

Optimizing Mobile Phase Solvent Purity for LCMS

Thermo Fisher Scientific

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This paper presents comparative chromatographic data from four different instruments for LCMS solvents offered by seven vendors. Data collected examine mass baseline, signal intensity, contamination by PEG and phthalates (plasticizers), and metal ion content which impacts ease of MS interpretation.

Methods and Instrumentation

Experiment I was conducted at two Thermo Fisher Scientific sites (Fair Lawn, NJ and Cambridge, MA, USA).

Introduction

In the life sciences, from biomarker discovery to metabolomics, investigators frequently study molecules requiring analysis in trace amounts (femtomole range). Liquid chromatography mass spectrometry (LCMS) has gained broad usage in this research because the technique supports qualitative and quantitative applications with low limits of detection. For example, many clinically relevant biomarkers such as parathyroid hormone and prostate specific antigen are present in blood at concentrations of nanograms per milliliter.

Improving sensitivity and mass accuracy in LCMS is an ongoing process. As instrumentation advances lead to ever-lower analyte detection limits, an underlying issue is the need to reduce noise—the extraneous peaks caused by solvent background, which limits the ultimate performance of LCMS.

Optimizing the quality of mobile phase solvents can contribute to improving the chromatographic or mass spectroscopic properties of the analyte as well as the overall detection limits of the instrument system (1). Historically, when the LCMS technique was still in development, HPLC-grade solvents were used to prepare the mobile phase. Years later, some investigators still use HPLC-grade solvents to prepare the composition of the mobile phase for LCMS applications. However, solvents designated “HPLC grade” do not meet the stringent purity requirements of the mass spectrometry detector and are best used with LC/UV detectors.

In contrast, solvents designated “LCMS grade” should provide low mass noise level, minimal organic contamination, and minimal metal content to fulfill the high purity need of LCMS. To address this need, Thermo Fisher Scientific, through the Fisher Chemical product line, has developed the Optima® LC/MS solvent grade. These solvents are manufactured using additional purification processes, quality control measures, and packaging innovations in order to meet the required purity level of advanced LCMS systems.

Chromatographic data for the Fisher Chemical Optima LC/MS Solvents (acetonitrile and water) were compared with four other solvent brands using two different instrument systems, a single quadrupole mass spectrometer (Fair Lawn site) and the Thermo Scientific LTQ-FT system (Cambridge site). Each solvent was analyzed with a gradient as a blank injection and also with an angiotensin standard peptide mixture. The objective was to compare background noise and signal intensity of the peptide standards across each vendor’s solvent system as well to look for typical contamination peaks known to be found in these high purity solvents.

For single quadrupole LCMS, an Agilent 1100 Series LC equipped with the Model SL mass spectrometry detector (MSD) was used. μ BondaPak® C18 column with internal diameter 2.1mm and a 300mm length was selected. Pore size for this column’s packing was 10 μ m. Flowrate was 0.425mL/min. The instrument system was equipped with a diode array detector, and electrospray ionization was used in positive and negative modes of the MSD. Scan range was 15 to 1500 m/z, fragmentation voltage 70V, and capillary voltage 3000V.

For hybrid linear ion trap MS analysis, a Thermo Scientific LTQ-FT was used. A column of 0.19mm external diameter (75 μ m I.D.) and 200mm length was packed with Thermo Scientific Hypersil Gold C18 with 5 μ m particle size. Samples were run under the following conditions: m/z range was 250 to 1000, 200K resolution, top 5 configuration with one MS scan and five MS/MS scans, and dynamic exclusion set to 1 with a limit of 90 seconds. 150 femtomole of angiotensin standard mix from Michrom Biosciences was loaded on column per injection. A 2.5 hour LCMS separation was used for all blank and standard samples.

Mobile phase solvents acetonitrile and water were obtained from four vendors, and in the figures/tables these are referred to as vendor J, R, E, and H. These were compared with Fisher Chemical Optima LC/MS Acetonitrile (A955) and Water (W6). Various LC gradients were utilized in the two chromatographic systems.

Experiment II was conducted at three Thermo Fisher Scientific sites (Fair Lawn, NJ, USA; Courtaboeuf, France; and Breda, The Netherlands).

Chromatographic data for Fisher Chemical Optima LC/MS Solvents (A456 Methanol, W6 Water, and A955 Acetonitrile) were compared with two other solvent brands (referred to as vendor X and B) using three instrument systems each having a different limit of detection. Similar to the first experiment, the objective was to compare solvent baseline noise as well as the signal intensity of MS standards across each vendor's solvent system. Operating conditions for the LC and MS of each instrument system are provided in Table 1.

	Courtaboeuf, France		Breda, The Netherlands		Fair Lawn, NJ USA
MS System	LTQ Orbitrap XL		TSQ Vantage (Triple Quadrupole)		Agilent 1100 Single Quadrupole
HPLC System	Bypass		Accela UPLC		Conventional-DAD
Type of Column	Direct to Mass		Hypersil Gold 50mm x 2.1mm ID x 1.9 µm particle size		µBondaPak® C18 300mm x 2.1mm
Flow Rate	0.5mL/min.		0.4 mL/min.		0.425 mL/min.
Mass Range	50 to 800 m/z		Pos-Precursor 230.2; Neg-Precursor 213.1		15 to 1500 m/z 200 to 1500 report
Gradient Profile	A%(Aqu) B%(Solv)		A%(Aqu) B%(Solv)		A%(Aqu) B%(Solv)
0	100	0	95	5	Various
2 min.	100	0	10	90	
15 min. (3 min.-Breda)	0	100	10	90	
17 min. (3.01min.-Breda)	0	100	95	5	
17.1 min. (4 min.-Neth)	100	0	95	5	

Table 1. Primary operating conditions of LC and MS used in each instrument system in Experiment II.

Results

When selecting solvents from a vendor to use in an LCMS mobile phase, the chromatographer should consider five fundamental factors related to solvent purity: (1) the level of baseline noise, (2) the extent of LC/UV impurities, (3) the degree of signal intensity from standard analytes, (4) the degree of contamination with phthalates (plasticizers), and (5) the metal ion content.

Experiment I.

Baseline Noise and LC/UV Impurities. Many LCMS systems are equipped with diode array detection (UV/VIS). At 210nm Fisher Chemical acetonitrile provides a flat baseline and very low LC/UV noise (Fig. 1), which is important in proteomics applications.

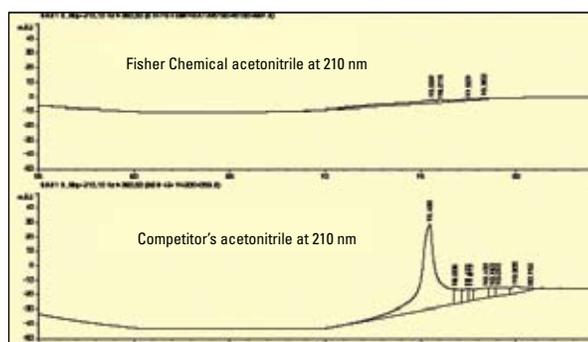


Fig. 1. Top panel shows a typical LC/UV baseline for Fisher Chemical acetonitrile (A955) compared with a competitor's acetonitrile in the bottom panel. Single peak height approximates ≤ 2 mau in A955. The competitor's material shows a large impurity peak (60 mau) at 75 minutes, and its baseline is more "curved" than the baseline for A955.



Figures 2 and 3 show that the Fisher Chemical acetonitrile/water mobile phase produces the lowest mass background in positive and negative TIC modes using the single quadrupole LCMS system. Moreover, analysis by LTQ-FT indicates that regardless of the retention region of the LCMS gradient, the average TIC

intensity is lowest for Fisher Chemical's acetonitrile/water system (Fig. 4 and Table 2). This is especially true for the organic region with Optima LC/MS Acetonitrile (A955) providing significantly less background compared to other brands.

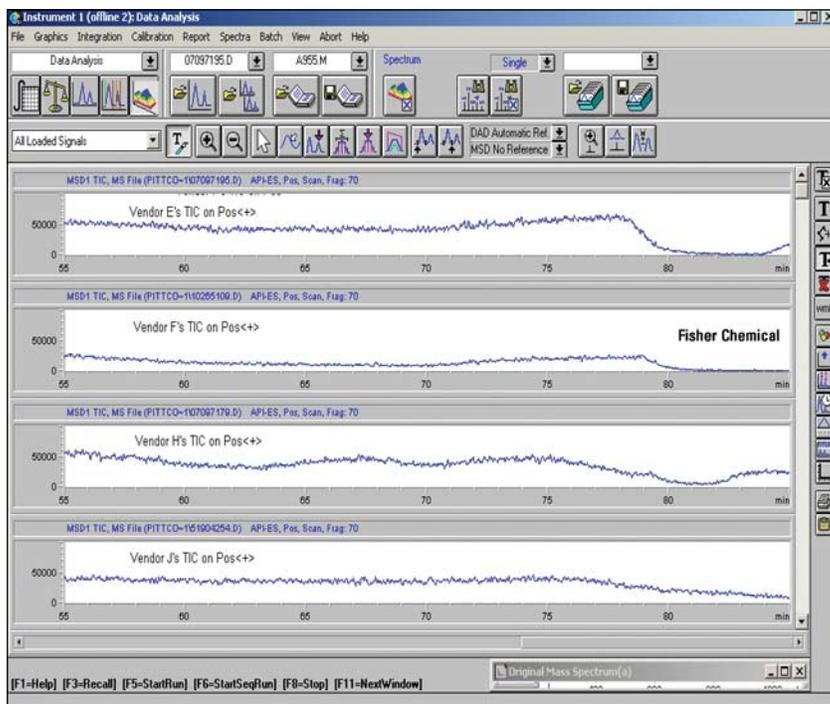


Fig. 2. Mass background in positive mode of blank solvent sample using single quadrupole LCMS. Observe that the Fisher Chemical acetonitrile/water mobile phase consistently produced the lowest background noise in TIC compared to other brands.

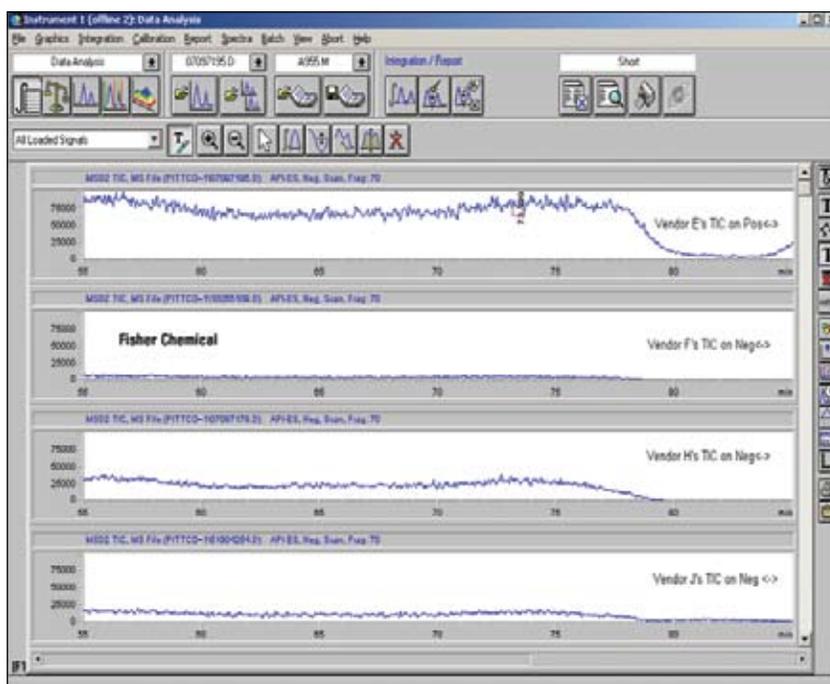


Fig. 3. Mass background in negative mode of blank solvent sample using single quadrupole LCMS. Note that the Fisher Chemical solvent system produced the flattest baseline and the lowest background noise in TIC.

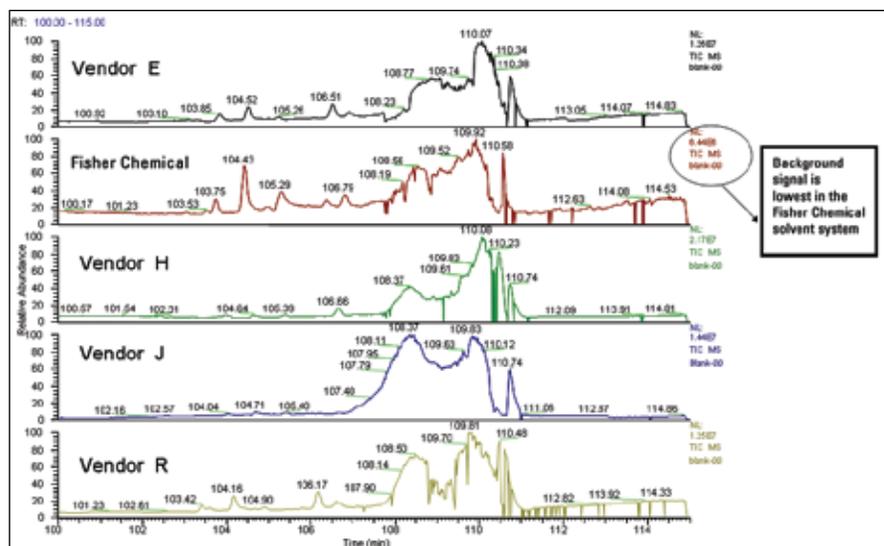


Fig. 4. TIC intensity of blank solvent sample (high organic region) using LTQ-FT.

VENDOR	AQUEOUS	ORGANIC
Vendor J	1.19 e6	1.63 e7
Vendor R	6.98 e5	1.62 e7
Fisher Chemical	6.08 e5	7.85 e6
Vendor E	6.26 e5	1.43 e7
Vendor H	6.15 e5	1.99 e7

Table 2. Average TIC intensity for blank solvent samples (four replicates) using LTQ-FT system. Overall retention time: 0 – 150 min. Aqueous retention time: 15 – 28 min. Organic retention time: 100 – 115 min.

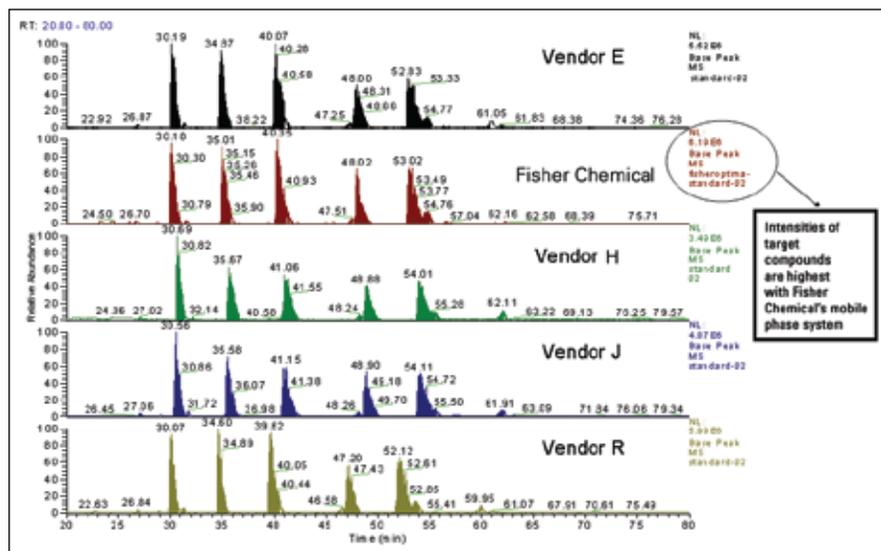


Fig. 5. Base peak intensity for 150 fmole angiotensin peptide standard (LTQ-FT).

Signal Intensity. According to Dolan (2), very often LCMS quantification of an active pharmaceutical ingredient requires precision and accuracy in the 1 – 2% range. For this type of analysis, a large signal intensity of analyte is required. Low background noise contributed by the mobile phase is critical for maximizing signal intensity of target analytes at low

concentration. An angiotensin peptide standard was used as a target analyte to compare signal intensities in mobile phase solvents from different vendors. Figure 5 shows that the highest signal intensity for a 150 fmole angiotensin peptide standard was obtained in the LTQ-FT using the Optima acetonitrile/water system.



Contamination with Phthalates. Phthalates (plasticizers) are contaminants commonly found in mobile phase solvents. Well-known sources of phthalate include lab gloves, plastic bottles and vials, filter paper and even laboratory air containing aerosolized surfactants, fire retardants, and antioxidants. Contamination from common phthalates such as diisooctyl phthalate ($m/z = 391$) and dibutylphthalate ($m/z = 279$) were lowest

in the Optima LC/MS solvent system (Figs. 6, 7). In some cases the Optima LC/MS solvents outperformed other vendors' solvents by an order of magnitude across various contaminating peaks. This degree of purity is particularly important as these contaminants take capacity in the instrument's ion traps as well as affecting the success of performing reproducible chromatography over extended periods of analysis.

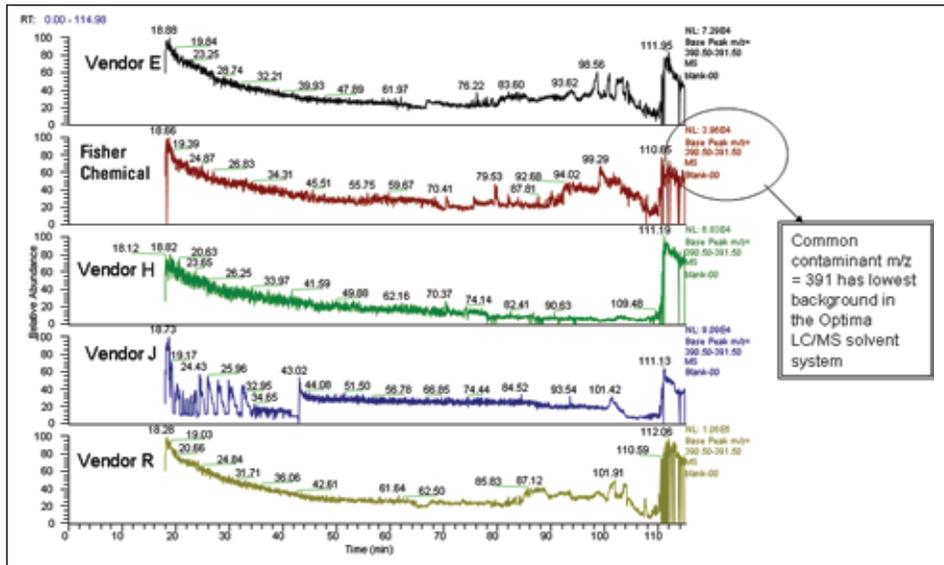


Fig. 6. Comparative data from five solvent systems using the LTQ-FT at $m/z = 391$ ($M + H$)⁺ for diisooctyl phthalate.

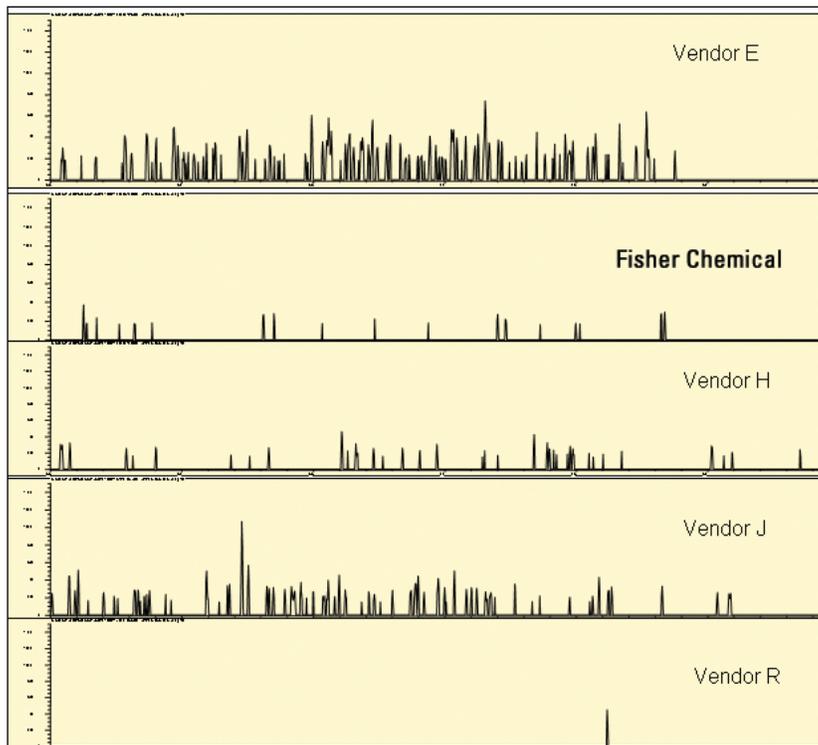


Fig. 7. Comparative data from five solvent systems using the single quadrupole LCMS at $m/z = 391$ ($M + H$)⁺ for diisooctyl phthalate. **Note:** Fisher Chemical's Optima LC/MS mobile phase has less ion interference compared to other vendors.



Metal Ion Content. High metal ion content in the mobile phase enables the formation of mass adducts with target analytes. For example, introduction of alkali metals such as sodium and potassium into the experimental system can further complicate interpretation of results, particularly if quantification is an objective of the study. These metals can also join with phthalates having carboxyl and carbonyl ether or ester groups (3) to form cluster adducts which create problems with reproducibility of results (4). Although a variety of approaches exist for interpretation of data collected in the presence of adducts, limitation of

their presence with the analyte of interest remains an important factor in method development.

Adducts can form when phthalates and alkali metals are present together. Mass spectra from both instrument systems illustrate adduct formation involving diisooctyl phthalate 413 m/z ($M + Na$)⁺ in the various solvent systems (Figs. 8, 9). Thermo Fisher Scientific's Fair Lawn, NJ manufacturing site maintains very effective control over the metal ion content during processing and packaging so that Optima LC/MS solvents have the lowest metal content in the industry (Table 3).

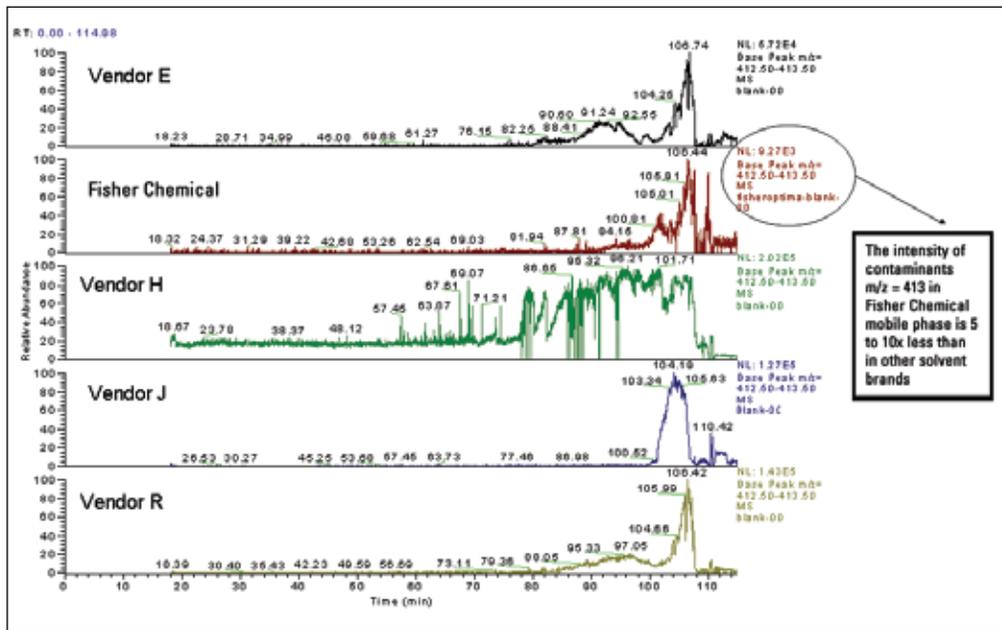


Fig. 8. Adduct formation involving diisooctyl phthalate 413 m/z ($M + Na$)⁺ in the LTQ-FT.

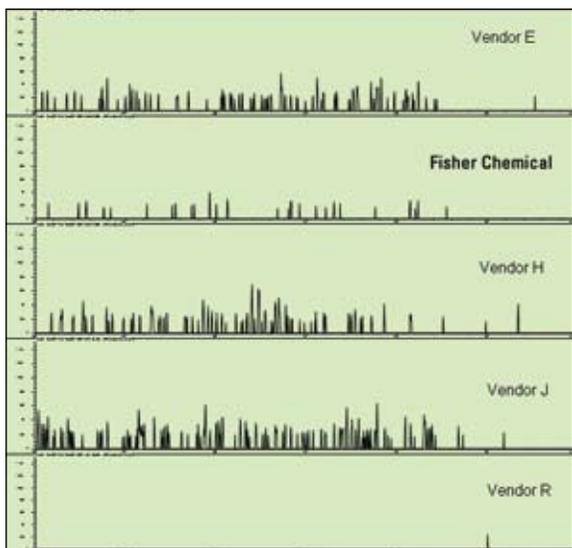


Fig. 9. Adduct formation involving diisooctyl phthalate 413 m/z ($M + Na$)⁺ in the single quadrupole LCMS. Observe that the Fisher Chemical Optima LC/MS solvent system has fewer interfering peaks compared with other suppliers.

SPECIFICATIONS	A955 ACETONITRILE (ppb, max.)	A456 METHANOL (ppb, max.)	W6 WATER (ppb, max.)
<i>Trace ionic impurities</i>			
Aluminum (Al)	25	10	10
Barium (Ba)	5	10	10
Cadmium (Cd)	5	10	10
Calcium (Ca)	25	20	20
Chromium (Cr)	5	10	10
Cobalt (Co)	5	10	10
Copper (Cu)	5	10	10
Iron (Fe)	5	10	10
Lead (Pb)	5	10	10
Magnesium (Mg)	10	10	10
Manganese (Mn)	5	10	10
Nickel (Ni)	5	10	10
Potassium (K)	10	10	10
Silver (Ag)	5	10	10
Sodium (Na)	50	50	20
Tin (Sn)	5	10	10
Zinc (Zn)	10	10	10

Table 3. Trace metal ion impurities in three Optima LC/MS solvents.



Experiment II.

Baseline Noise and LC/UV Impurities. At 254nm Fisher Chemical methanol has a low LC/UV response using diode array detection without any significant

impurity peak (Fig. 10) which is important for various research applications in the pharmaceutical, drug discovery, and life science areas.

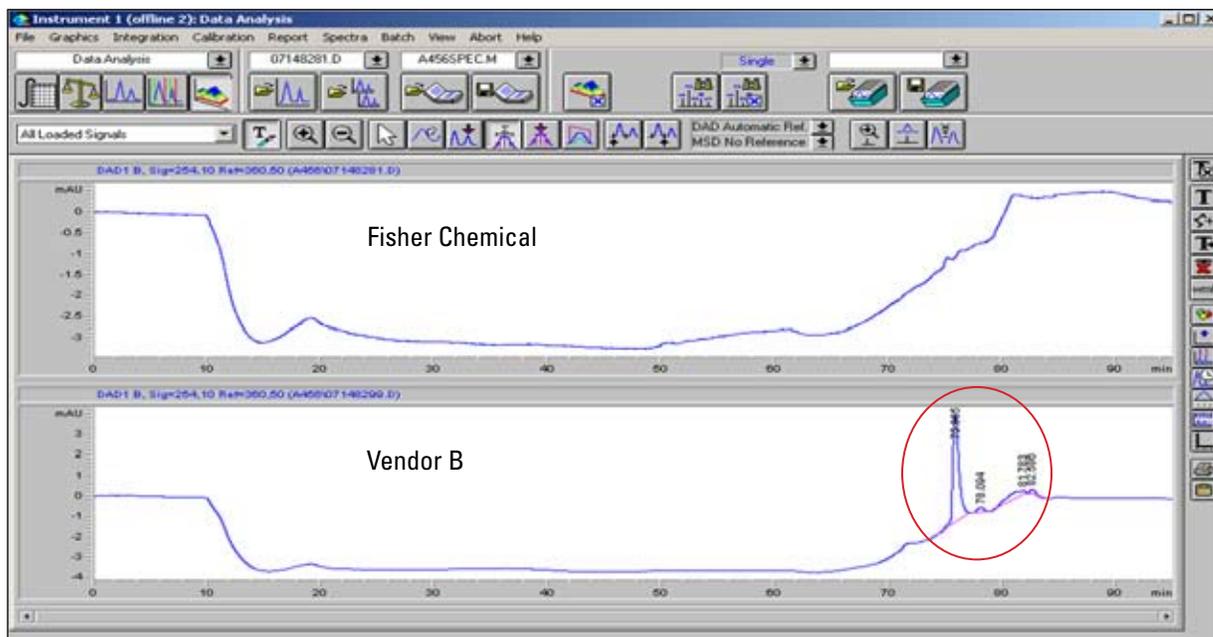


Fig. 10. Top panel shows a typical LC/UV baseline at 254nm for Fisher Chemical methanol (A456) compared to Vendor B methanol in the bottom panel. A significant impurity peak (4mau) is observed at 75 minutes in the Vendor B methanol.

Figures 11 and 12 illustrate that the Fisher Chemical water/methanol mobile phase produces the lowest mass background in positive TIC mode using the Thermo Scientific LTQ Orbitrap XL system. Moreover, the full MS spectrum from 50 – 800 m/z in positive mode shows fewer background peaks with less intensity for

Optima LC/MS water/methanol at end of gradient compared to the other solvent brands (Fig. 13). Similar results are also observed when LCMS instruments operated in TIC negative mode revealed the mass baseline (noise level) lowest for the Optima LC/MS methanol profile compared to other solvent brands (Figs. 14, 15).

TIC / Methanol / Positive Ions

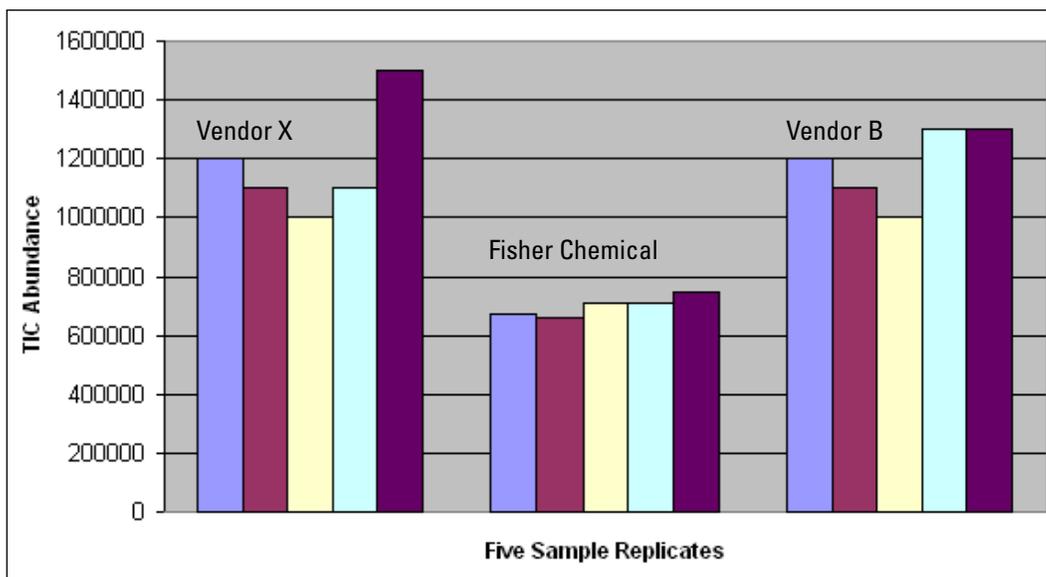
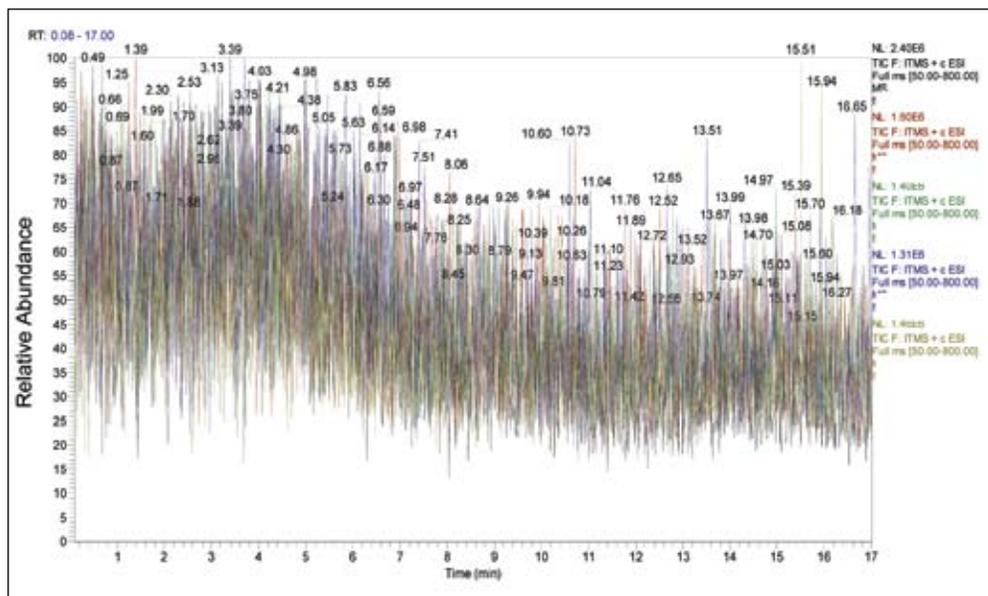
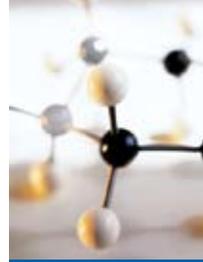
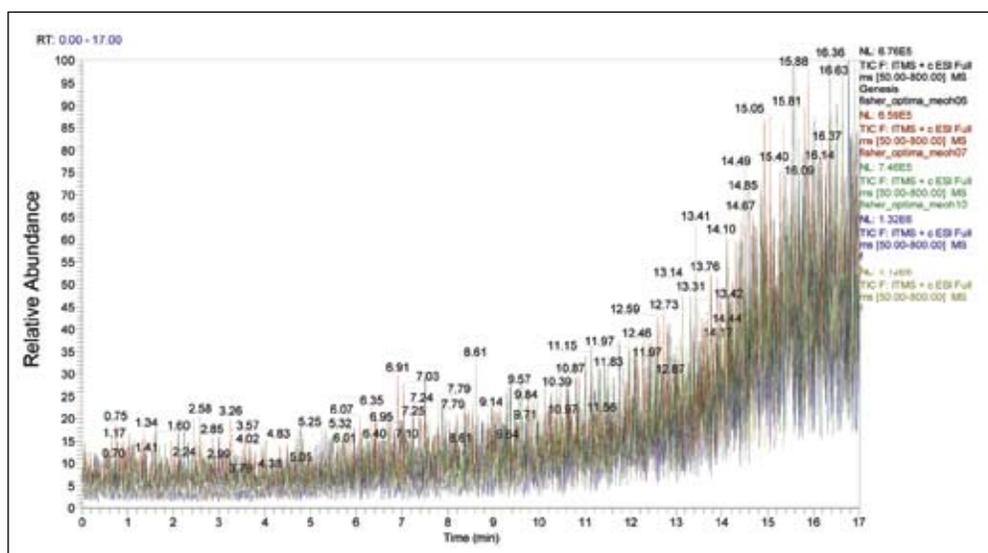


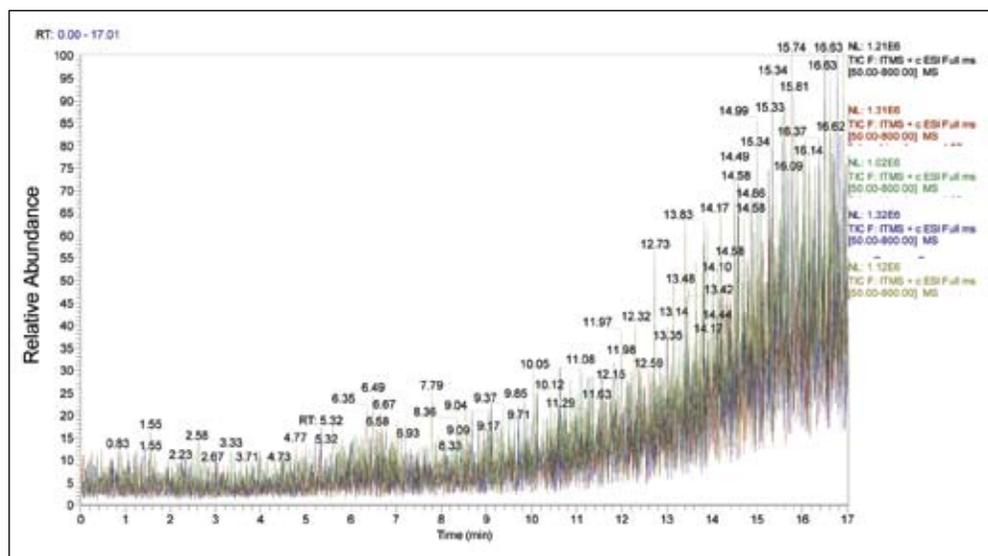
Fig. 11. Mass background in positive mode of blank methanol sample using the LTQ Orbitrap XL. Fisher Chemical methanol profile consistently produced the lowest background noise in TIC compared to the other vendors.



12a.
Vendor X – Water/Methanol gradient, TIC, Positive Ions

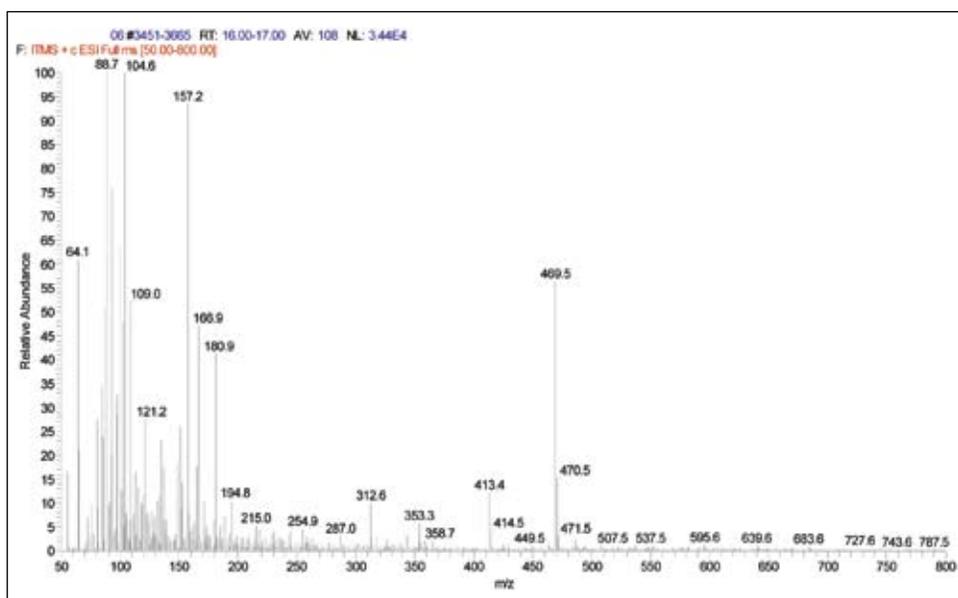


12b.
Fisher Chemical

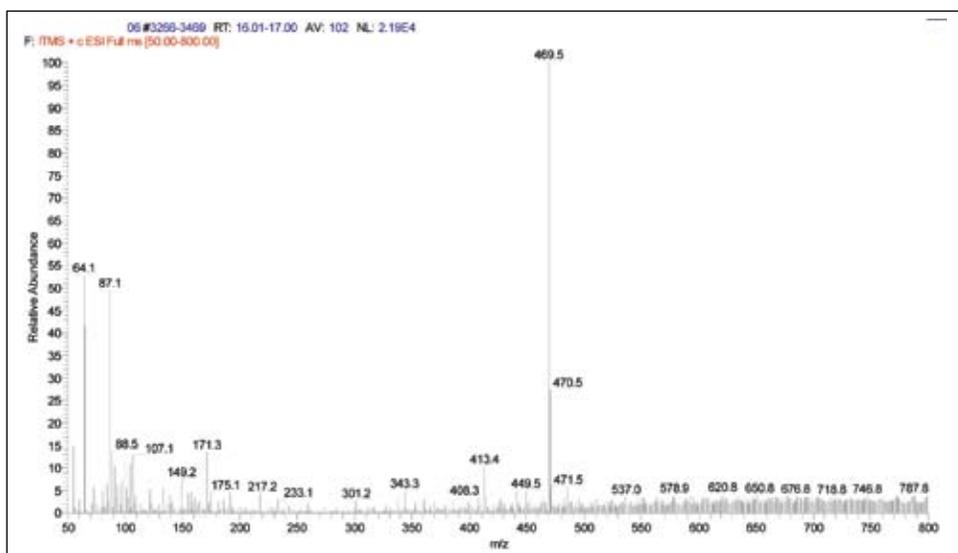


12c.
Vendor B

Fig. 12a-c. TIC intensity for five replicates of water/methanol gradient in positive mode using LTQ Orbitrap XL. Methanol data is summarized by vendor in Figure 11. (a) Vendor X, (b) Fisher Chemical Optima, and (c) Vendor B.



13a.
Vendor X Methanol



13b.
Fisher Chemical Methanol



13c.
Vendor B Methanol

Fig. 13a-c. MS spectrum from 50 – 800 m/z in positive mode using LTQ Orbitrap XL. (a) Full MS scan of Vendor X methanol at end of gradient. (b) Full MS scan of Fisher Chemical Optima methanol (A456). (c) Full MS scan of Vendor B methanol.

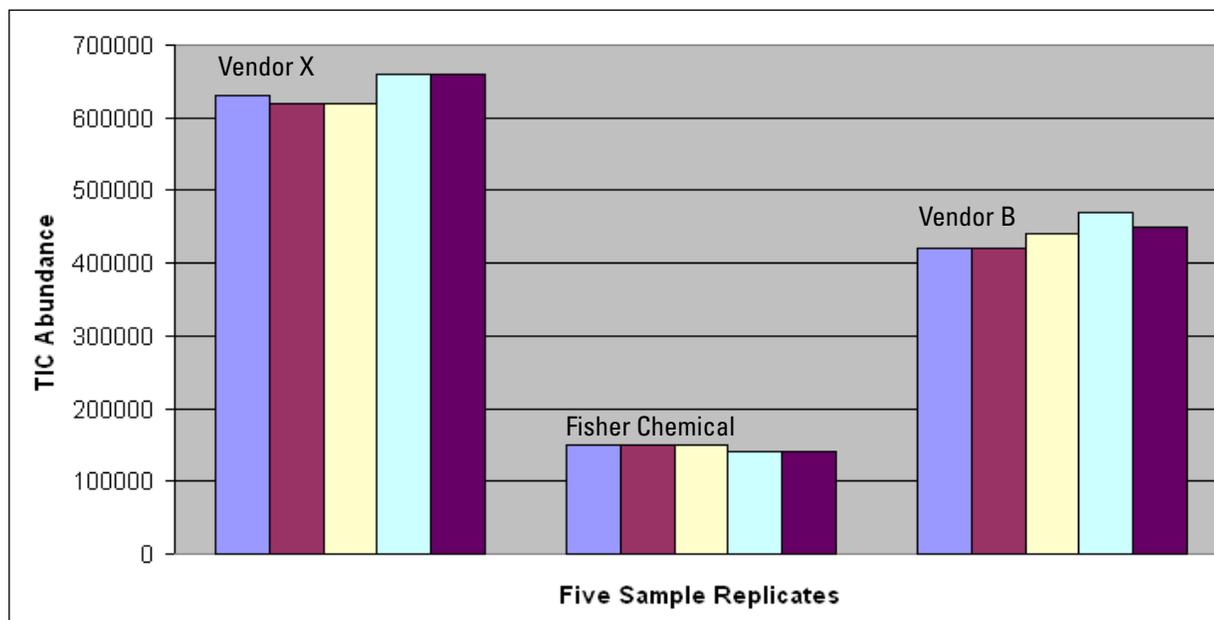


Fig. 14. Mass background in negative mode of blank methanol sample using the LTQ Orbitrap XL. Fisher Chemical methanol profile consistently produced the lowest background noise in TIC compared to the other vendors.

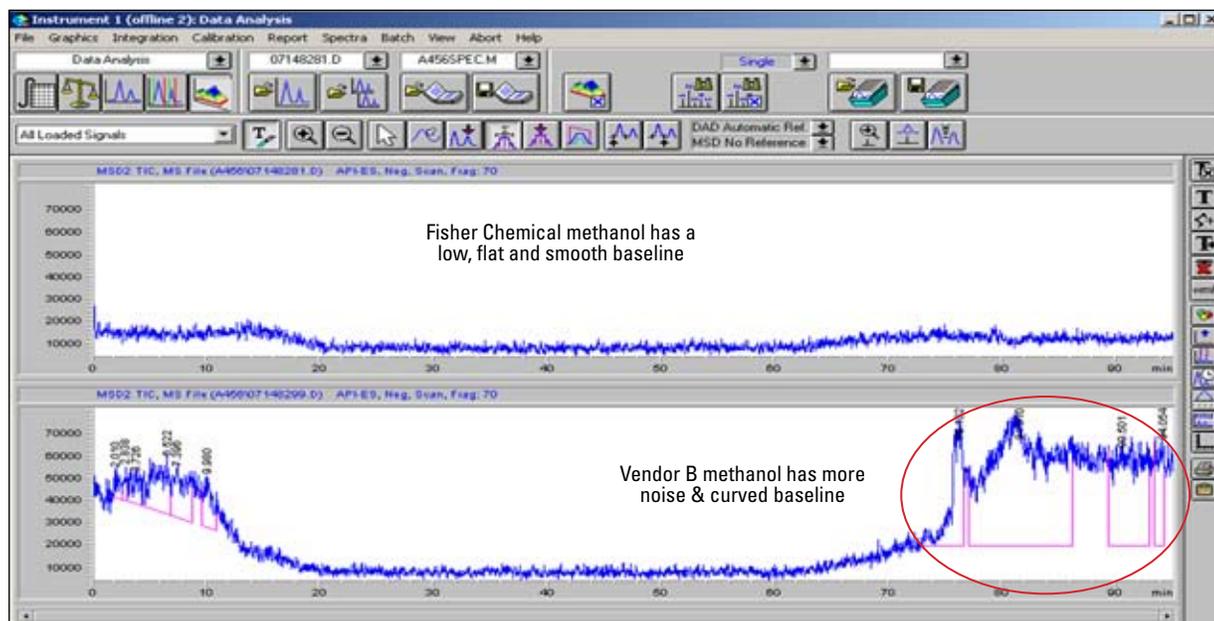


Fig. 15. Mass background in negative mode of blank methanol sample using single quadrupole LCMS. Top panel shows a typical Fisher ChemicalOptima LC/MS methanol (A456) profile displaying low noise and a flat baseline in TIC compared to Vendor B which showed more noise and a curved baseline.

On the other hand, for water/acetonitrile gradients analyzed in TIC negative and positive mode with LTQ Orbitrap, the mass background for water and acetonitrile was similar to Vendor B but significantly lower than Vendor X (data not shown). Nevertheless, the mass spectrum of acetonitrile background in positive mode is about 5x lower for the Optima LC/MS solvent compared to Vendor B using the single quadrupole LCMS (Fig. 16)

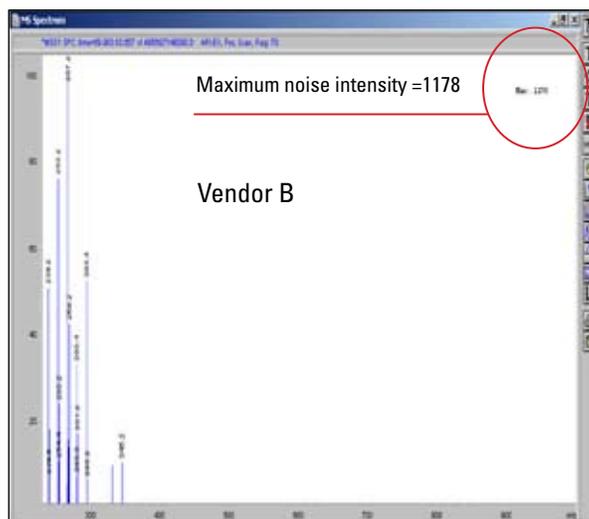
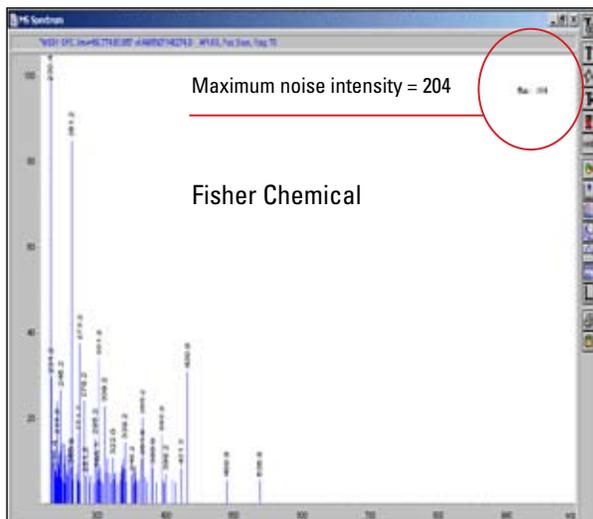


Fig. 16. MS spectrum of acetonitrile background from 200 – 1000 m/z in positive mode using single quadrupole LCMS. **Note** - maximum noise intensity for Fisher Chemical acetonitrile is 5X lower than Vendor B Acetonitrile.

Signal Intensity. In Experiment I, the signal intensity of target compounds was highest with Optima acetonitrile/water system (Fig. 5). Similarly, signal intensity for two different analytes was evaluated in an acetonitrile/water system using the TSQ Vantage MS with the precursor conditions listed in Table 4. For Propazine (CAS # 139-40-2) in the positive mode, a 0.05ng/mL (217 pM) sample showed higher background for Vendor B acetonitrile/water than for the Optima LC/MS solvent pair. Therefore, the signal-to-noise is somewhat better for the Fisher Chemical Optima solvents (Fig. 17). However, a 0.05ng/mL (232

pM) sample of Mecoprop (CAS # 7085-19-0) in the negative mode yielded similar baseline noise for both solvent systems (Fig. 18).

Compound	Polarity	Precursor Mass	S-lens Voltage (V)	Product Mass	Collision Energy (V)
Propazine	+	230.2	69	146.0	23
		230.2	69	188.1	16
Mecoprop	-	213.1	40	141.3	15

Table 4. Precursor conditions for target compounds Propazine and Mecoprop analyzed with TSQ Vantage MS.

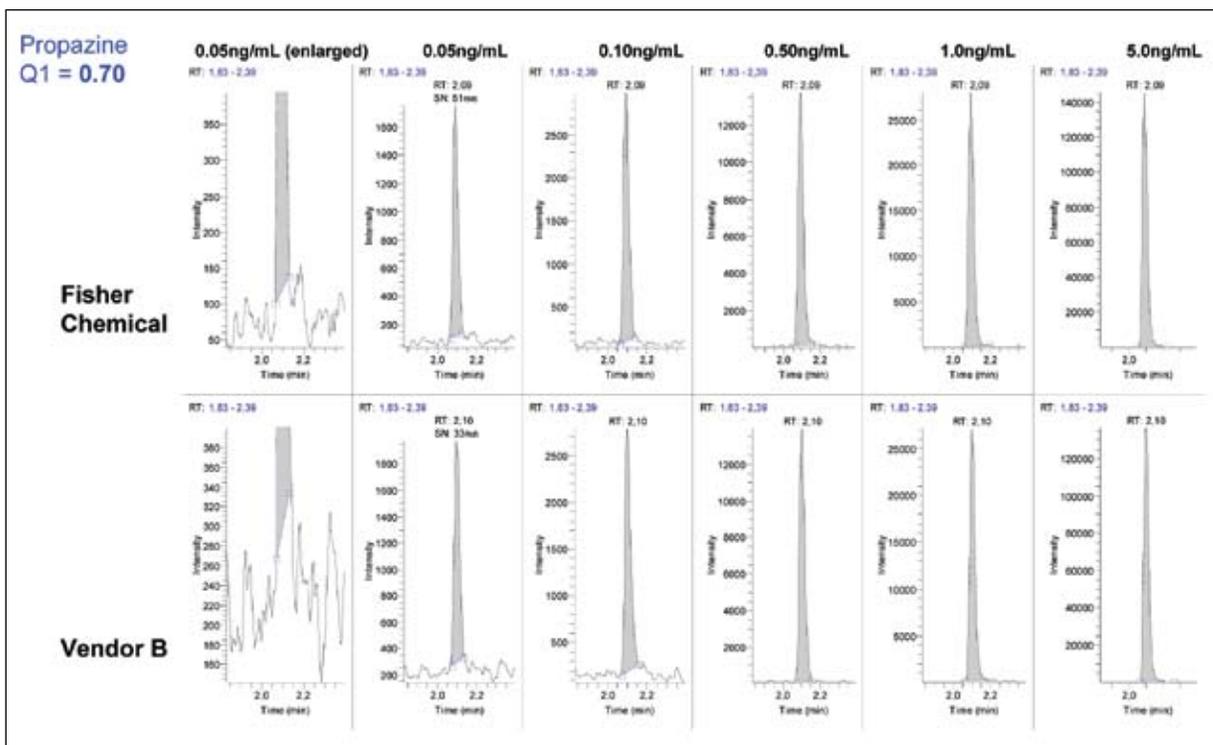


Fig. 17. Signal intensity for Propazine compound in positive mode using TSQ Vantage MS. Background noise is higher for Vendor B acetonitrile/water mobile phase than for the Fisher Chemical Optima solvent pair. Therefore, SN is somewhat better for the Fisher Chemical Optima solvent system.

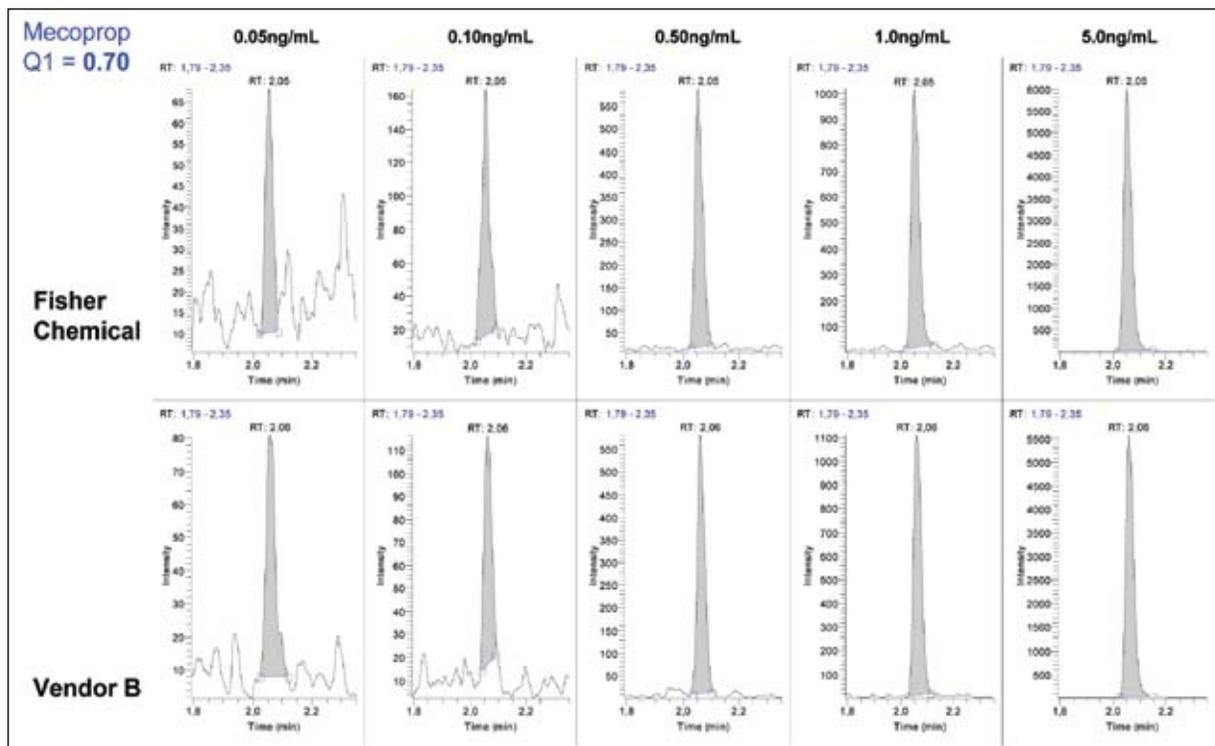


Fig. 18. Signal intensity for Mecoprop compound in negative mode using TSQ Vantage MS. Background noise is nearly equal for both Fisher Chemical Optima and Vendor B acetonitrile/water mobile phases.

Contamination with PEG. Polyethylene glycol (PEG) is a synthetic polymer produced in a range of molecular weights. It is a contaminant commonly found in LCMS mobile phase solvents. Well-known sources of PEG

include skin creams and shampoos, toothpaste, Thermo Scientific Triton X-100, and glassware detergents. PEG contamination was 2-3x lower in the Optima LC/MS solvent system as compared to other solvent brands (Fig. 19).

PEG Contamination in Water, Acetonitrile and Methanol

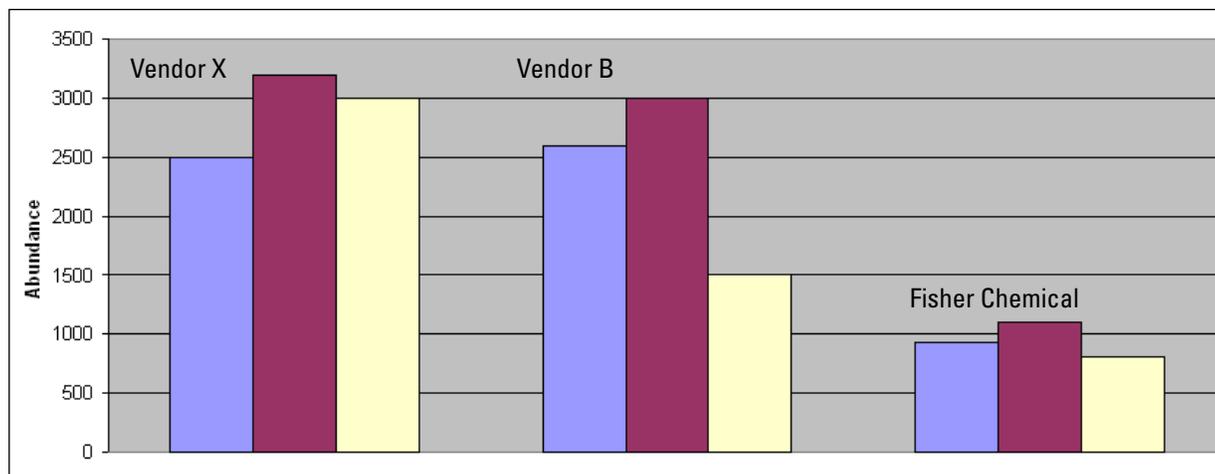


Fig. 19. PEG contamination lowest in Fisher Chemical Optima LC/MS mobile phase solvents (water, acetonitrile, and methanol) as determined by LTQ Orbitrap XL.



Conclusions

Purity is a crucial consideration when selecting appropriate solvents for use in the LC/MS mobile phase. Seven commercially available solvent brands were compared using four different LC/MS systems with the following results:

1. Fisher Chemical Optima LC/MS solvents have fewer peaks compared to other vendors' LC/MS solvents, especially within the high organic portions of the gradient. Also, the mass baseline (noise level) is very low for both positive and negative modes in TIC.
2. Optima LC/MS solvents are not only low in mass background, they also have very low LC/UV response using diode array detection.
3. Signal intensity for standard peptide peaks was highest using Optima LC/MS mobile phase solvents compared to other commercial brands.
4. Contamination from PEG and various phthalate peaks was prevalent in greater quantities in other vendors' LC/MS solvents than with Fisher Chemical Optima LC/MS solvents.
5. Optima LC/MS solvents provide exceptionally low metal ion content, which makes MS interpretation easier. Thermo Fisher Scientific uses proprietary manufacturing and packaging techniques at its Fair Lawn, NJ facility to prepare these solvents with minimal metal ion contamination.

References

- ¹M.G. Bartlett. J. Chromatography B (2005) 825: 97.
- ²J.W. Dolan. LCGC North America (2005) 23: 1256.
- ³K. Mortier, et al. J. Am. Soc. Mass Spectrom. (2003) 15(4): 585-592.
- ⁴W. Lambert. T+K (2004) 71(2): 64.

Cross-References to Competitor Products

Acetonitrile	1L	2.5L	4L
Fisher Chemical	A955-1	A955-212	A955-4
EMD	AX0156-6	NA	AX0156-1
Merck	1000291000	1000292500	NA
J.T. Baker	9829-2	NA	9829-3
Sigma-Aldrich	34967-1L	34967-2.5L	34967-4x4L
Biosolve	12041	NA	NA

Methanol	1L	2.5L	4L
Fisher Chemical	A456-1	A456-212	A456-4
EMD	MX0486-6	NA	MX0496-6
Merck	1060351000	1060352500	NA
J.T. Baker	9830-2	NA	9830-3
Sigma-Aldrich	34966-1L	34966-2.5L	34966-4x4L
Biosolve	136841	NA	NA

2-propanol	1L	2.5L	4L
Fisher Chemical	A461-1	A461-212	A461-4
J.T. Baker	9627-2	NA	9627-3
Sigma-Aldrich	34965-1L	34965-2.5L	NA
Biosolve	162641	NA	162641

Water	1L	2.5L	4L
Fisher Chemical	W6-1	W6-212	W6-4
EMD	WX0001-6	NA	WX0001-1
J.T. Baker	9831-2	NA	9831-3
Sigma-Aldrich	39253-1L	NA	39253-4x4L
Biosolve	232141	NA	NA

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Specification

Optima LC/MS Acetonitrile; A955

Assay (by GC), min	99.9%
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Optical Abs, wavelength, nm	au max
280	0.005
254	0.005
230	0.01
225	0.015
220	0.015
215	0.025
210	0.03
205	0.04
200	0.05
195	0.15
190	1.00

LC/MS Gradient Suitability, nm	Single max peak (au)
254	0.0005
210	0.002

LC/MS at Positive Mode Max	50ppb Reserpine
LC/MS at Negative Mode Max	50ppb Aldicarb
Water (KF) %	0.01
Residue after Evaporation, ppm Max	0.8

Trace Ionic Impurities	ppb, Max
Aluminum (Al)	25
Barium (Ba)	5
Cadmium (Cd)	5
Calcium (Ca)	25
Chromium (Cr)	5
Cobalt (Co)	5
Copper (Cu)	5
Iron (Fe)	5
Lead (Pb)	5
Manganese (Mn)	5
Magnesium (Mg)	10
Nickel (Ni)	5
Potassium (K)	10
Silver (Ag)	5
Sodium (Na)	50
Tin (Sn)	5
Zinc (Zn)	10

Titrateable Acid, mEQ/g	0.008
Titrateable Base, mEQ/g	0.0006



Specification

Optima LC/MS Methanol; A456

Assay (by GC), min	99.9%
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Optical Abs, wavelength, nm	au max
280	0.005
260	0.005
254	0.01
230	0.1
220	0.2
214	0.4
210	0.5

LC/MS Gradient Suitability, nm	Single max peak (au)
254	0.001
220	0.005

LC/MS at Positive Mode Max	50ppb Reserpine
LC/MS at Negative Mode Max	50ppb Aldicarb
Water (KF) %	0.02
Residue after Evaporation, ppm, Max	1

Trace Ionic Impurities	ppb, Max
Aluminum (Al)	10
Barium (Ba)	10
Cadmium (Cd)	10
Calcium (Ca)	20
Chromium (Cr)	10
Cobalt (Co)	10
Copper (Cu)	10
Iron (Fe)	10
Lead (Pb)	10
Magnesium (Mg)	10
Manganese (Mn)	10
Nickel (Ni)	10
Potassium (K)	10
Silver (Ag)	10
Sodium (Na)	50
Tin (Sn)	10
Zinc (Zn)	10

Titrateable Acid, mEQ/g	0.0003
Titrateable Base, mEQ/g	0.0002



Specification

Optima LC/MS 2-Propanol; A461

Assay	99.9%
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Color (APHA), Max	5
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Optical Abs, wavelength, nm	au max
254	0.005
230	0.05
220	0.1
210	0.4

LCMS Suitability	Pass Test
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Water (KF) %	0.05
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Residue after Evaporation, ppm, Max	1
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Titrateable Acid or Base meq/g	0.0001
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Trace Ionic Impurities	ppb, Max
Aluminum (Al)	10
Calcium (Ca)	10
Copper(Cu)	5
Iron (Fe)	5
Lead (Pb)	5
Magnesium (Mg)	5
Manganese (Mn)	5
Nickel (Ni)	5
Potassium (K)	10
Silver (Ag)	5
Sodium (Na)	50
Zinc (Zn)	10



Specification

Optima LC/MS Water; W6

Optical Abs, wavelength, nm	au max
280	0.005
260	0.005
254	0.005
240	0.01
230	0.01
220	0.01
210	0.01

LC/MS Gradient Suitability, nm	Single max peak (au)
254	0.0005
210	0.005

Protease	Not Detected
LC/MS at Positive Mode Max	50ppb Reserpine
LC/MS at Negative Mode Max	50ppb Aldicarb
Residue after Evaporation, ppm, Max	1

Trace Ionic Impurities	ppb, Max
Aluminum (Al)	10
Barium (Ba)	10
Cadmium (Cd)	10
Calcium (Ca)	20
Chromium (Cr)	10
Cobalt (Co)	10
Copper (Cu)	10
Iron (Fe)	10
Lead (Pb)	10
Magnesium (Mg)	10
Manganese (Mn)	10
Nickel (Ni)	10
Potassium (K)	10
Silver (Ag)	10
Sodium (Na)	20
Tin (Sn)	10
Zinc (Zn)	10
Total Halogens (as chloride)	Not Detected

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