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How sensitive and accurate are routine NMR and MS measurements?

Andrey M. Tsedilin, Artem N. Fakhrutdinov, Dmitry B. Eremin, Sergey S. Zalesskiy, Alexander O. Chizhov, Natalya G. Kolotyrkina, and Valentine P. Ananikov

CONTENTS

Experimental section

Sample preparation and measurements.

Initial 0.1 M solutions of the model compounds were prepared in DMSO-d_6; all subsequent concentrations were prepared by successive tenfold dilutions of the initial solutions with a suitable solvent – DMSO-d_6 for the NMR studies and acetonitrile for the MS studies. Acetonitrile (HPLC grade) was ordered from Merck, and DMSO-d_6 was ordered from Cambridge Isotope Laboratories, Inc. Aliquot sampling was conducted using Hamilton syringes.

For statistical averaging, all experiments (including the sample preparation as well as the NMR, EI-MS and ESI-MS measurements) were carried out multiple times, and all were in a good agreement.

NMR Measurements.

^{1}H and ^{13}C NMR spectra were measured on Bruker DRX 500 MHz and Bruker Avance II 600 MHz instruments.

Avance II 600 MHz was equipped with a 5 mm BBO probe for all concentrations with acquisition time set to 4.09 s, spectral width set to 20 ppm, O1 set to 4.8 kHz for the ^{1}H spectra and acquisition time set to 1.36 s, spectral width set to 240 ppm, O1 set to 16.6 kHz for the ^{13}C{^{1}H} spectra. DRX 500 MHz was equipped with a 5 mm BBO probe for concentrations of 10^{-1} – 10^{-3} M, and a 5 mm BBI probe for lower concentrations with acquisition time set to 3.28 s, spectral width set to 20 ppm, O1 set to 4.0 kHz for ^{1}H spectra and acquisition time set to 1.08 s, spectral width set to 241 ppm, O1 set to 13.2 kHz for ^{13}C spectra.

^{1}H spectra were recorded using a zg30 pulse program with the number of scans set to 32 and a relaxation delay set to 7 s. ^{13}C{^{1}H} NMR spectra were recorded using a zgpg30 pulse program with the number of scans set to 1024 and a relaxation delay set to 0.6 s. Exponential weighting was applied to the FID, with line broadening factor set to 0.3 for ^{1}H and 2.0 for ^{13}C{^{1}H}. Residual proton (δ = 2.5) and carbon (δ = 39.5) signals of DMSO-d_6 were used as internal standard for referencing. All spectra were obtained at 303 K. The spectra were processed using Bruker Top Spin 3.2b software package.

EI-MS Measurements.

Mass spectra were measured on Agilent 5977A quadrupole instrument, using electron ionization (EI) source with sample injection *via* Agilent 7890 gas chromatograph. External calibration was performed with PFTBA (MS grade, Synquest Laboratories) in automatic mode. Measurements were performed in full-scan (scan range from *m/z* 50 to *m/z* 300, 6.7 scans/s) and

SIM (dwell 25 ms/mass) modes with ionization energy set at 70 eV, source temperature set at 230°C and transfer capillary temperature set at 310°C. Separation was carried out on Agilent HP-5ms fused silica capillary column (30 m length; 250 μm I.D.; 0.25 μm film thicknesses, (5% Phenyl)-methylpolysiloxane) using He (7.0 grade, NII KM) as carrier gas with flow set at 1 mL/min. Temperature program was started at 60°C and fixed for 4 min, then increased at a rate of 10ºC/min to 240ºC. It was next increased at a rate of 35°C/min to 310°C and held for 6 min. Injection port temperature was set at 310°C and operated in split mode at 10:1 ratio with sample injection volume of 1 μl. The spectra were processed using Agilent MassHunter B.06.00 software package.

ESI-MS Measurements.

High-resolution mass spectra were measured on Bruker maXis and Bruker micrOTOF II instruments using electrospray ionization (ESI) in MS mode. Measurements were performed in positive ion mode with interface capillary voltage set at 4.5 kV. "Tune wide" method optimized for scan range from *m/z* 250 to *m/z* 1000 was used. External calibration was performed with Electrospray Calibrant Solution (Agilent Technologies). Direct syringe injection was used for analyzed solutions in acetonitrile at flow rate of 3 μL/min. The MS spectra were acquired for 1 min. Nitrogen was applied as dry gas, interface temperature was set at 180°C. The spectra were processed using Bruker Data Analysis 4.0 software package.

Signal-to-noise ratios.

For NMR, the signal was considered to be of «high» quality if the S/N value was higher than 300, «good» quality for signals with S/N of 30–300 and «poor» quality for S/N lower than 30.

For GC-EI-MS, the signal was considered to be of «high» quality if the S/N was on the order of 10^2 or higher for the corresponding chromatography peaks (with the total ion current in full-scan mode, and the sum of ion currents in SIM mode), of «good» quality on the order of 10, and of «poor» quality on the order of 1. For concentrations of 10^{-3} M and higher, direct sample injection is fraught with a fast failure of the ionization source and the electron multiplier; therefore, high concentration solutions should be diluted to 10^{-3} M.

For ESI-MS, the S/N criteria were set as «high» for an order of 10^5 and higher, «good» for 10^4 – 10^3 and «poor» for 10^2 and lower. Similarly to EI, high concentration samples should be diluted to 10^{-5} M.

Representative NMR spectra at different concentrations

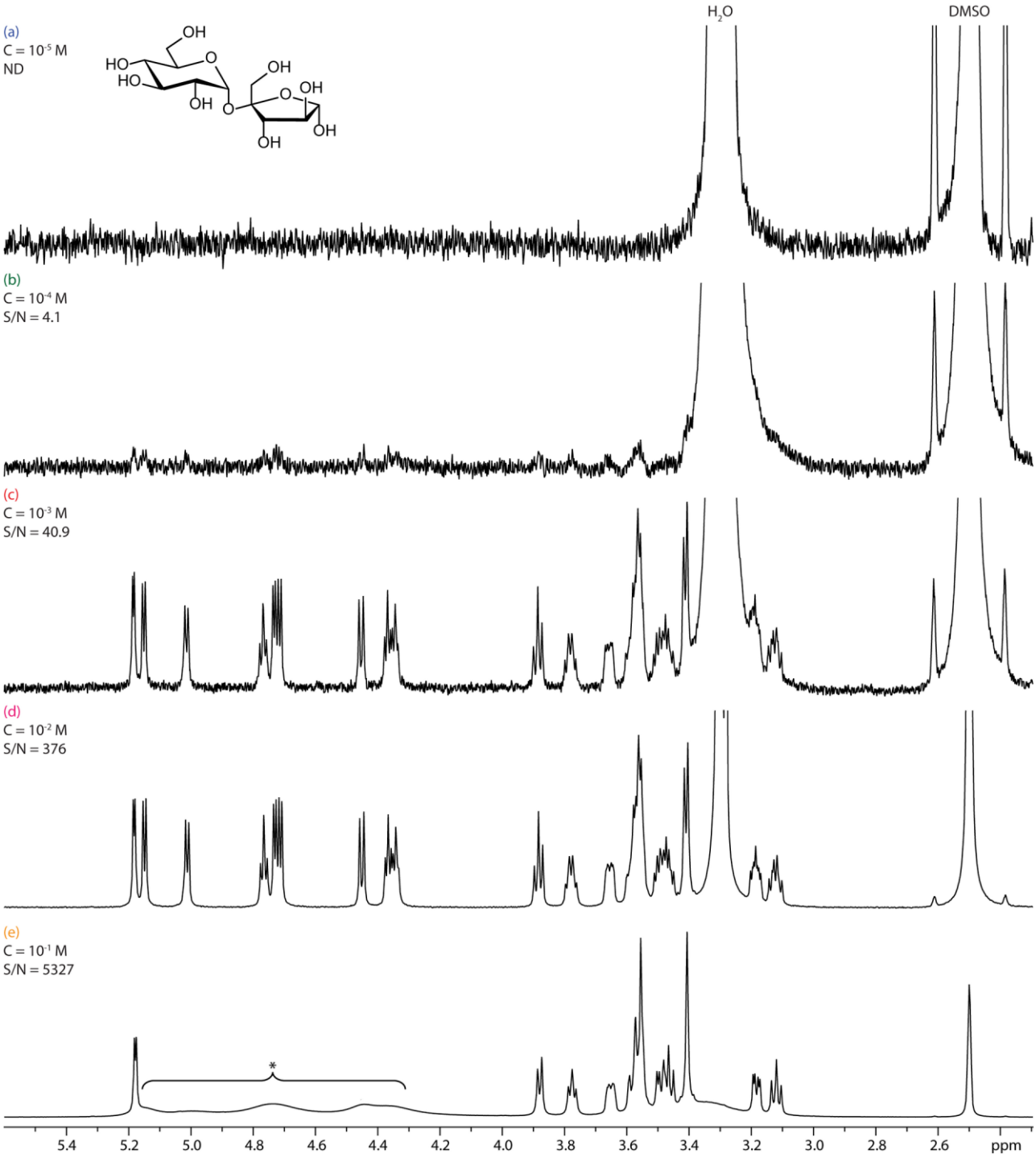

Figure S1. ^{1}H NMR spectra of solutions of sucrose in DMSO-d_6 with increasing concentration: 10^{-5} M – signals not detected (a), 10^{-4} M – poor (b), 10^{-3} M – good (c) and 10^{-2} – 10^{-1} M - high (d,e) signal quality (600 MHz, 303 K). Signal to noise ratio (S/N) is indicated in each case. Broadening of the signals of OH groups (marked by ∗) is due to high sample concentration (e).

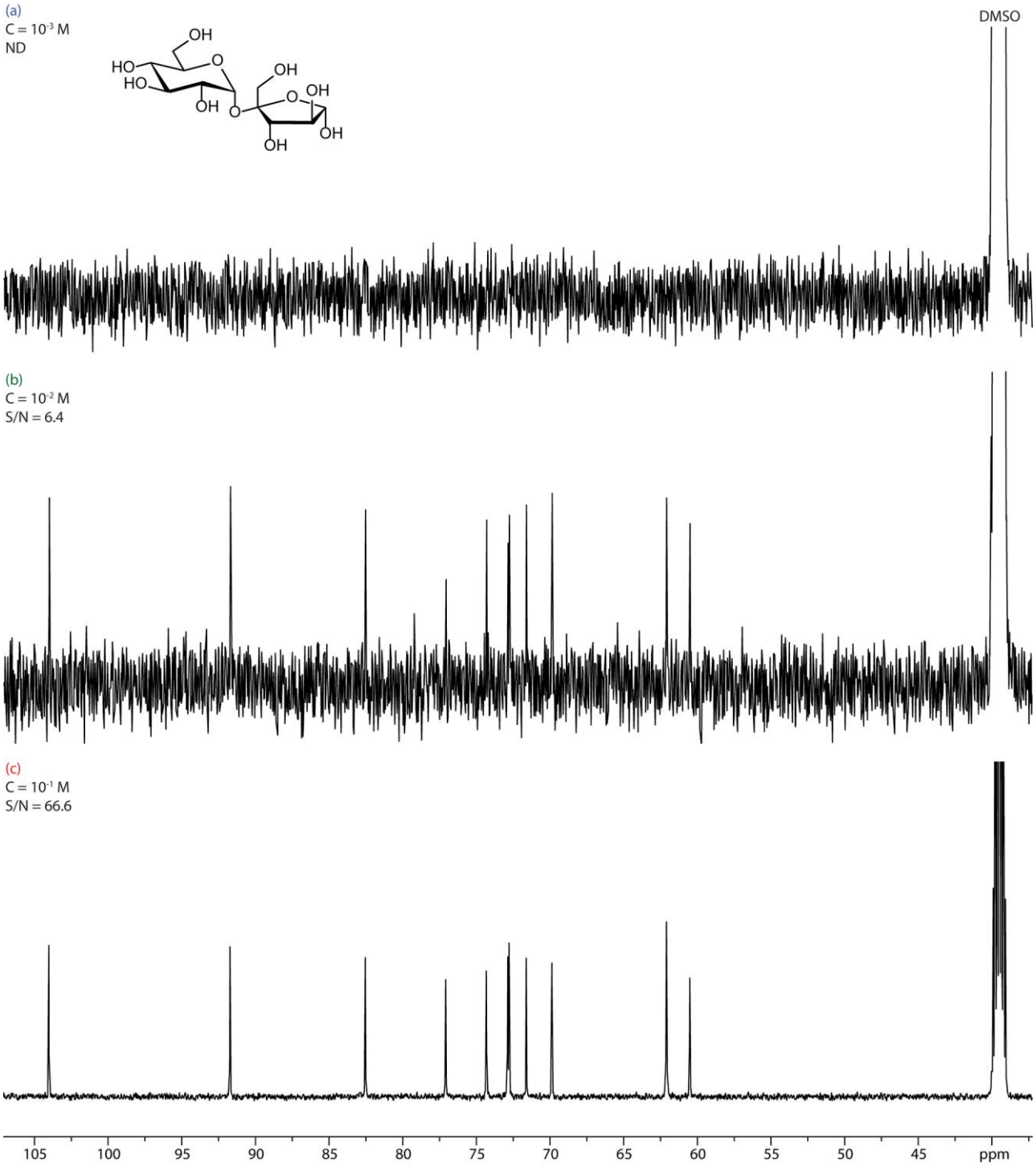

Figure S2. $^{13}C\{^{1}H\}$ NMR spectra of sucrose solutions in DMSO-d_6 with ND (a), poor (b) and good (c) signal quality (150 MHz, 303 K).

Representative GC-EI-MS spectra at different concentrations

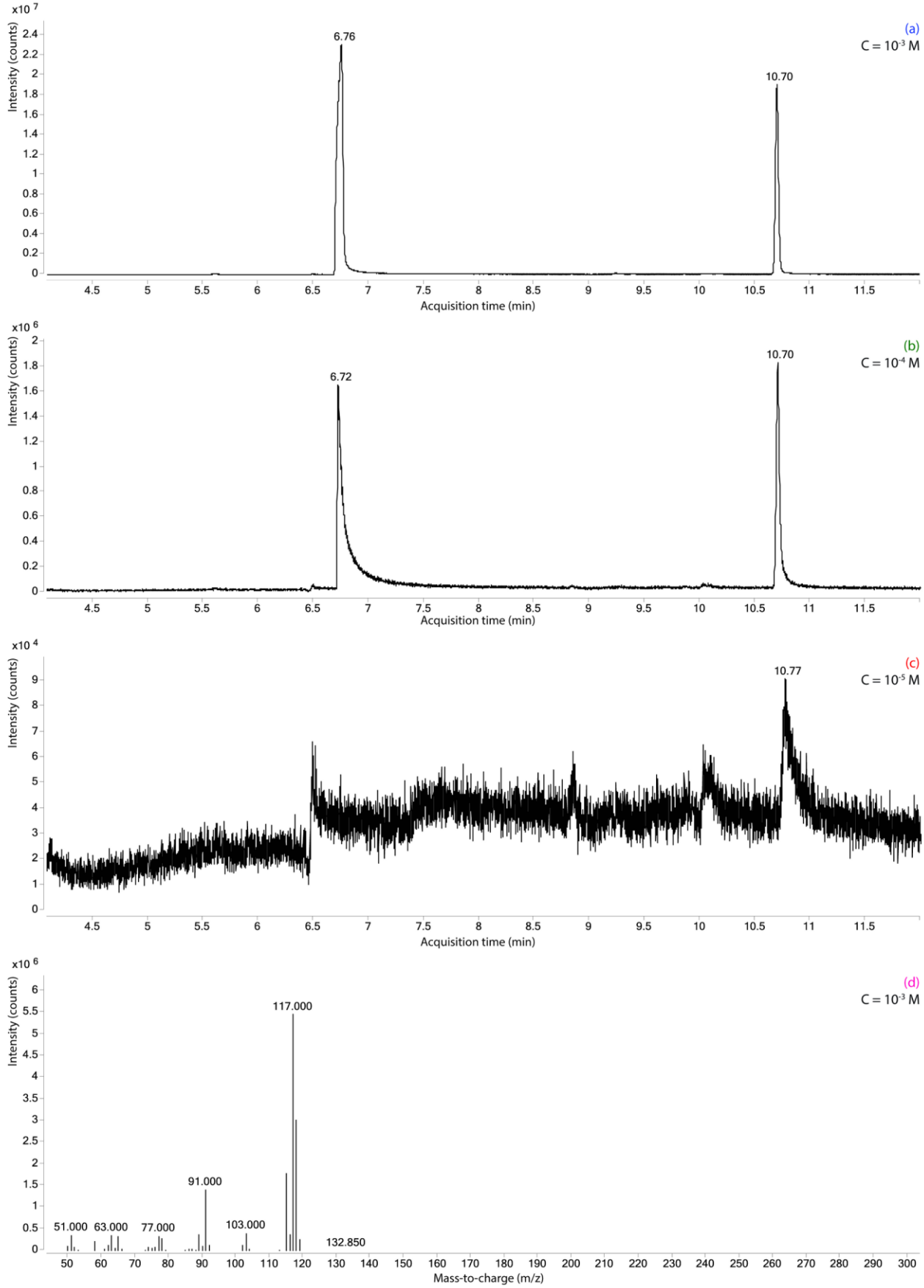

Figure S3. Total ion current (TIC) chromatograms of cyclopropylbenzene with high (a), good (b) and poor (c) signal quality and the mass spectrum (d). Peak at 6.72 min corresponds to DMSO-d_6.

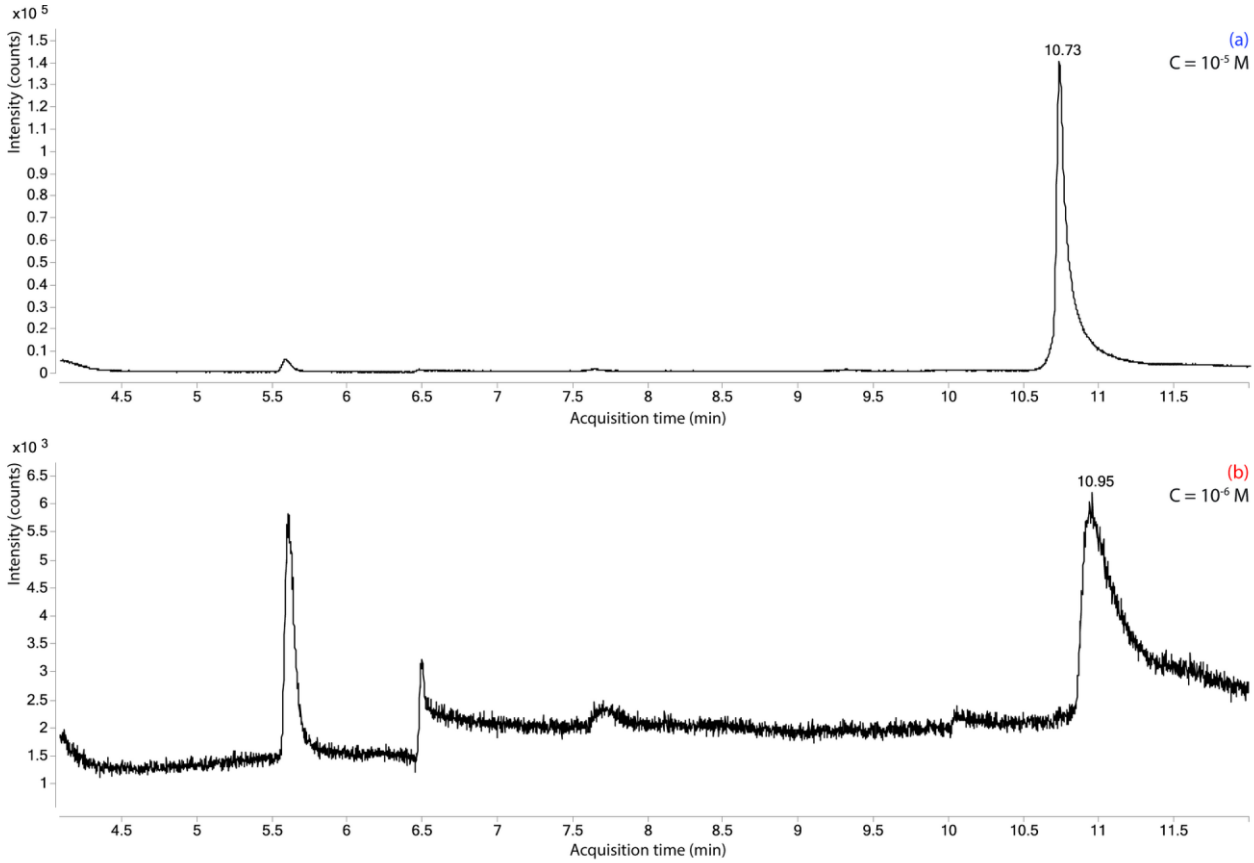

Figure S4. Selected ion monitoring (SIM) chromatograms of cyclopropylbenzene with high (a) and good (b) signal quality. Monitored ions: m/z 91, 155, 117 and 118.

Representative ESI-MS spectra at different concentrations

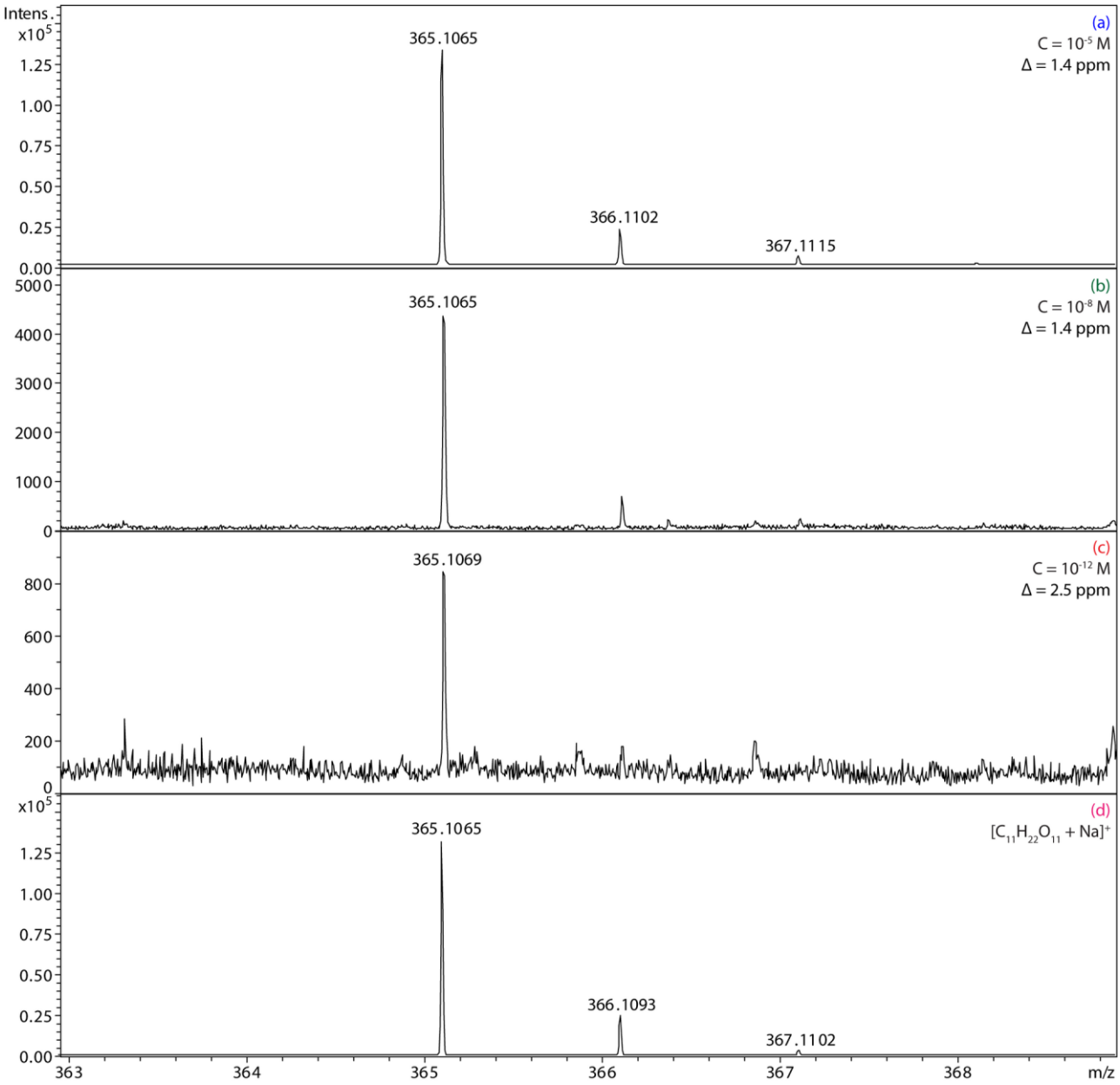

Figure S5. ESI mass spectra of sucrose with high (a), good (b) and poor (c) signal quality and the calculated mass spectrum (d).

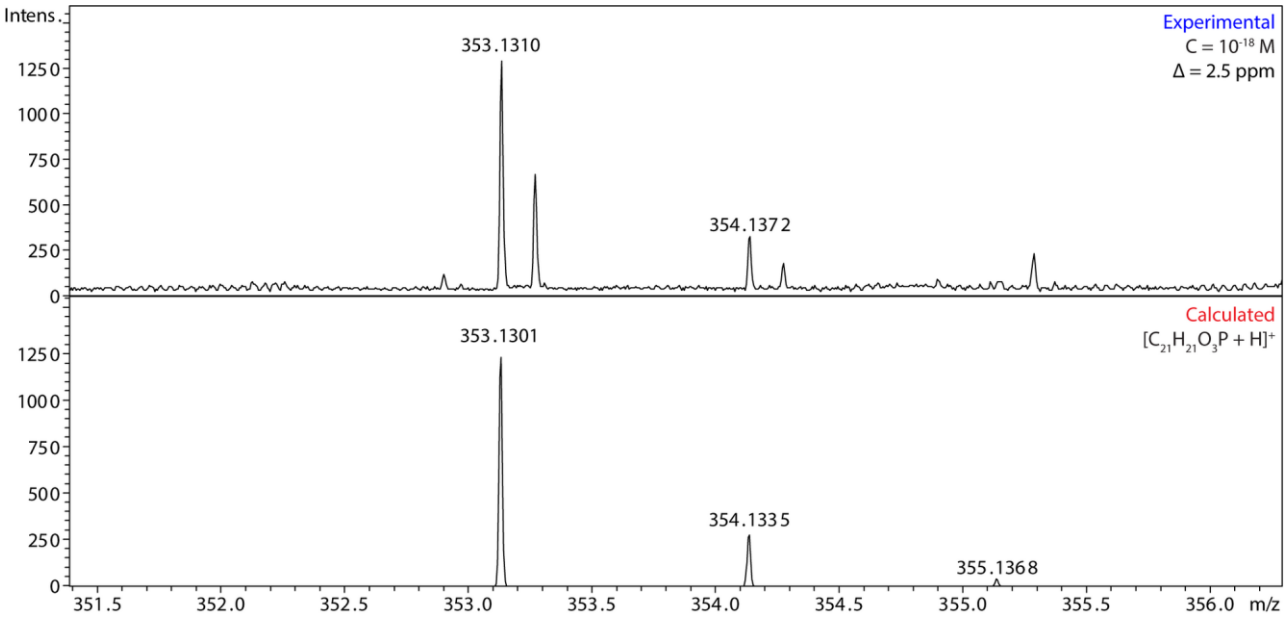

Figure S6. ESI mass spectrum of tris(*p*-methoxyphenyl)phosphine solution with 10^{-18} M concentration.