

APPLICATION NOTE

Tris (Perfluoroalkylethyl)silyl Alkyl Amines as Calibration Standards for Electron Ionization Mass Spectrometry in the Mass Range of 100–3000 Da

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A new fluorinated compound mixture has been developed for the calibration of the double focusing mass spectrometer in the mass range of 100–3000 Da in the positive electron ionization (EI) mode. Current calibration standards for EI have either limited mass range [perfluorotributylamine (PFTBA), perfluorokerosene (PFK), s-triazines (TRIS)] or poor peak intensities with significant chemical background in the instrument for several days (perfluoroalkyl phosphazine). The newly synthesized fluorinated silyl alkyl amines mixture is proposed as a reference/calibration standard for EI-MS. This standard produced abundant parent and fragment ions across the entire mass range without any memory effect. (J Am Soc Mass Spectrom 2001, 12, 1050–1054) © 2001 American Society for Mass Spectrometry

The development of several new fluorinated organic compounds for liquid/liquid and liquid/solid phase extractions and their use for automated solution phase parallel synthesis has opened up a need to develop methods to characterize these compounds by mass spectrometry [1–5]. These fluorinated compounds are volatile and have molecular weights in the range of 2000–3000 Da [5]. This class of compounds showed intense molecular ions and characteristic fragments in their positive electron ionization (EI) mass spectra.

The most commonly used calibration standards for positive EI-MS are perfluorinated compounds such as PFK and PFTBA [6–8]. PFK is also the most widely used calibration compound for accurate mass measurements providing regularly- and closely-spaced mass deficient peaks of adequate intensity. These peaks are easy to identify and generally do not interfere with analyte samples consisting of carbon, hydrogen, nitrogen, and oxygen. In addition, PFK is volatile and chemically inert, making this standard convenient to handle and easy to pump out of the ion source. The calibration standards PFTBA and PFK, however, have

upper mass limits of 671 and 900 Da respectively [6]. The commercially-available triazines are another series of standards [9–11] useful up to 1485 Da. Fomblin oils (Ultramark-F series, PCR, Inc.) [12–14] and phosphazine mixtures (Ultramark 1600 and 3200) [6, 9, 12] are used as calibration standards for positive EI-MS at higher mass ranges. Unfortunately, these Ultramark mass calibration standards have poor peak intensities and adhere to surfaces inside the instrument leading to chemical background for several days [15]. In order to completely remove all traces of Ultramark from the ion source and ion optics, it is necessary to go through multiple cleaning cycles. Calibration of mass spectrometers in the high mass range (2000–3000 Da) is limited in EI using currently available reference standards.

This study demonstrates the successful application of a newly synthesized TRIS (perfluoroalkylethyl)silyl alkyl amines mixture as a calibration standard for EI-MS in the range of 100–3000 Da. The mass spectral data for a variety of fluoro-organic materials obtained after calibration with the new standard, along with accurate mass measurements for several synthetic samples are presented.

Experimental

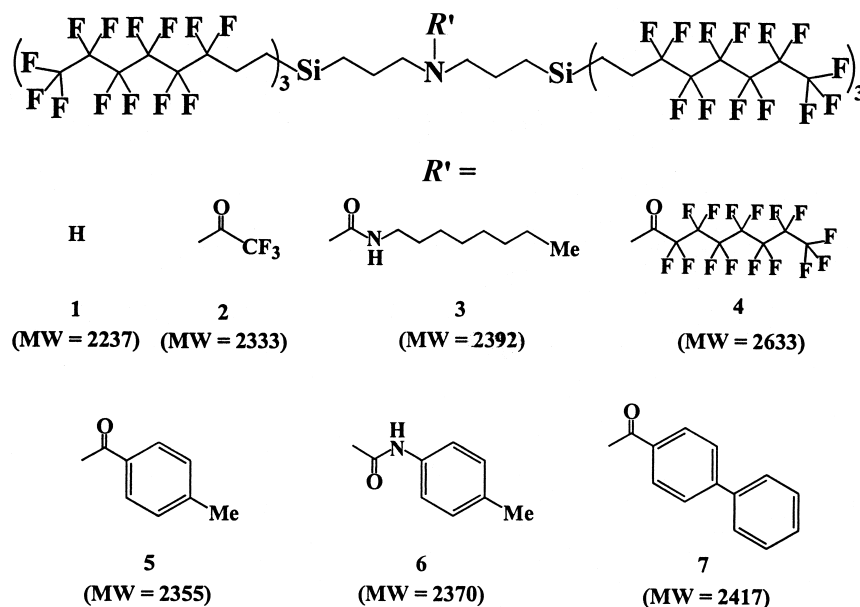
All fluorinated organic compounds studied were synthesized using a procedure previously discussed in detail elsewhere [5]. PFK, TRIS, and Ultramark used as

Published online July 24, 2001

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calibration standards were obtained from commercial sources.

The measurements were performed on an AutoSpec magnetic sector mass spectrometer (Micromass, Manchester, UK) equipped with a standard EI source

operating in positive ionization mode. Typical ionization conditions were electron energy of 70 eV, ion source temperature of 160 °C, and acceleration voltage of 8 kV. The mass spectrometer was scanned from m/z 100 to m/z 3100 with a resolution of 4000 ($m/\Delta m$) (10%

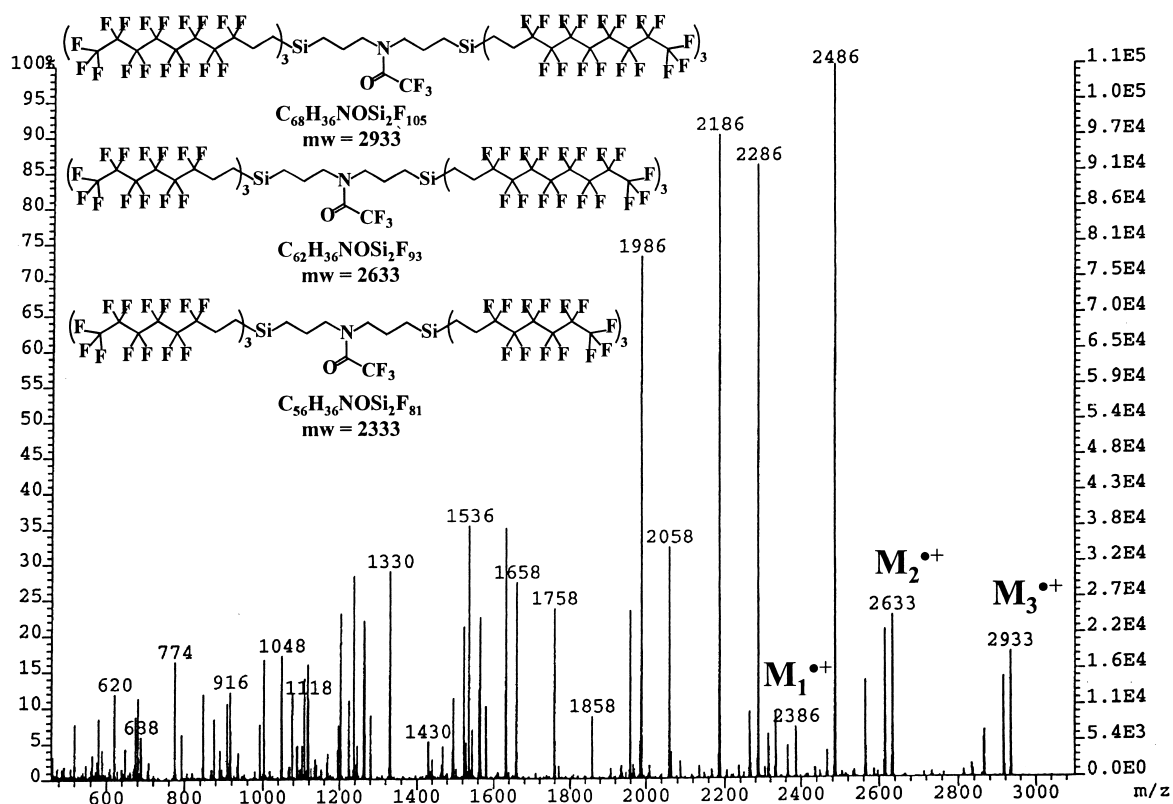


Figure 1. Chemical structures and single-scan positive EI mass spectra of the new calibration standard obtained at the resolution of 4000 (10% valley).

Table 1. Elemental composition and calculated monoisotopic masses of the ions in the positive EI mass spectra of the new calibration standard

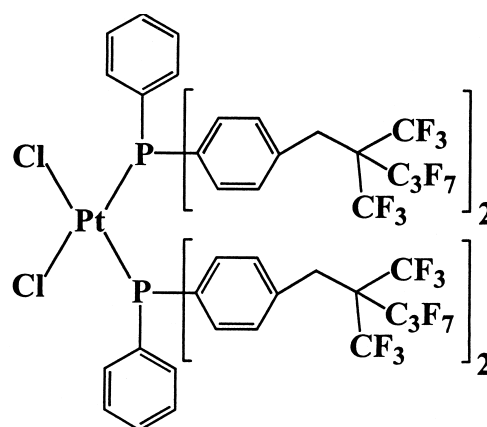
Elemental composition	Calculated masses	Elemental composition	Calculated masses
C ₆₈ H ₃₆ NOSi ₂ F ₁₀₅	2933.065888	C ₄₄ H ₂₈ NOSi ₂ F ₆₄	1858.068755
C ₆₈ H ₃₆ NOSi ₂ F ₁₀₄	2914.067485	C ₄₂ H ₂₈ NOSi ₂ F ₆₀	1758.075142
C ₆₇ H ₃₆ NOSi ₂ F ₁₀₂	2864.070678	C ₄₀ H ₂₈ NOSi ₂ F ₅₆	1658.081529
C ₆₆ H ₃₆ NSi ₂ F ₁₀₂	2836.075764	C ₃₆ H ₂₀ NOSiF ₅₄	1536.045193
C ₆₂ H ₃₆ NOSi ₂ F ₉₃	2633.085049	C ₃₀ H ₂₀ NOSiF ₄₂	1236.064354
C ₆₂ H ₃₆ NOSi ₂ F ₉₂	2614.086646	C ₂₈ H ₁₉ NOSiF ₃₇	1116.064513
C ₆₁ H ₃₆ NOSi ₂ F ₉₀	2564.089839	C ₂₄ H ₁₉ NOSiF ₂₉	916.077287
C ₆₀ H ₃₆ NSi ₂ F ₉₀	2536.094925	C ₂₁ H ₁₈ SiF ₂₆	792.076264
C ₅₈ H ₃₂ NOSi ₂ F ₈₈	2486.061733	C ₁₉ H ₁₃ NOSiF ₂₅	774.036724
C ₅₆ H ₃₆ NOSi ₂ F ₈₁	2333.104210	C ₁₇ H ₁₃ NOSiF ₂₁	674.043111
C ₅₆ H ₃₆ NOSi ₂ F ₈₀	2314.105807	C ₁₀ H ₄ F ₁₅	409.007349
C ₅₄ H ₃₂ NOSi ₂ F ₈₀	2286.074507	C ₁₀ H ₃ F ₁₄	389.001121
C ₅₅ H ₃₆ NOSi ₂ F ₇₈	2264.109000	C ₉ H ₃ F ₁₂	339.004314
C ₅₄ H ₃₆ NSi ₂ F ₇₈	2236.114086	C ₈ H ₄ F ₁₁	309.013736
C ₅₂ H ₃₂ NOSi ₂ F ₇₆	2186.080894	C ₈ H ₃ F ₁₀	289.007508
C ₅₃ H ₃₆ NOSi ₂ F ₇₄	2164.115387	C ₇ H ₃ F ₈	239.010701
C ₅₀ H ₃₂ NOSi ₂ F ₇₂	2086.087281	C ₅ H ₂ F ₇	195.004473
C ₅₁ H ₃₆ NOSi ₂ F ₇₀	2064.121774	C ₃ F ₇	168.988823
C ₄₈ H ₂₈ NOSi ₂ F ₇₂	2058.055981	C ₆ H ₉ NOF ₃	168.063624
C ₄₇ H ₂₈ NOSi ₂ F ₇₀	2008.059174	C ₃ F ₅	130.992016
C ₄₈ H ₃₂ NOSi ₂ F ₆₈	1986.093668	C ₂ F ₅	118.992016

valley), using centroid mode acquisition. Accurate mass measurements were obtained at a resolution of 7000 (10% valley) by the linear voltage scanning procedure in the centroid mode acquisition. All samples placed in glass capillaries were introduced into the ion source by a direct insertion probe and were heated from room temperature to 400 °C.

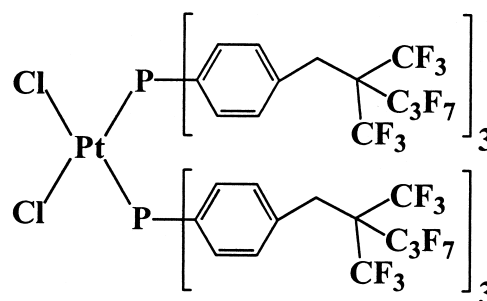
Results and Discussion

A series of seven fluorinated organic compounds were originally synthesized for use in the purification of solution phase parallel synthesis [5]. These compounds have a general structure of $R_3\text{Si}(\text{CH}_2)_3\text{N}(R')(\text{CH}_2)_3\text{SiR}_3$, where $R = \text{CH}_2\text{CH}_2\text{C}_6\text{F}_{13}$ is a perfluorinated substituent and R' could be one of the seven different functional groups in Scheme 1. The molecular weights of these compounds ranged from 2237 to 2417 Da.

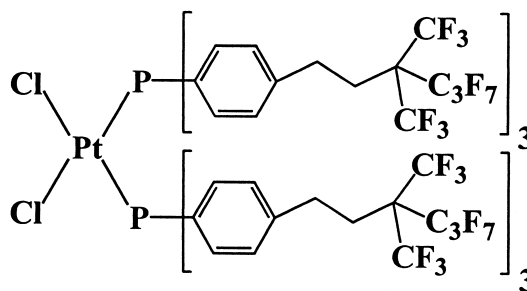
The initial mass calibration was achieved using Ultramark as a reference standard. The EI spectra of these compounds show a series of intense, singly charged ion peaks with good distribution over the entire mass range. The parent molecular ions M^+ and their fragments, $(M - F)^+$, $(M - \text{CF}_3)^+$, $(M - R')^+$, and $(M - \text{CH}_2\text{CH}_2\text{Si}[\text{CH}_2\text{CH}_2\text{C}_6\text{F}_{13}]_3)^+$, $(M - \text{CH}_2\text{CH}_2\text{C}_6\text{F}_{13})^+$, were most abundant. The high volatility of these fluorinated compounds, ease of their synthesis, and distribution of ion peaks with high intensities led us to explore them as calibration standards for positive EI-MS. The mass difference between adjacent fragments typically ranged from 19 Da (loss of F) to 347 Da (loss of $-\text{CH}_2\text{CH}_2\text{C}_6\text{F}_{13}$) for individual compounds. In order to increase the number of mass ions observed and the



Sample 8



Sample 9



Sample 10

Scheme 2

periodic distribution of peaks, we have developed a mixture of fluorinated compounds with symmetrical and unsymmetrical fluorinated R chains ($-\text{CH}_2\text{CH}_2\text{C}_6\text{F}_{13}$ and $-\text{CH}_2\text{CH}_2\text{C}_8\text{F}_{17}$) for use as a new calibration standard. The molecular weights of these three compounds are 2333, 2633, and 2933 Da, allowing calibration up to 3000 Da. Figure 1 shows chemical structures and a single-scan mass spectrum, in the positive EI mode, of the proposed calibration mixture. Table 1 lists the fragment ions observed along with their elemental composition and calculated accurate masses. In contrast to Ultramark, this calibration mixture showed no significant chemical noise after its use.

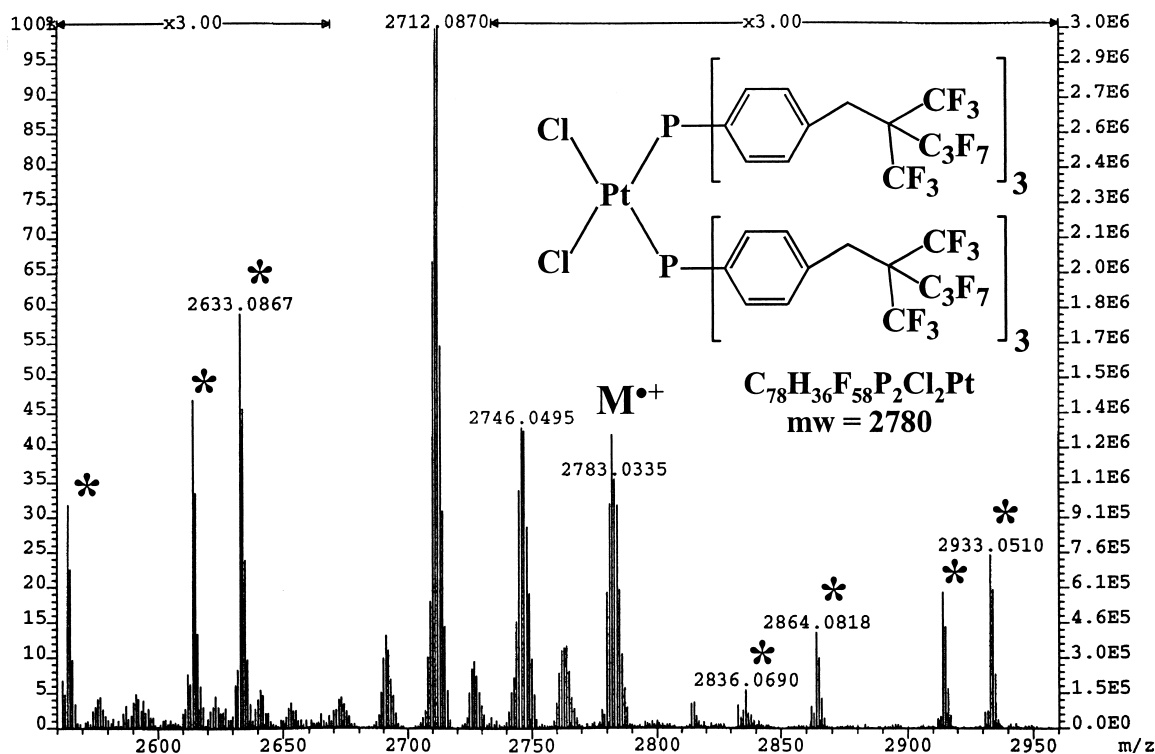


Figure 2. Computerized positive EI voltage scan mass spectrum (average of eight scans) of Sample 9 (above, from Scheme 2 using the new calibration standard obtained at a resolution of 7000 (10% valley). Asterisks indicate reference peaks.

All seven compounds (1 to 7) were re-examined using the new calibration standard. The results are correlated well with those that were obtained with the Ultramark reference compound calibration.

The accurate mass measurements were performed on three synthetic compounds containing platinum and several fluorinated chains. The chemical structures of these compounds are shown in Scheme 2. For these measurements, the unknown and the reference mixture were introduced simultaneously through the direct insertion probe. The results were obtained by a linear voltage scan over a narrow mass range that included reference masses bracketing the ion(s) of interest. The exact masses for the reference peaks were assigned using the peak centroid mode and the accurate masses

were obtained for the analyte peaks using the mass spectrometer data system. A typical computerized voltage scanning result, obtained for Sample 9 (in Scheme 2) at 7000 resolution (10% valley), is presented in Figure 2. Table 2 summarizes accurate mass measurements of these synthetic compounds. An error of less than 5 ppm was obtained by utilizing the new calibration mixture as an exact mass internal standard in the EI positive mode.

Conclusion

The new fluorinated compound mixture has been successfully used as a reference standard in the mass range of 100–3000 Da in positive ion EI-MS. This mixture has several of the attractive properties necessary for a calibration standard: volatility, uniform abundant ion distribution over the entire mass range, and absence of any memory effect. Accurate mass measurements can be made using the new calibration mixture with errors less than 5 ppm. This standard has been successfully and routinely used in our laboratory for more than a year. The procedure to synthesize these standards is relatively simple. Further synthetic developments such as addition of different functional groups and/or extension of fluorinated chains could extend the upper mass limit beyond 3000 Da.

Table 2. Accurate mass measurement results using computerized voltage scan procedure utilizing the new reference standard^a

Sample	M ⁺ (Da), observed	Error Δ, (Da) ^b	Error (ppm)	Elemental composition of M ⁺
8	2116.039	−0.008	−3.8	¹² C ₆₄ ¹ H ₃₄ ¹⁹ F ₅₂ ³¹ P ₂ ³⁵ Cl ₂ ¹⁹⁴ Pt
9	2780.016	−0.011	−4.0	¹² C ₇₈ ¹ H ₃₆ ¹⁹ F ₇₈ ³¹ P ₂ ³⁵ Cl ₂ ¹⁹⁴ Pt
10	2865.106	−0.005	−1.7	¹² C ₈₄ ¹ H ₄₈ ¹⁹ F ₇₈ ³¹ P ₂ ³⁵ Cl ₂ ¹⁹⁵ Pt ^c

^aResolution = 7000.

^bΔ = calculated mass − measured mass.

^c¹⁹⁵Pt was chosen because of the interference with 2864 reference peak.

Acknowledgments

We thank Q. Zhang for the samples of platinum complex compounds and Professor J. J. Grabowski for useful discussions. We also gratefully acknowledge the support of the National Science Foundation in carrying out these studies.

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