.6504\ \delta^{11}B$, $r^2 = 1$.

Anatoxin-a(s), a Potent Anticholinesterase from *Anabaena flos-aquae*

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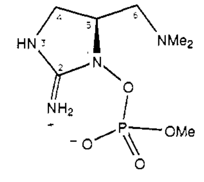
Anatoxin-a(s) is a neurotoxic alkaloid associated with the blue-green alga *Anabaena flos-aquae*.[1] It potent toxicity (LD_{50} 20–40 μg/kg mice) is attributed to exceptional anticholinesterase activity.[2] We report here the isolation of anatoxin-a(s) from a cultured strain NRC 525-17 and a field-collected bloom implicated in animal poisonings[3] and the determination of its structure as **1**.



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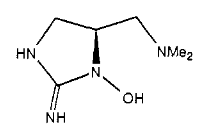

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Freeze-dried alga was extracted with 0.05 N AcOH/EtOH. The filtered extract was partitioned between water and CH_2Cl_2, the aqueous layer was washed with *n*-BuOH and evaporated in vacuo, and the residue was extracted successively with small portions of 0.05 N AcOH/MeOH and 0.05 N AcOH/EtOH to give a toxic concentrate. Gel filtration on Toyopearl HW40F (Supelco)[4] followed by HPLC on CN and ODS columns gave pure anatoxin-a(s) as a colorless solid in 0.05% yield. Toxin isolation was followed by assaying fractions for anticholinesterase activity.[5] Anatoxin-a(s) decomposed rapidly in basic solution but was

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