

Evaluation of LCMSMS Deuterium Scrambling in Clinically Significant Small Molecules

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Introduction

Introduction and Objective:

LC-MS/MS is a powerful tool that brings numerous benefits to the clinical sample analysis arena. However, due to the complexity of the instrumentation there are some unique challenges that also accompany these benefits. Even following sample extraction and cleanup, matrix effects from the samples can cause interferences or impact ionization efficiency. Deuterium-labeled internal standards are the most common and prevalent labeled internal standards used to compensate for matrix effects. Some deuterium labeled compounds may exhibit hydrogen-deuterium scrambling/exchange in the collision cell which can impact MS/MS transition selection.

In this study we investigated numerous variables that potentially contribute to scrambling in order to ascertain reproducibility and impact on scrambling ratios: influences of different LC-MS systems (tandem quadrupole vs. quadrupole time-of-flight), matrix selection, concentration, with and without HPLC, collision energies, and deuterium placement in the internal standard. Numerous small molecules of clinical importance were investigate including: hydroxyvitamin D, testosterone, immunosuppressants, bath salts, and spice cannabinoids.

Materials and Procedures

LCMS Systems:

Waters Alliance UPLC-Xevo G2 Q-ToF

Agilent 1100 HPLC-6410 triple quad

Cerilliant Solution Standards Used:

25-Hydroxyvitamin D3, Cat# H-083

25-Hydroxyvitamin D3-d₆, Cat# H-074

25-Hydroxyvitamin D2, Cat# H-073

Testosterone, Cat# T-037

Testosterone-d₃, Cat# T-046

Testosterone-¹³C₃, Cat# T-037

(±)-Δ⁹-THC, Cat# T-005

(±)-Δ⁹-THC-d₃, Cat# T-003

(±)-11-Hydroxy-Δ⁹-THC, Cat# H-026

(±)-11-Hydroxy-Δ⁹-THC, Cat# H-041

(±)-11-nor-9-Carboxy-Δ⁹-THC, Cat# T-006

(±)-11-nor-9-Carboxy-Δ⁹-THC-d₃, Cat# T-004

(±)-11-nor-9-Carboxy-Δ⁹-THC-d₆, Cat# T-007

Cannabinol, Cat# C-045

Cannabinol-d₃, Cat# C-084

JWH-018 4-Hydroxypentyl metabolite, Cat# S-035

JWH-018 4-Hydroxypentyl metabolite-d₅, Cat# S-039

JWH-073 3-Hydroxybutyl metabolite, Cat# S-037

JWH-073 3-Hydroxybutyl metabolite-d₅, Cat# S-040

3,4-MDPV HCl, Cat# M-146

3,4-MDPV-d₈ HCl, Cat# M-146

Ethylone HCl, Cat# E-071

Ethylone-d₅ HCl, Cat# E-072

Butylone HCl, Cat# B-045

Butylone-d₃ HCl, Cat# B-046

Mephedrone HCl, Cat# M-138

Mephedrone-d₃ HCl, Cat# M-139

Methylone HCl, Cat# M-140

Methylone-d₃ HCl, Cat# M-140

Everolimus-d₄, Cat# E-070

Mycophenolic acid, Cat# M-106

Mycophenolic acid-d₃, Cat# M-137

Serum Extraction:

200μL of sample in serum + 200μL of methanol, vortexed to mix.

Added 1 mL of heptane, vortexed for 30sec,

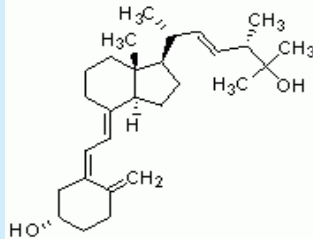
Centrifuged for 4min at 3000rpm

900μL of top layer dried under nitrogen

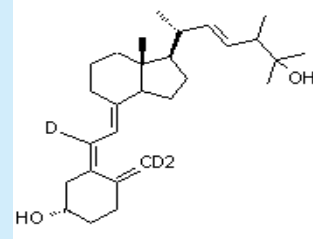
Reconstituted in 100μL of ethanol

Comparisons of 25-Hydroxyvitamin D Deuterium Scrambling

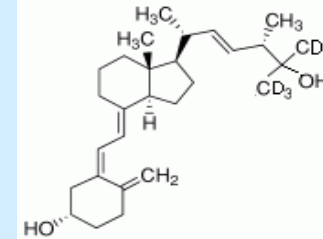
25-Hydroxyvitamin D2



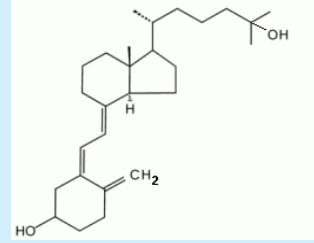
25-Hydroxyvitamin D2-d₃



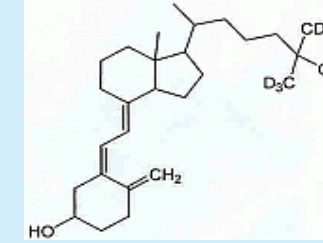
25-Hydroxyvitamin D2-d₆



25-Hydroxyvitamin D3



25-Hydroxyvitamin D3-d₆



Labeled 25-Hydroxyvitamin D2 and D3 Scrambling in Serum

Compound	Label	System	Concentration μg/mL	Transition d _{n-1}	Transition d _n	Scrambling % d _{n-1} / d _n
25-Hydroxyvitamin D2	d ₃	Xevo G2	2	398→379	398→380	28.6
			0.2	398→379	398→380	35.4
		6410	5	416→397	416→398	2.8
				416→379	416→380	19.7
				398→379	398→380	30.4
			50	416→397	416→398	2.8
	d ₆	6410	5	416→379	416→380	20
				398→379	398→380	30.5
		6410	5	419→400	419→401	2
				419→382	419→383	8.8
				401→382	401→383	5.9
			50	419→400	419→401	2
25-Hydroxyvitamin D3	d ₆	6410	5	419→382	419→383	9
				401→382	401→383	5.4
		6410	2.5	407→388	407→389	4
				407→370	407→371	18.8
				389→370	389→371	9.2

Transitions Comparisons for Native and Labeled 25-Hydroxyvitamin D2 and D3 in EtOH on 6410

Parent → Water loss					
Compound	Label	Concentration μg/mL	Transition d _{n-1}	Transition d _n	Scrambling % d _{n-1} / d _n
25-Hydroxyvitamin D2	d ₃	100	416→397	416→398	2.9
	d ₆	100	419→400	419→401	2
	native	50	413→394	413→395	0.5
25-Hydroxyvitamin D3	d ₆	50	407→388	407→389	4
	native	100	401→382	401→383	0.5

Parent → 2 Water losses

Compound	Label	Concentration μg/mL	Transition d _{n-1}	Transition d _n	Scrambling % d _{n-1} / d _n
25-Hydroxyvitamin D2	d ₃	100	416→379	416→380	19.5
	d ₆	100	419→382	419→383	8.9
	native	50	413→376	413→377	0.5
25-Hydroxyvitamin D3	d ₆	50	407→370	407→371	18.9
	native	100	401→364	401→365	0.3

Water loss → 2 Water losses

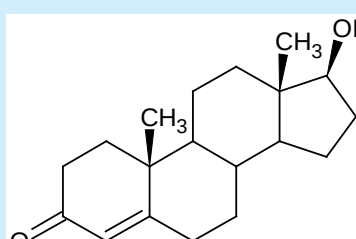
Compound	Label	Concentration μg/mL	Transition d _{n-1}	Transition d _n	Scrambling % d _{n-1} / d _n
25-Hydroxyvitamin D2	d ₃	100	398→379	398→380	30.4
	d ₆	100	401→382	401→383	5.4
	native	50	398→376	398→377	0.4
25-Hydroxyvitamin D3	d ₆	50	389→370	389→371	11.2
	native	100	383→364	383→365	0.3

Notes: 25-Hydroxy D2-d₆ water loss→2 water loss has same transition as 25-Hydroxyvitamin D3 parent→water loss. Can be problem if compounds are not well resolved chromatographically.

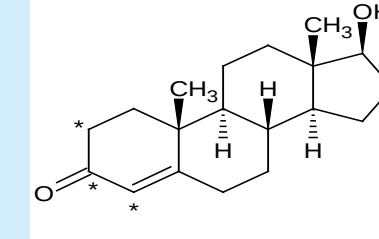
Selection of Transitions Greatly Impacts Observed Scrambling

Investigation of Testosterone Scrambling

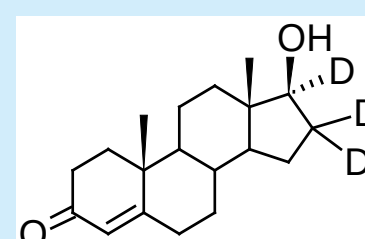
Testosterone



Testosterone-¹³C₃



Testosterone-d₃



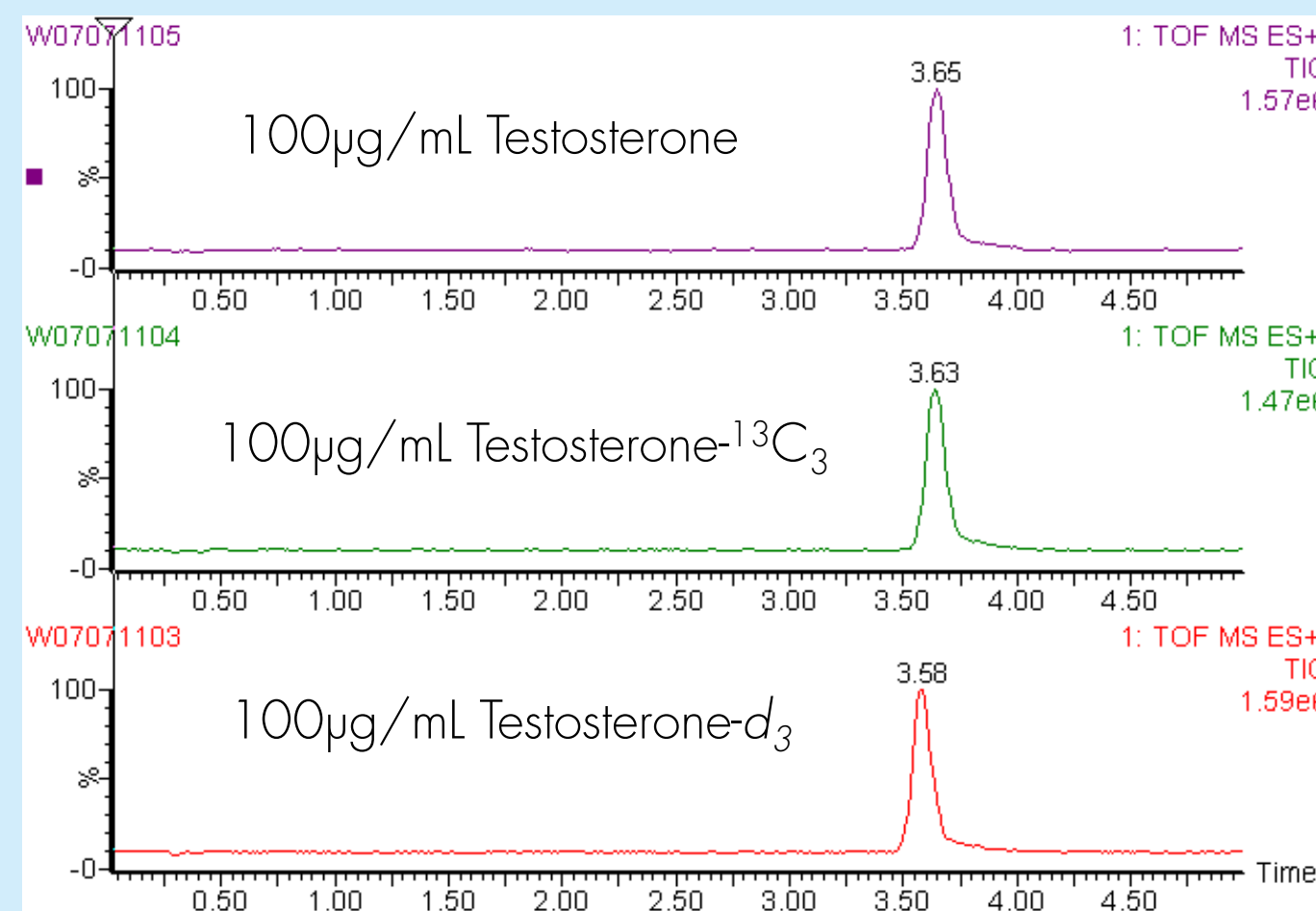
Major transitions are:
Native: 289→97 & 289→109
Testosterone-d₃: 292→97 & 292→109
Testosterone-¹³C₃: 292→100 & 292→112
No scrambling at major transitions

Testosterone Scrambling at Minor Transitions

Label	Method	Instrument	Concentration μg/mL	Transitions D _{n-1} or ¹³ C _{n-1}	Transitions D _n or ¹³ C _n	*Scrambling % D _{n-1} / D _n
d ₃	Infusion	Q-ToF	10	292→255	292→256	31.9
			100			36.5
			10			35.7
	LC	6410	100			37.7
			10			36.3
			100			0.1
¹³ C ₃			100	289→252	289→253	0.0
native			100	289→252	289→253	0.0

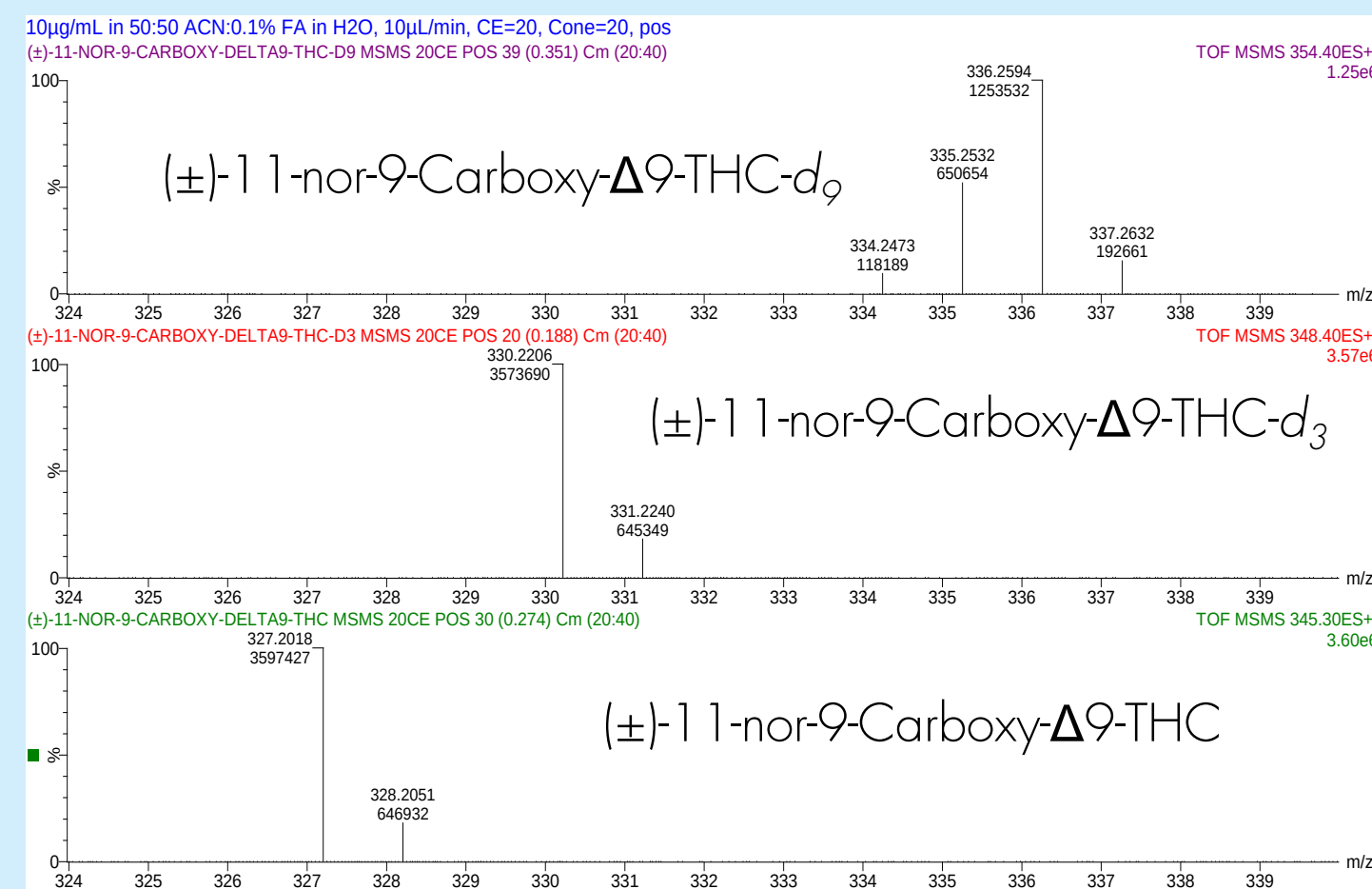
* or Scrambling % ¹³C_{n-1} / ¹³C_n

Testosterone Chromatograms on Xevo G2

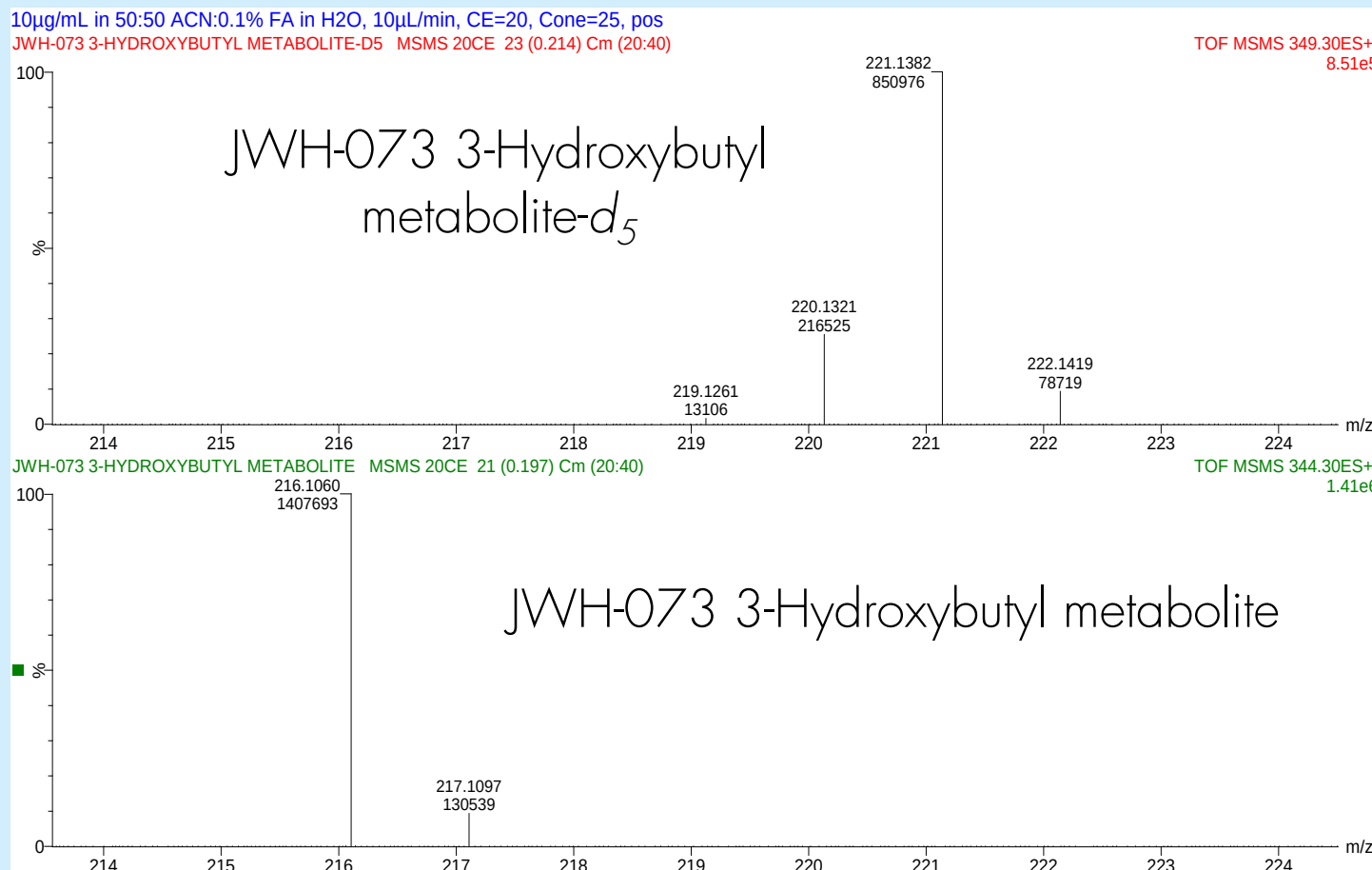


Investigation of Scrambling in Spice Cannabinoids, Bath Salts, and Immunosuppressants

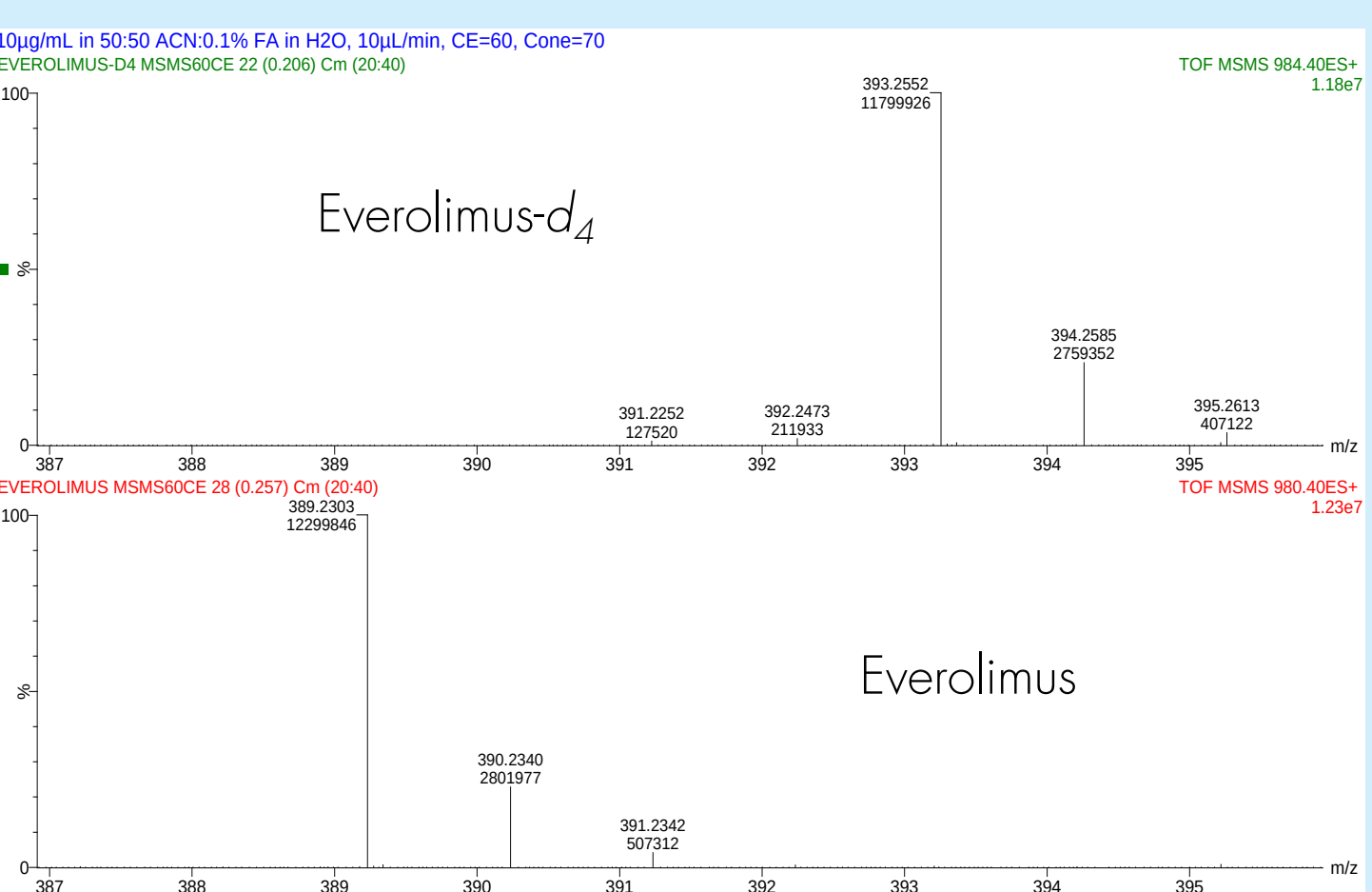
(±)-11-nor-9-Carboxy-Δ⁹-THC Scrambling at m/z 327



JWH-073 3-Hydroxybutyl Metabolite Scrambling at m/z 216



Everolimus Scrambling at m/z 389



Spice Cannabinoids, Bath Salts, and Immunosuppressants Scrambling Comparison usinf Xevo G2

Compound	Label	Polarity	Collision Energy	Transition(s) d _n	Scrambling % d _{n-1} / d _n
(±)-Δ ⁹ -THC	d ₃	pos	25	318→262, 196	0
	native	pos	25	315→259, 193	0
(±)-Δ ⁹ -THC	d ₃	neg	30	318→262, 196	can't determine
	native	neg	30	315→259, 193	can't determine
(±)-11-Hydroxy-Δ ⁹ -THC	d ₃	pos	15	334→316	3.12
	native	pos	15	331→313	0
(±)-11-Hydroxy-Δ ⁹ -THC	d ₃	pos	25	334→any	can't determine
	native	pos	25	331→any	can't determine
(±)-11-nor-9-Carboxy-Δ ⁹ -THC	d ₆	neg	30	352→254	0
	d ₃	neg	30	346→248	0
	native	neg	30	343→245	0
(±)-11-nor-9-Carboxy-Δ ⁹ -THC	d ₆	neg	20	352→334	0
	d ₃	neg	20	346→328	0
	native	neg	20	343→325	0
(±)-11-nor-9-Carboxy-Δ ⁹ -THC	d ₆	pos	20	354→336	51.91
	d ₃	pos	20	348→330	0
	native	pos	20	345→327	0
(±)-11-nor-9-Carboxy-Δ ⁹ -THC	d ₆	pos	20	354→308	48.88
	d ₃	pos	20	348→302	0
	native	pos	20	345→299	0
Cannabinol	d ₃	neg	30	316→248	0
	native	neg	30	313→245	0
Cannabinol	d ₃	pos	20	318→262, 196	0
	native	pos	20	315→259, 193	0
JWH-018 4-Hydroxypentyl metabolite	d ₅	pos	20	363→345	22.83
	native	pos	20	358→340	0
JWH-018 4-Hydroxypentyl metabolite	d ₅	pos	20	363→155	0
	native	pos	20	358→155	0
JWH-073 3-Hydroxybutyl metabolite	d ₅	pos	20	349→221	25.44
	native	pos	20	344→216	0
JWH-073 3-Hydroxybutyl metabolite	d ₅	pos	20	363→155	0
	native	pos	20	358→155	0
3,4-MDPV HCl	d ₈	pos	15	284→134	0
	native	pos	15	284→126	0
Ethylone HCl	d ₅	pos	15	227→209	0
	native	pos	15	222→204	0
Butylone HCl	d ₃	pos	15	225→209, etc	0
	native	pos	15	222→204, etc	0
Mephedrone HCl	d ₃	pos	10	181→163	0
	native	pos	10	178→160	0
Methylone HCl	d ₃	pos	10	211→163	0
	native	pos	10	208→160	0
Methylone HCl	d ₃	pos	10	211→135	0
	native	pos	10	208→132	0
Everolimus	d ₄	pos	60	984→393	1.80
	native	pos	60	980→389	0
Mycophenolic acid	d ₃	neg	15	322→278	0
	native	neg	15	319→275	0

CONCLUSIONS

- Scrambling was observed for several of the analytes at select transitions. In all cases, scrambling was mitigated or eliminated by optimizing instrument conditions and transition selection.
- Awareness of potential scrambling is important for proper internal standard selection.
- Scrambling was observed on both the Agilent 6410 triple quadrupole and the Waters Xevo G2 Q-ToF to approximately the same degree. For a specific transition, scrambling ratios were consistent between solvent and serum. No matrix effects on scrambling.
- Direct infusion can provide rapid and accurate determination of scrambling ratios. Infusion and chromatographic injection results were consistent.
- Scrambling may be mitigated or eliminated by altering instrument conditions and transition selection. However, there is a need to consider potential impact of scrambling on transitions chosen for optimal sensitivity.
- Deuterium-labeled internal standards are a viable option for LC-MS/MS analysis with selection of the appropriate transition. Deuterated standards can be more cost effective than ¹³C labeled internal standards, more widely available and with lower cost per test. ¹³C labeled internal standards are most effective when deuterium scrambling issues can not be resolved.