Electronic Supplementary Material (ESI) for JAAS.

Characterization of Matrix Effects using an Inductively Coupled Plasma-Sector Field Mass Spectrometer

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Table S1 Recoveries (ratio of sensitivity in the presence of 5 mM Cs to sensitivity in the absence of 5 mM Cs) when using a single internal standard (IS) to compensate for matrix effects

		% Change	Recovery using internal standard			
Analyte	Mass	5 mM Cs*	IS $^{7}Li^{+}$	IS $^{88}Sr^{+}$	IS $^{153}Eu^{+}$	IS $^{238}U^{+}$
Li	7	-28%	X	89%	89%	81%
B	11	5%	*146%*	*130%*	*130%*	118%
Mg	24	-21%	110%	97%	98%	89%
Sc	45	-21%	110%	98%	98%	89%
Ga	71	-24%	106%	94%	94%	85%
As	75	-25%	105%	93%	93%	85%
Sr	88	-19%	113%	X	100%	91%
Cd	111	-23%	107%	95%	95%	86%
Ba	138	-16%	118%	105%	105%	95%
Eu	153	-20%	112%	100%	X	91%
Yb	172	-14%	*121%*	107%	107%	97%
U	238	-11%	*124%*	110%	110%	X

* % change in analyte sensitivity due to presence of 5 mM Cs
All measurements made using the optimum lens voltage in the absence of Cs.
Numbers in *italics* indicates a recovery that is less than 80% or more than 120%

Table S2 Recoveries (ratio of sensitivity in the presence of 5 mM Tb to sensitivity in the absence of 5 mM Tl) when using a single internal standard (IS) to compensate for matrix effects

Analyte	Mass	% Change 5 mM Tb*	Recovery using internal standard IS $^{7}Li^{+}$	IS $^{88}Sr^{+}$	IS $^{153}Eu^{+}$	IS $^{238}U^{+}$
Li	7	-34%	X	111%	*127%*	96%
B	11	-29%	107%	119%	*136%*	102%
Mg	24	-46%	82%	91%	104%	*78%*
Sc	45	-47%	80%	89%	102%	*77%*
Ga	71	-46%	82%	91%	105%	*79%*
As	75	-48%	*79%*	87%	100%	*75%*
Sr	88	-40%	90%	X	114%	86%
Cd	111	-45%	83%	92%	106%	80%
Ba	138	-37%	95%	106%	*121%*	91%
Eu	153	-48%	*79%*	87%	X	*75%*
Yb	172	-34%	100%	111%	*127%*	96%
U	238	-31%	105%	116%	*133%*	X

* % change in analyte sensitivity due to presence of 5 mM Tl
All measurements made using the optimum lens voltage in the absence of Tl.
Numbers in *italics* indicates a recovery that is less than 80% or more than 120%

Table S3 Recoveries (ratio of sensitivity in the presence of 5 mM Tl to sensitivity in the absence of 5 mM Tl) when using a single internal standard (IS) to compensate for matrix effects

Analyte	Mass	% Change 5 mM Tl*	Recovery using internal standard IS $^{7}Li^{+}$	IS $^{88}Sr^{+}$	IS $^{153}Eu^{+}$	IS $^{238}U^{+}$
Li	7	-49%	X	110%	*134%*	106%
B	11	-44%	109%	120%	*147%*	116%
Mg	24	-57%	83%	91%	112%	88%
Sc	45	-56%	85%	93%	114%	90%
Ga	71	-57%	84%	92%	113%	89%
As	75	-59%	80%	87%	107%	85%
Sr	88	-53%	91%	X	*123%*	97%
Cd	111	-53%	91%	100%	*123%*	97%
Ba	138	-52%	94%	103%	*127%*	100%
Eu	153	-62%	*74%*	82%	X	*79%*
Yb	172	-54%	90%	99%	*121%*	95%
U	238	-51%	94%	103%	*127%*	X

* % change in analyte sensitivity due to presence of 5 mM Tl
All measurements made using the optimum lens voltage in the absence of Tl.
Numbers in *italics* indicates a recovery that is less than 80% or more than 120%

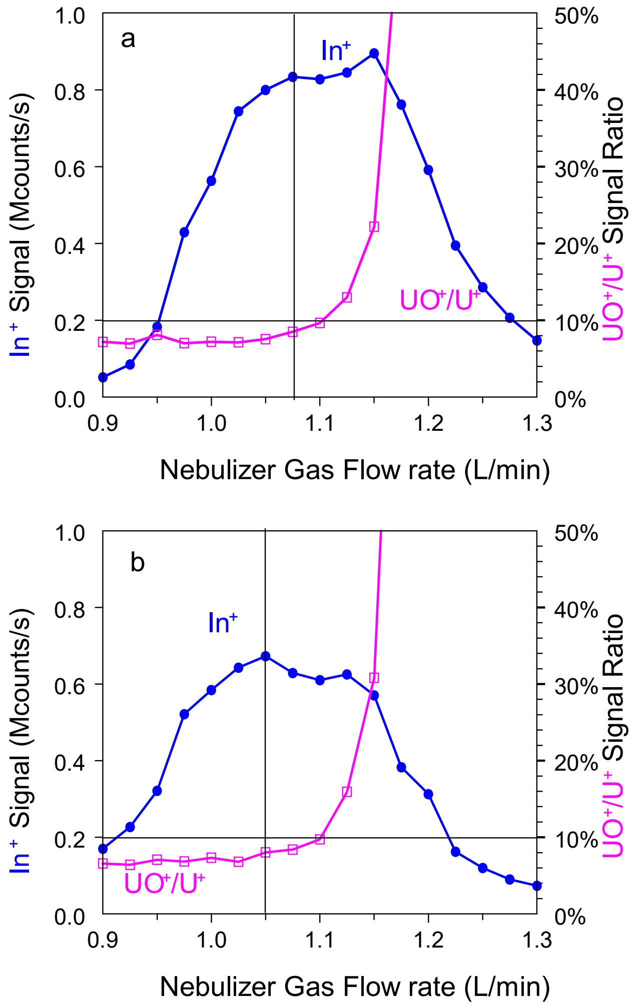

Figure S1. $^{115}In^+$ signal intensity (1 ng/mL) and UO^+/U^+ signal ratio as a function of nebulizer gas flow rate at a fixed focus lens voltage (−880V). The data shown in (a) were acquired 3 months earlier than the data shown in (b).

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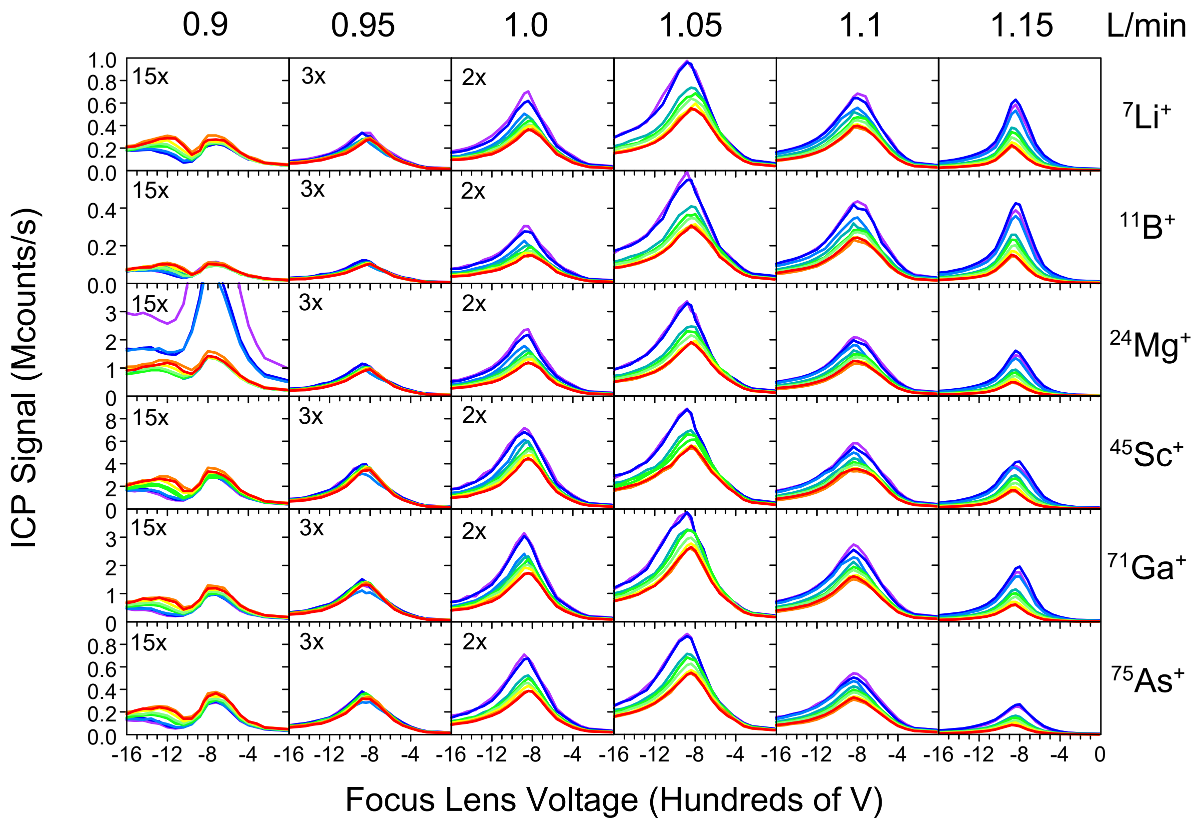

Figure S2. At each nebulizer gas flow rate, nine sets of measurements of ICP-MS signal versus focus lens voltage were made from a 20 ppb multi-element solution. Measurements were made before and after each of the solutions containing one of the eight matrix elements at a concentration of 5 mM. Analytes are listed on the right. The intensities measured at nebulizer gas flow rates of 0.9, 0.95 and 1.0 L/min were multiplied by 15, 3, and 2, respectively, prior to plotting. Order of data acquisition (also chronologically): prior to any 5 mM matrix ( ), after 5 mM Na ( ), after 5 mM Cu ( ), after 5 mM Y ( ) , after 5 mM In ( ) , after 5 mM Cs ( ), after 5 mM Tb ( ), after 5 mM Lu ( ), after 5 mM Tl ( ).

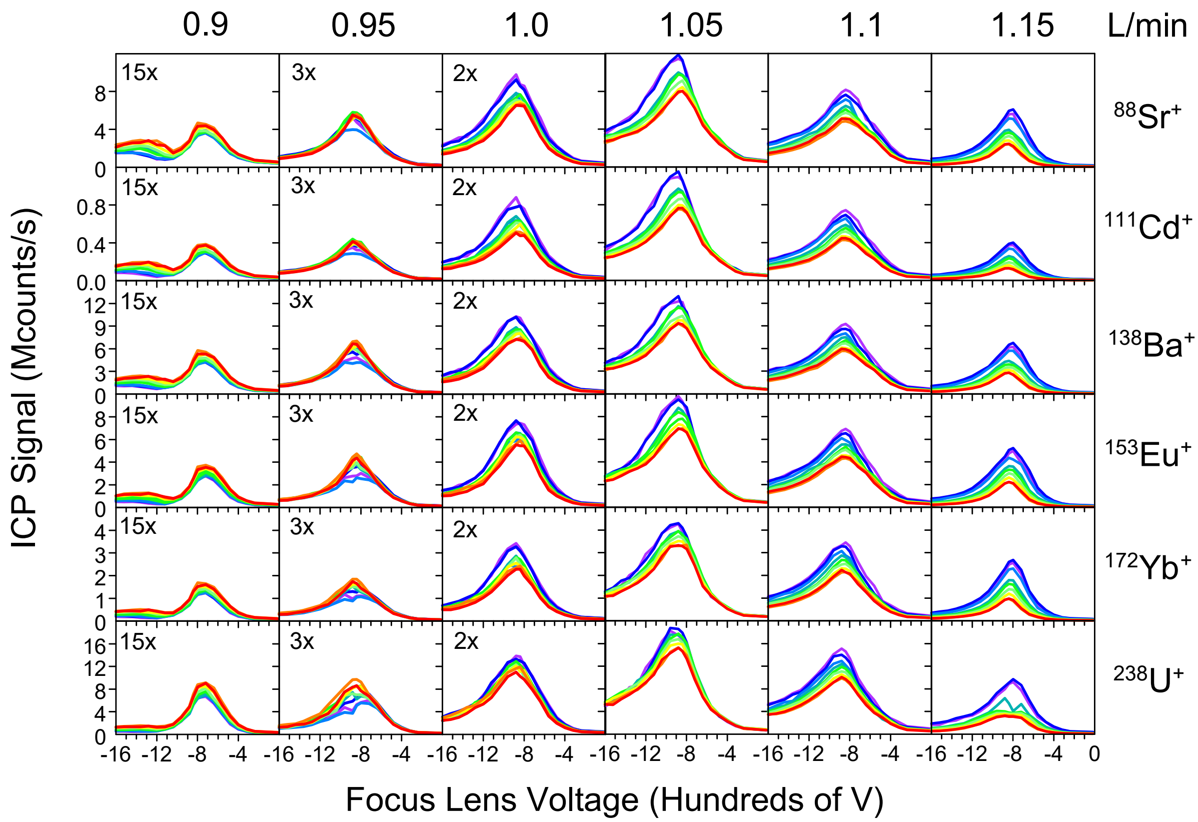

Figure S3. At each nebulizer gas flow rate, nine sets of measurements of ICP-MS signal versus focus lens voltage were made from a 20 ppb multi-element solution. Measurements were made before and after each of the solutions containing one of the eight matrix elements at a concentration of 5 mM. Analytes are listed on the right. The intensities measured at a nebulizer gas flow rates of 0.9, 0.95 and 1.0 L/min were multiplied by 15, 3, and 2, respectively, prior to plotting. Order of data acquisition (also chronologically): prior to any 5 mM matrix ( ), after 5 mM Na ( ), after 5 mM Cu ( ), after 5 mM Y ( ), after 5 mM In ( ), after 5 mM Cs ( ), after 5 mM Tb ( ), after 5 mM Lu ( ), after 5 mM Tl ( ).

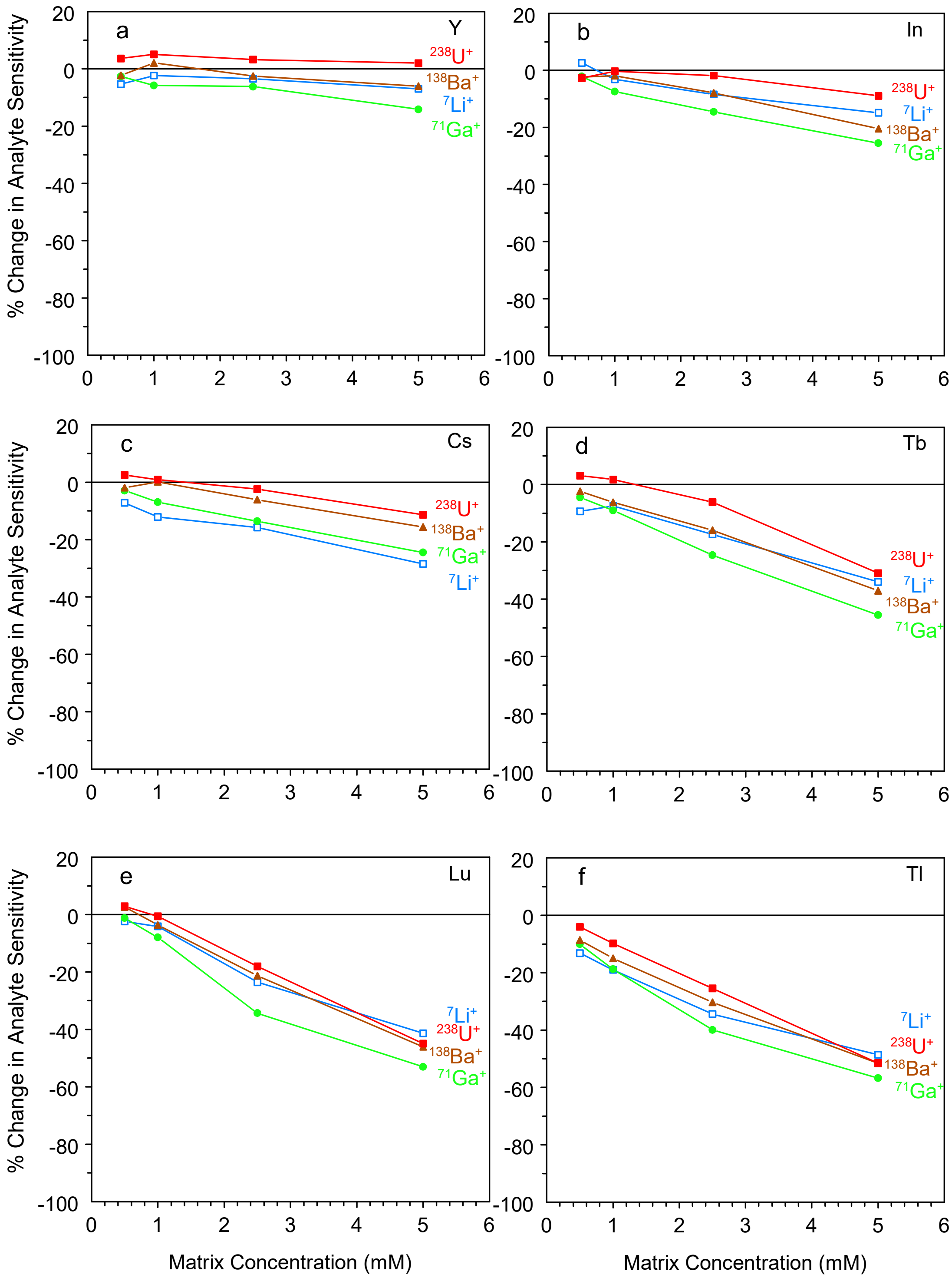

Figure S4. Matrix-induced change in $^{7}Li^{+}$, $^{71}Ga^{+}$, $^{138}Ba^{+}$ and $^{238}U^{+}$ analyte ion sensitivity as a function of matrix element concentration. (a) Y matrix. (b) In matrix. (c) Cs matrix. (d) Tb matrix. (e) Lu matrix. (f) Tl matrix.

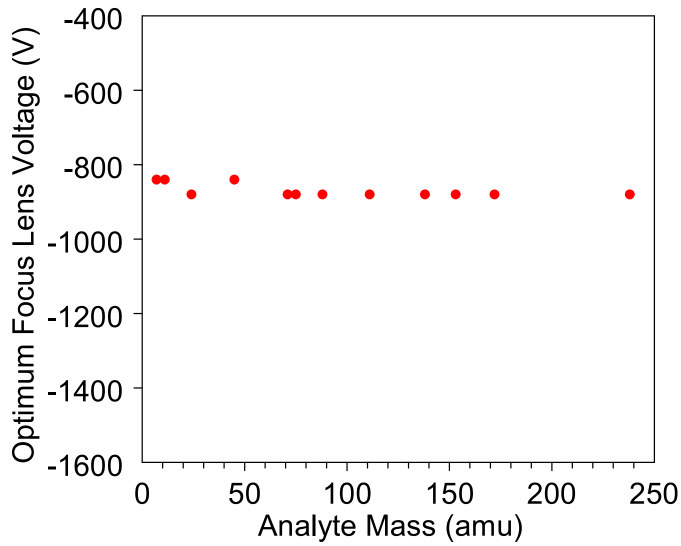

Figure S5. Optimum focus lens voltage as a function of analyte mass.

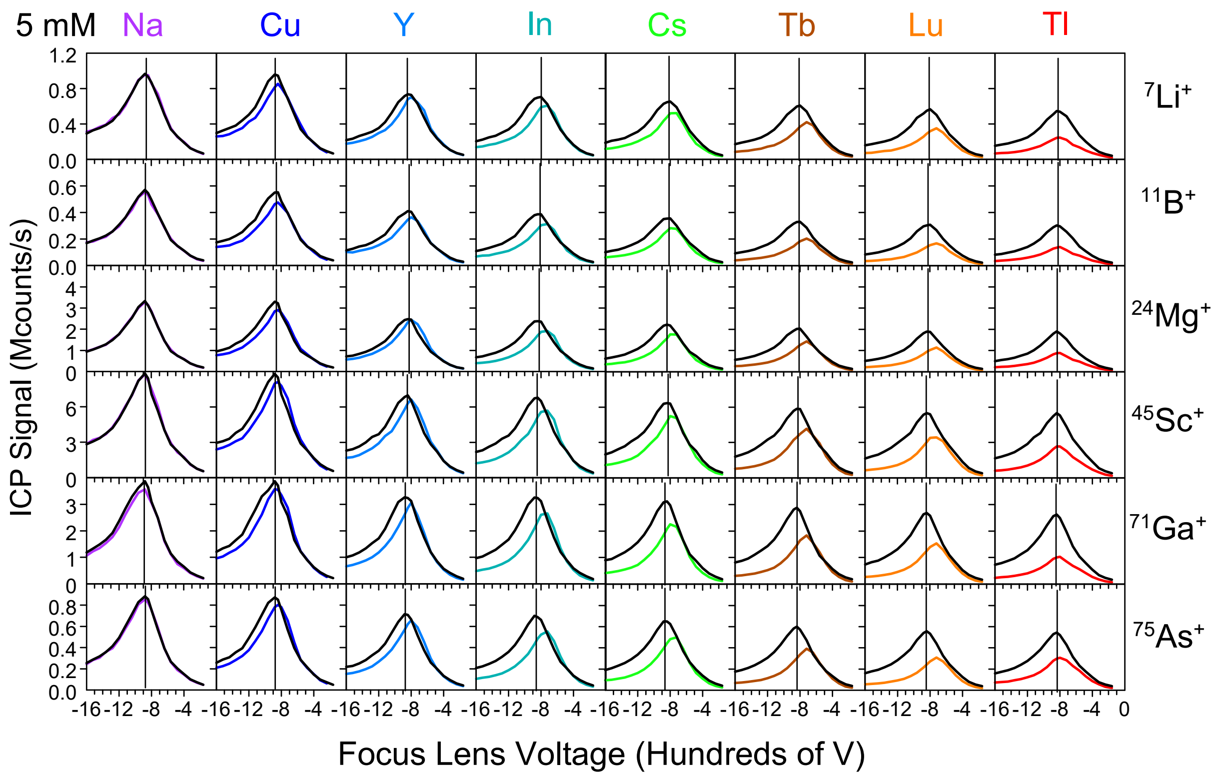

Figure S6. ICP-MS signals as a function of lens voltage in the absence and presence of 5 mM matrix element at the optimum nebulizer gas flow rate. Matrix elements listed on top. Analytes listed on the right.

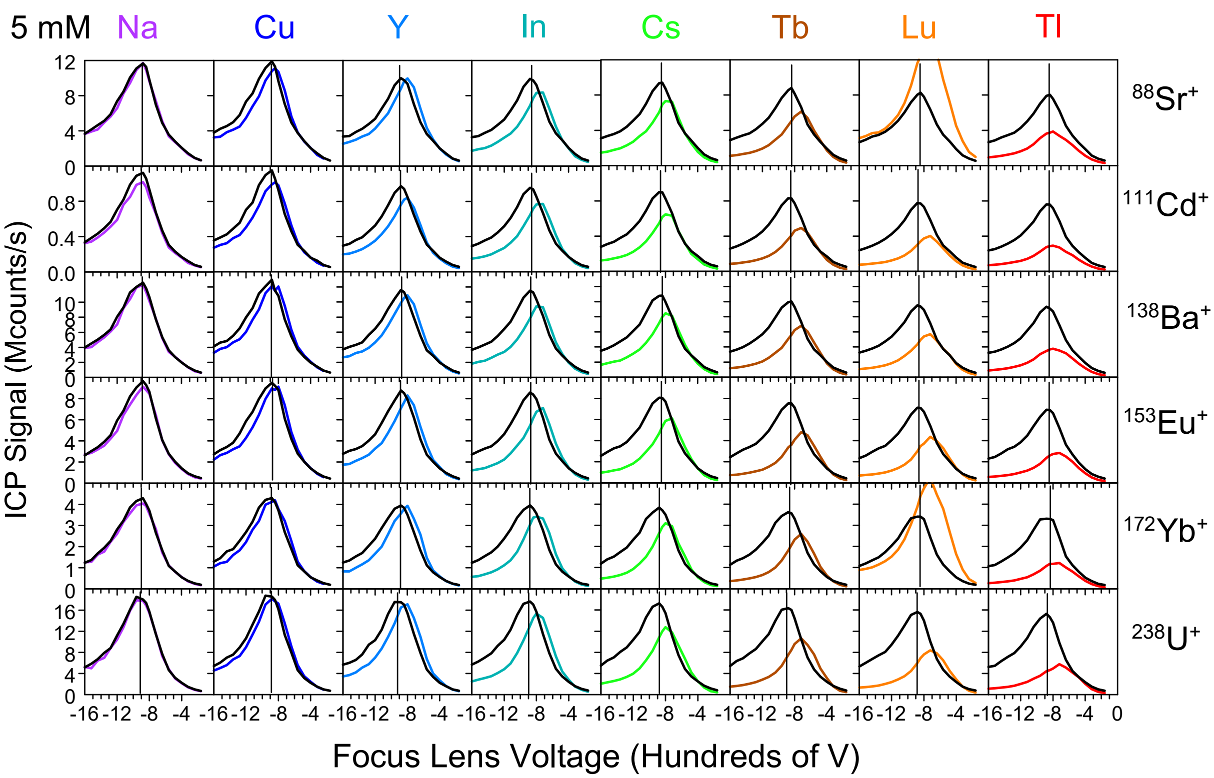

Figure S7. ICP-MS signals as a function of lens voltage in the absence and presence of 5 mM matrix element at the optimum nebulizer gas flow rate. Matrix elements listed on top. Analytes listed on the right. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

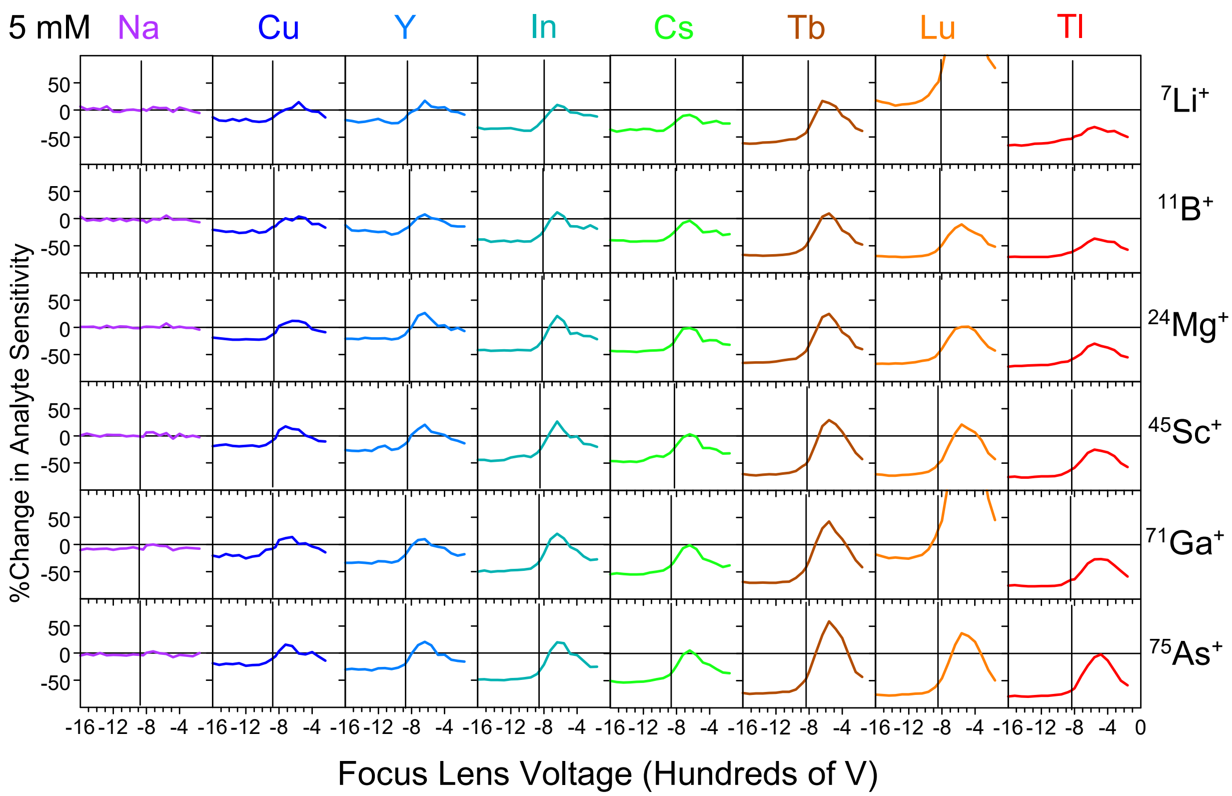

Figure S8. Matrix induced change in ICP-MS sensitivity as a function of lens voltage at the optimized nebulizer gas flow rate. Matrix elements listed on top. Analytes listed on the right.

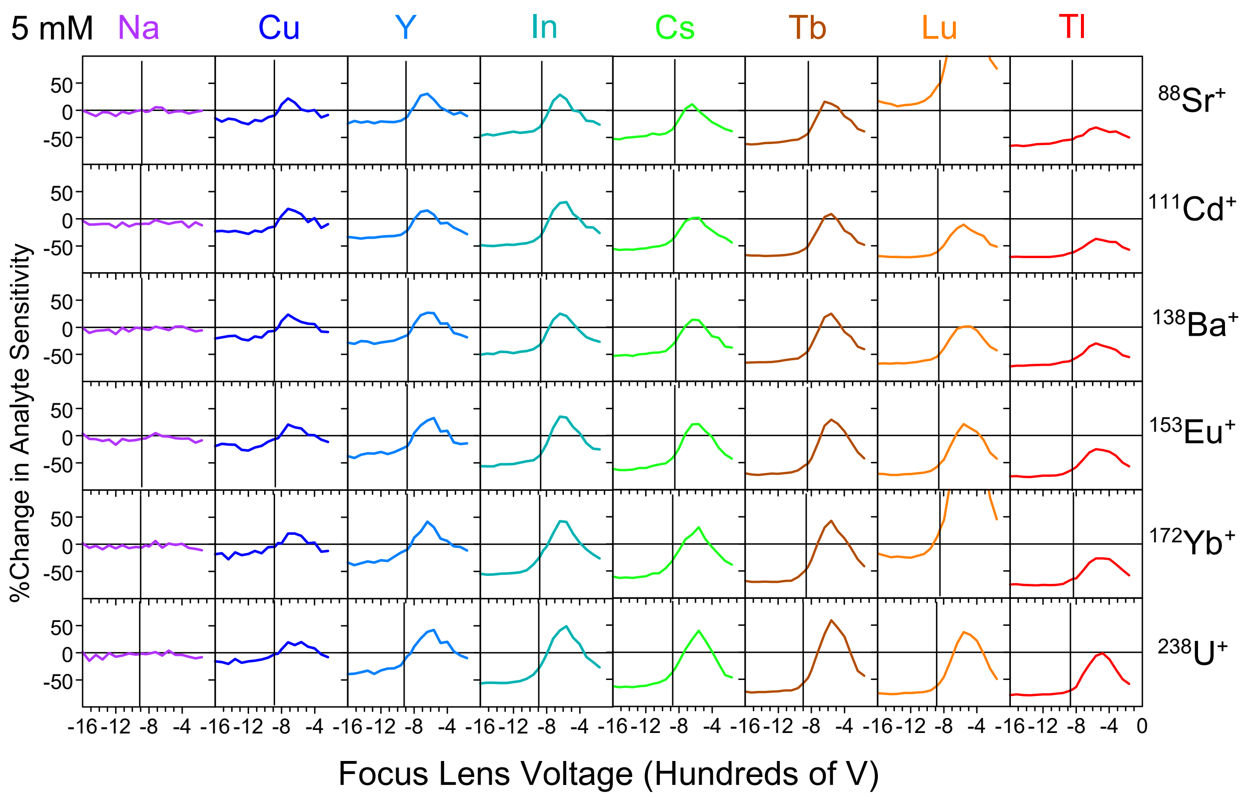

Figure S9. Matrix induced change in ICP-MS sensitivity as a function of lens voltage at the optimized nebulizer gas flow rate. Matrix elements listed on top. Analytes listed on the right. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

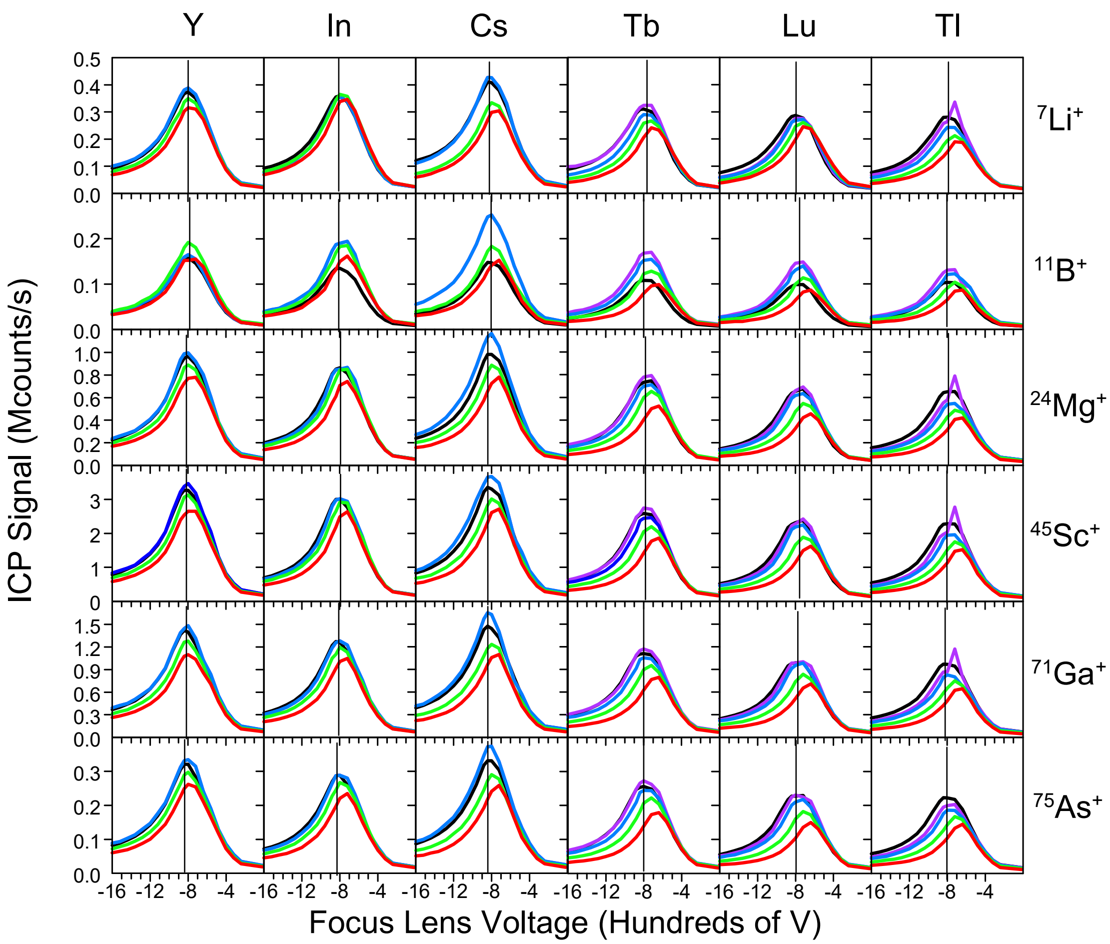

Figure S10. ICP-MS analyte ion signals as a function of lens voltage at the optimum nebulizer gas flow rate in the absence ( ) or presence of 0.5 ( ), 1.0 ( ), 2.5 ( ) and 5 ( ) mM matrix element (Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltageMatrix elements listed on top. Analytes listed on the right.

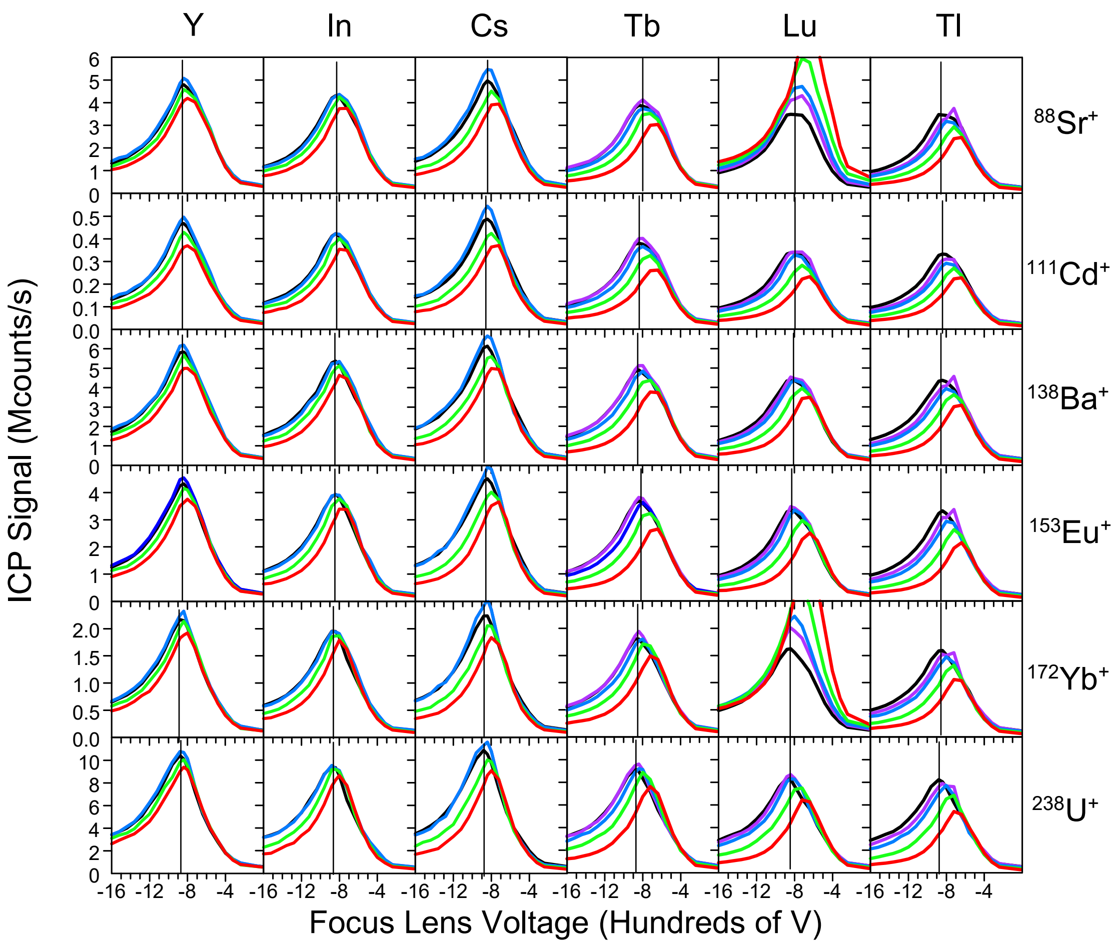

Figure S11. ICP-MS analyte ion signals as a function of lens voltage at the optimum nebulizer gas flow rate in the absence ( ) or presence of 0.5 ( ), 1.0 ( ), 2.5 ( ) and 5 ( ) mM matrix element. Matrix elements listed on top. Analytes listed on the right. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

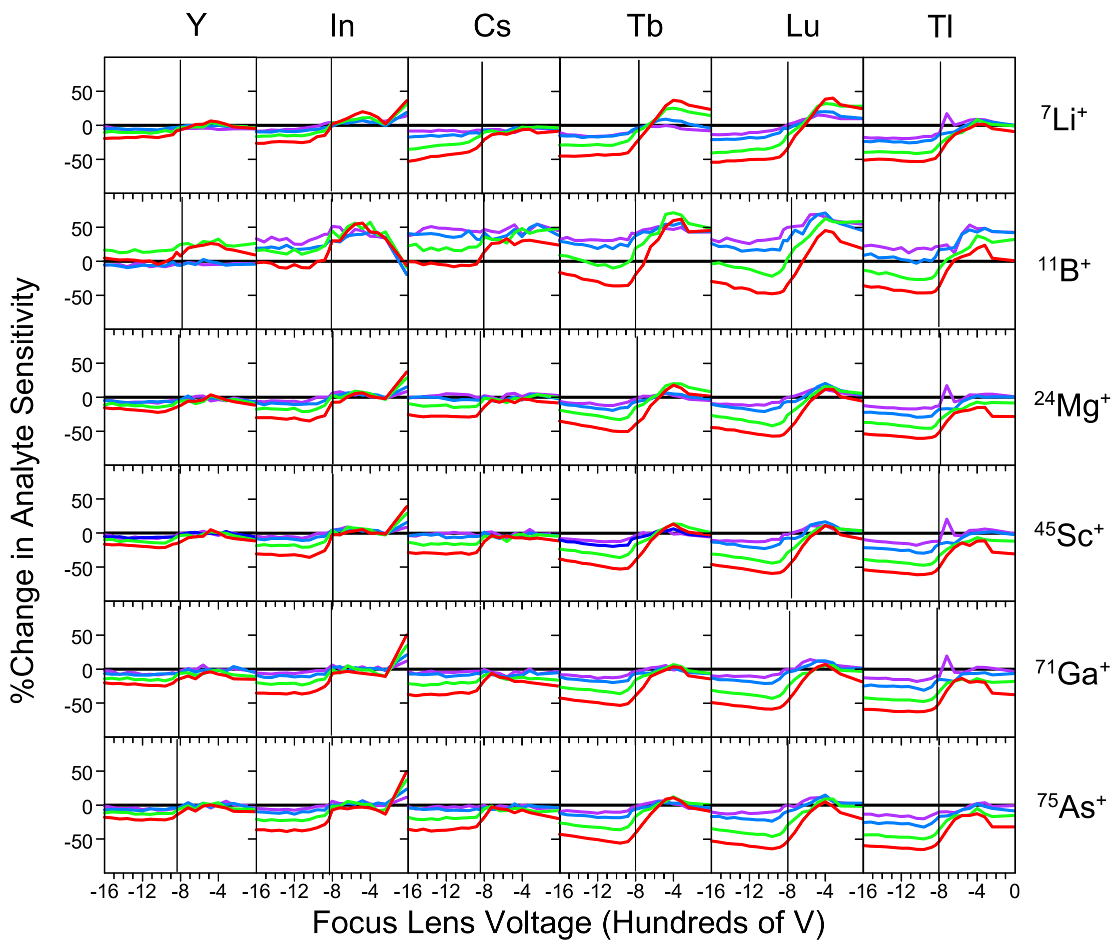

Figure S12. Matrix-induced change in analyte ion sensitivity due to the presence of 0.5 ( ), 1 ( ), 2.5 ( ), or 5 ( ) mM matrix element (Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltage.

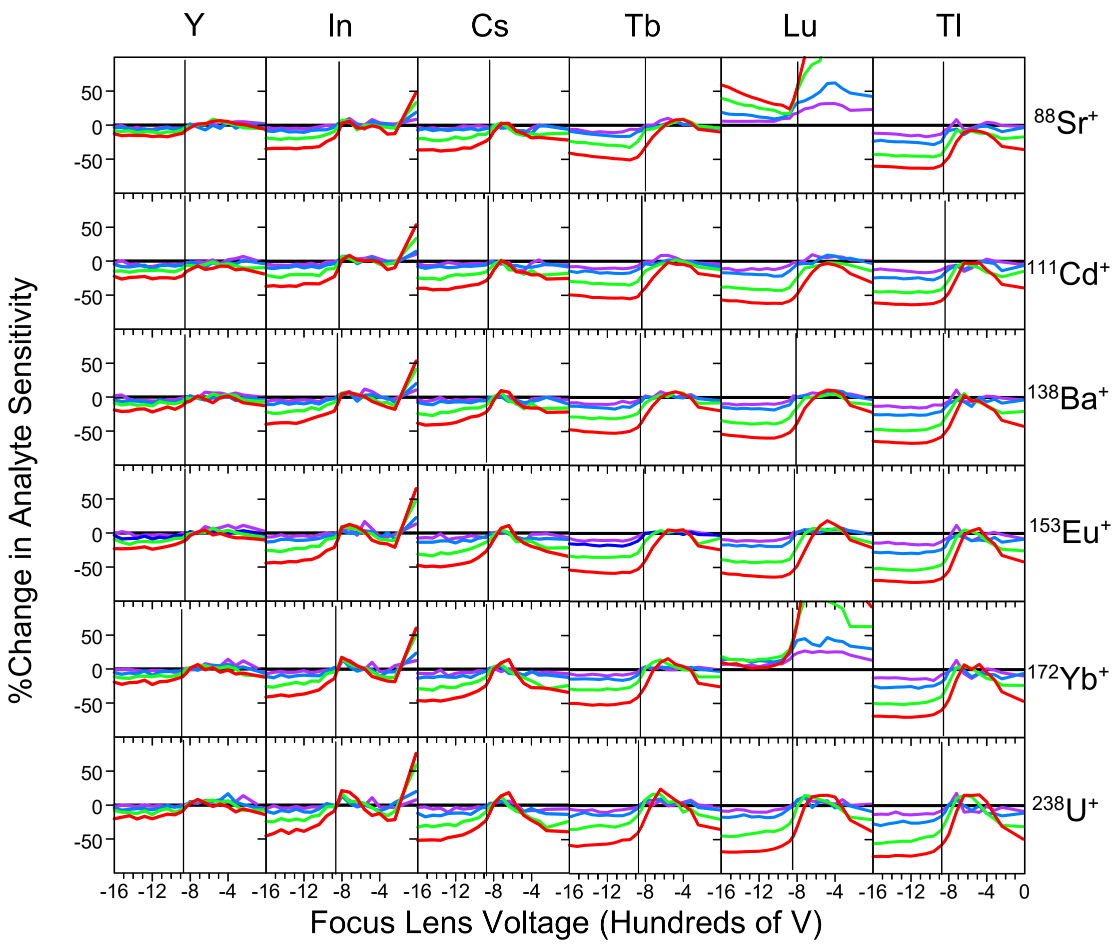

Figure S13. Matrix-induced change in analyte ion sensitivity due to the presence of 0.5 ( ), 1 ( ), 2.5 ( ), or 5 ( ) mM matrix element (Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltage. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

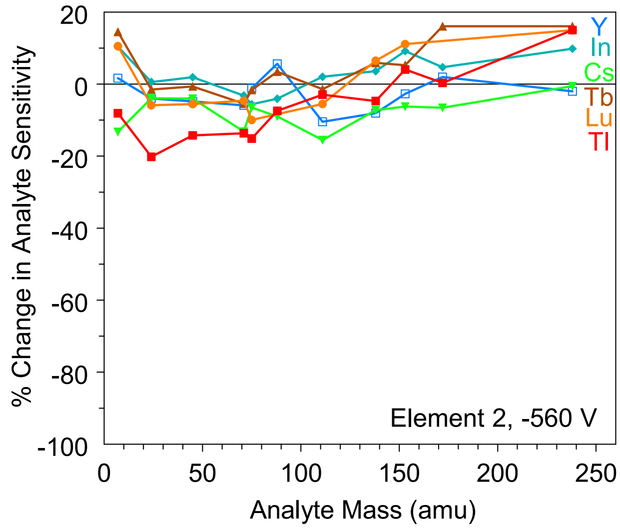

Figure S14. Change in analyte ion sensitivity as a function of analyte ion mass at a focus lens voltage of −560 V (320 V more positive than the optimum focus lens voltage in the absence of a matrix element) from data shown in Fig. 10, 11 in the presence of 5 mM Y, In, Cs, Tb, Lu or Tl.

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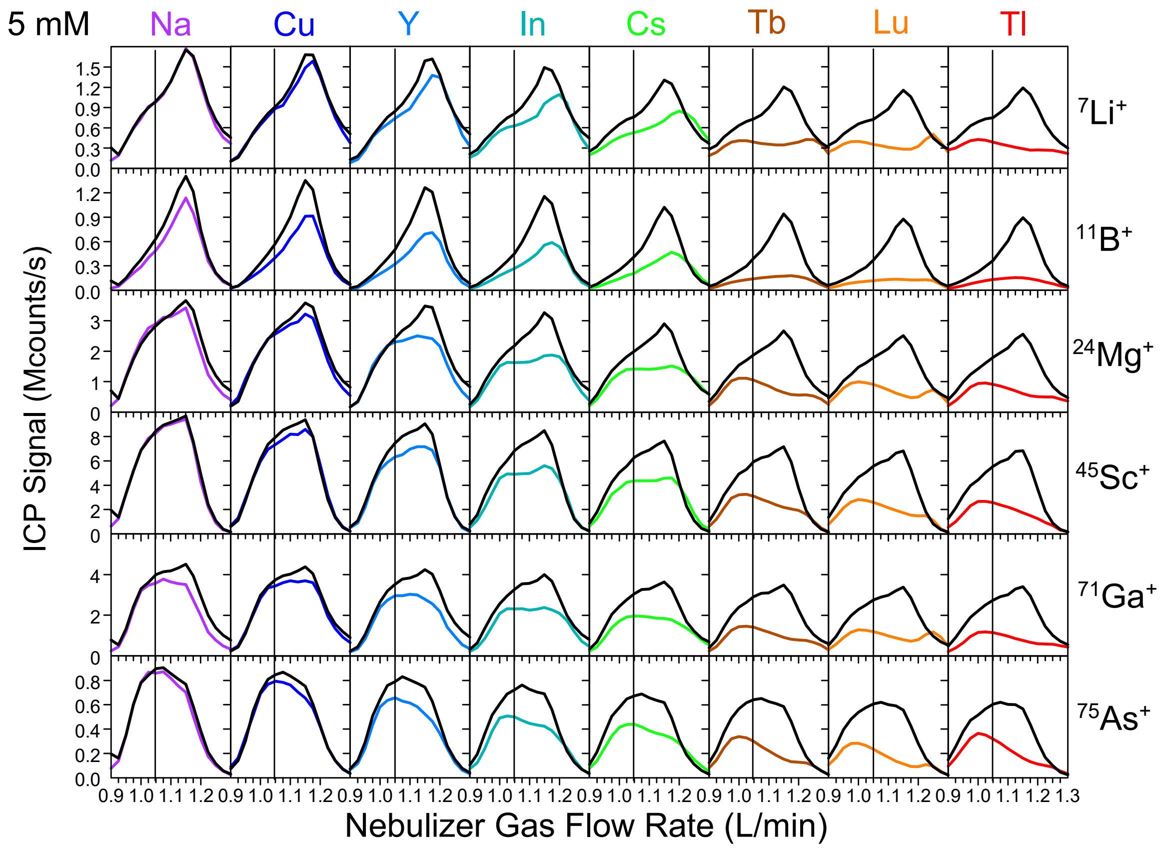

Figure S15. Analyte ion signals in the absence or presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of nebulizer gas flow rate. Optimum lens voltage (−880 V) for maximum sensitivity in the absence of a matrix element while the UO^{+}/U^{+} signal ratio was 0.1 or less. The guard electrode inserted between torch and coil was grounded.

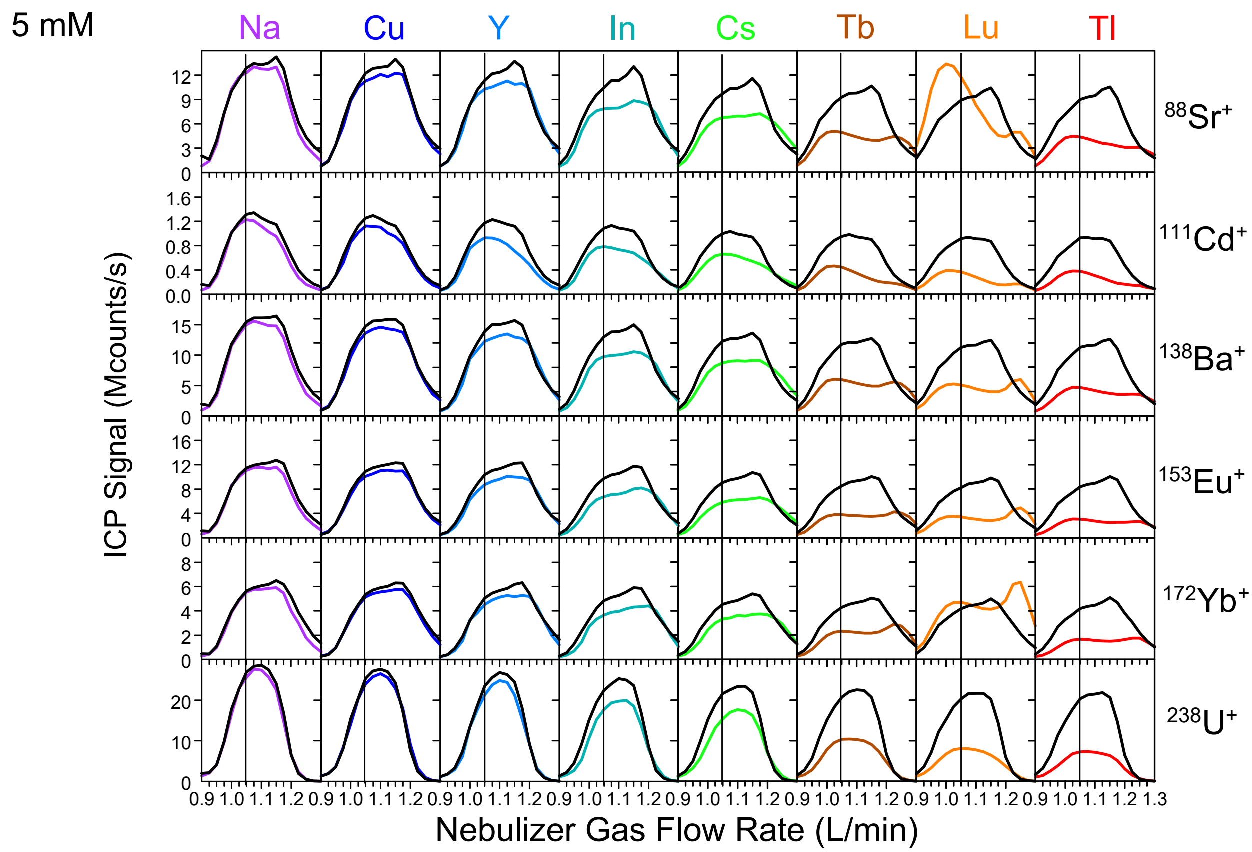

Figure S16. Analyte ion signals in the absence or presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of nebulizer gas flow rate. Optimum lens voltage (−880 V) for maximum sensitivity in the absence of a matrix element while the UO^+/U^+ signal ratio was 0.1 or less. The guard electrode inserted between torch and coil was grounded. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

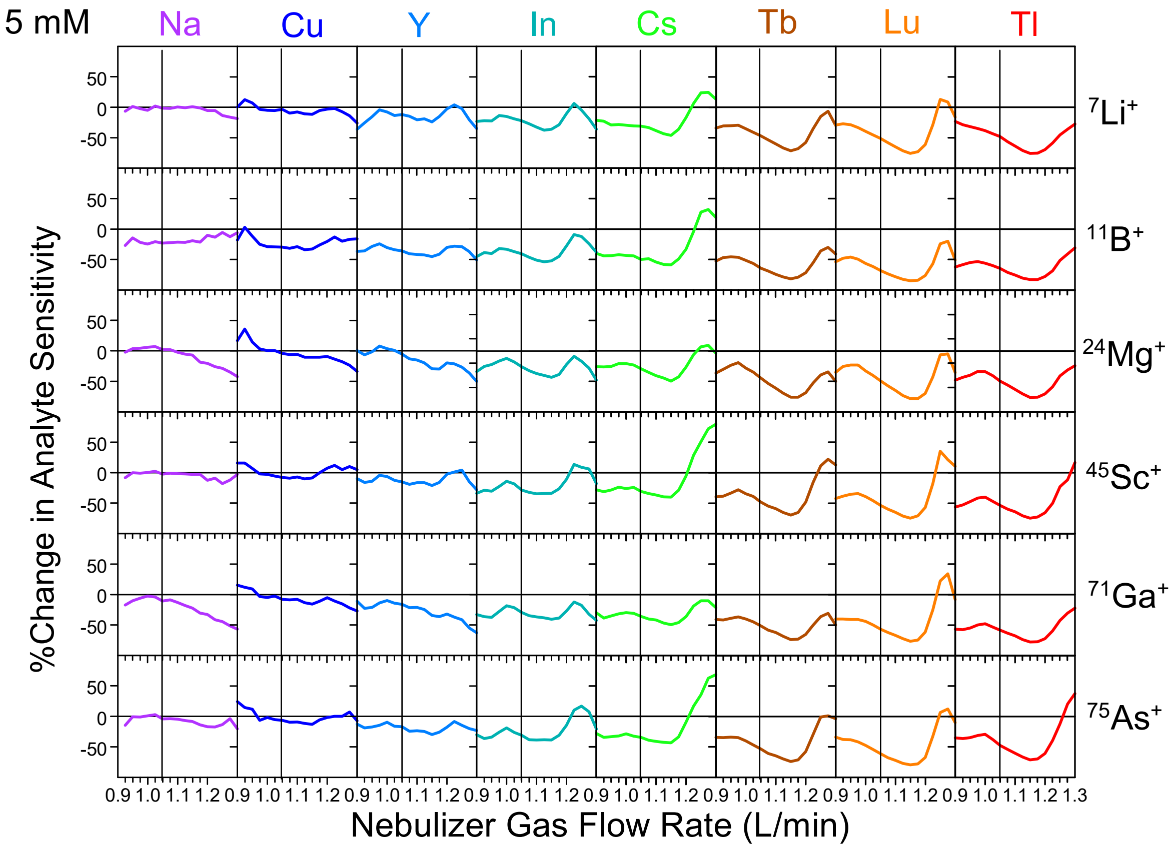

Figure S17. Matrix-induced change in analyte ion sensitivity due to 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltage. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^{+}/U^{+} signal ratio was 0.1 or less. The vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was grounded.

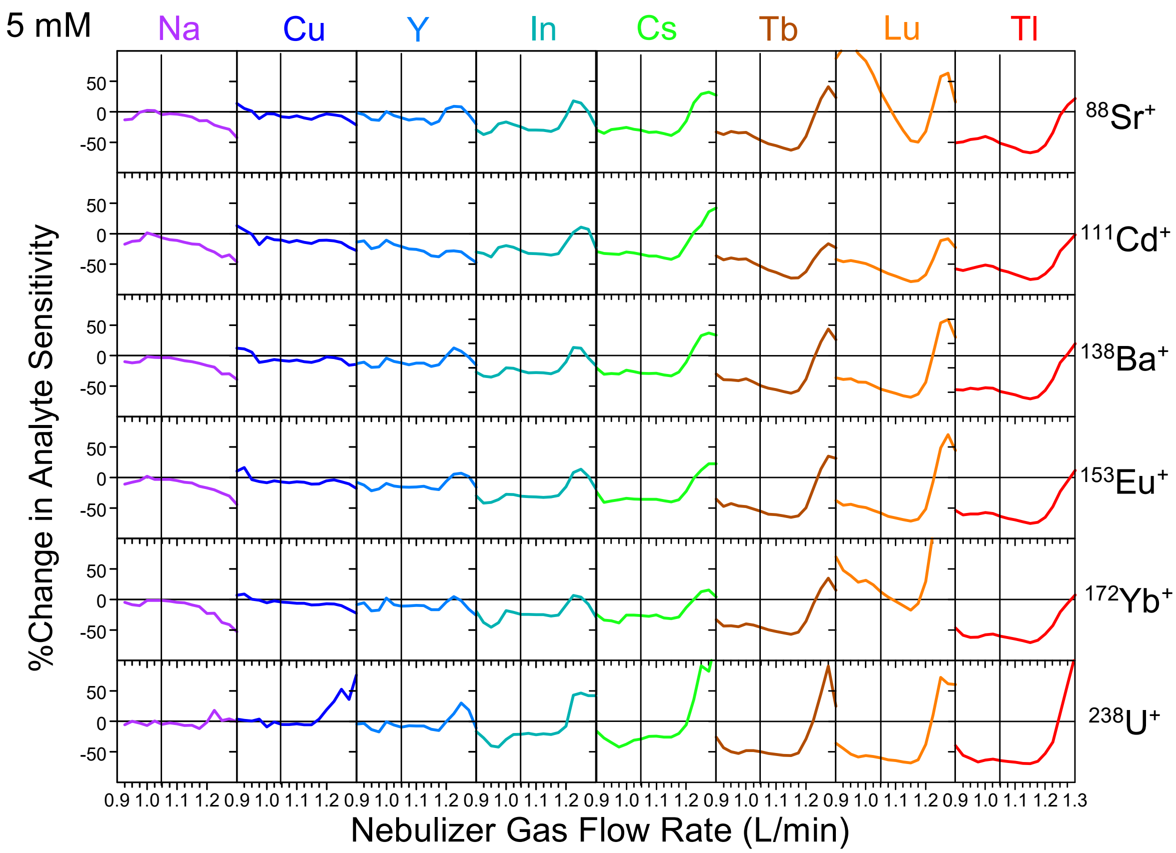

Figure S18. Matrix-induced change in analyte ion sensitivity due to 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltage. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^+/U^+ signal ratio was 0.1 or less. The vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was grounded. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

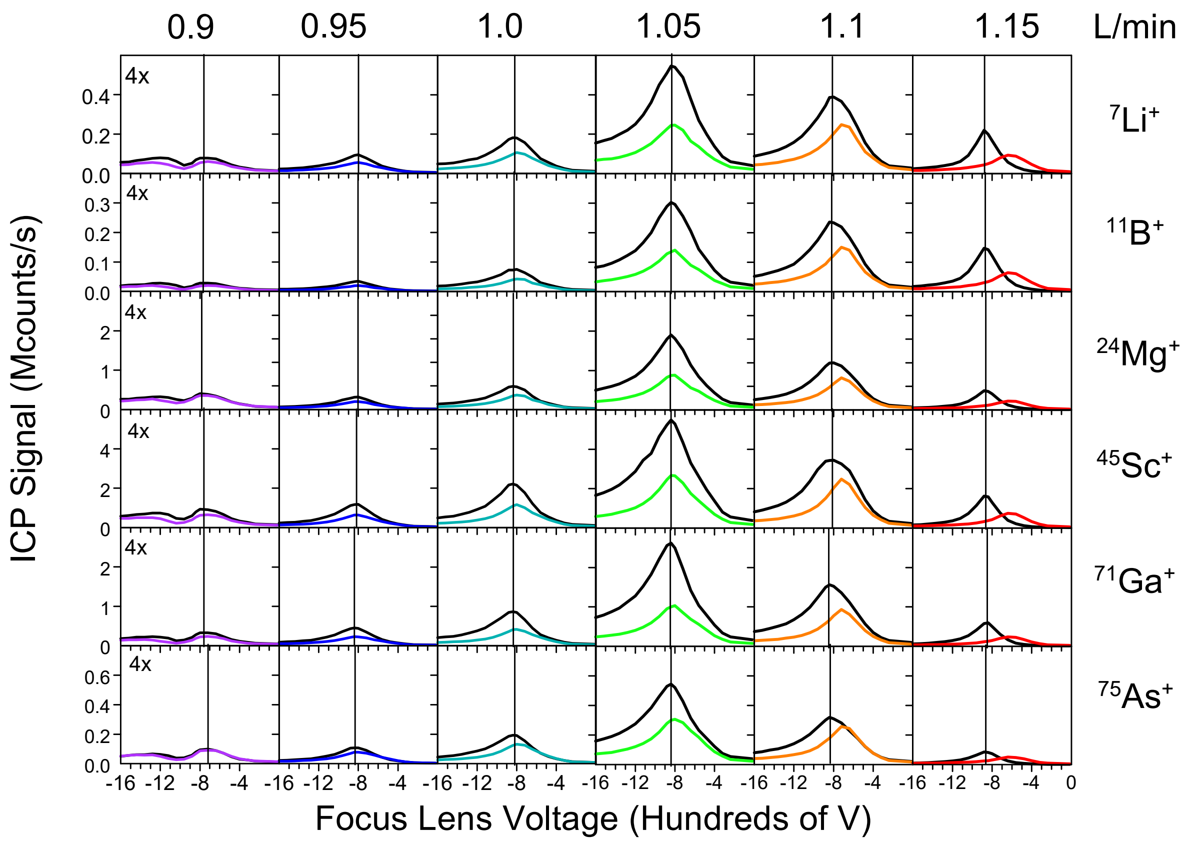

Figure S19. Analyte ion signals as a function of lens voltage in the absence (———) or presence of 5 mM Tl in solution at nebulizer gas flow rates of 0.90, 0.95, 1.00, 1.05, 1.10, and 1.15 L/min. The y-axis scale is the same for each particular analyte ion (within a row of plots), independent of nebulizer gas flow rate with the exception of the first column (0.90 L/min). All signals measured at 0.90 L/min were multiplied by 4 in order to allow the signals to be more easily seen in the plots. Typically a nebulizer gas flow rate of 1.05 L/min would be used to maximize sensitivity while keeping the UO^+/U^+ signal ratio at or below 0.1.

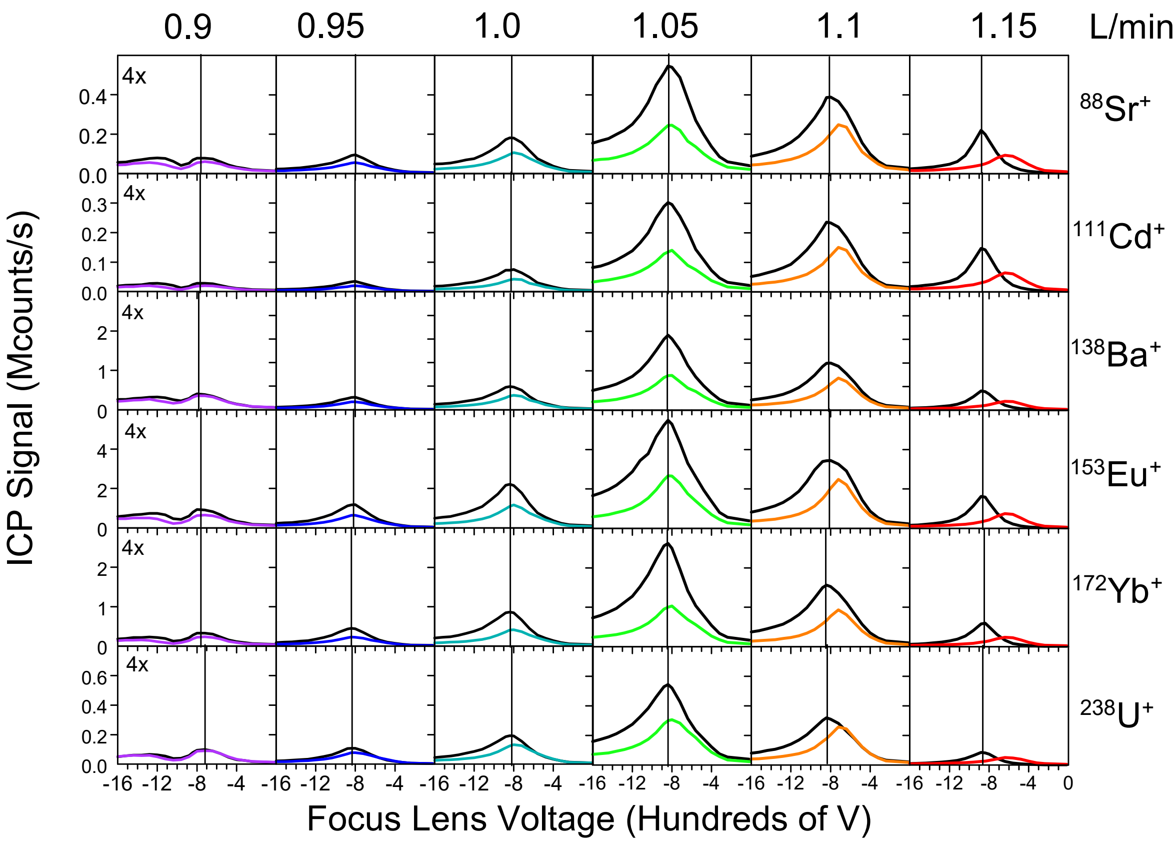

Figure S20. Analyte ion signals as a function of lens voltage in the absence (———) or presence of 5 mM Tl in solution at nebulizer gas flow rates of 0.90, 0.95, 1.00, 1.05, 1.10, and 1.15 L/min. The y-axis scale is the same for each particular analyte ion (within a row of plots), independent of nebulizer gas flow rate with the exception of the first column (0.90 L/min). All signals measured at 0.90 L/min were multiplied by 4 in order to allow the signals to be more easily seen in the plots. Typically a nebulizer gas flow rate of 1.05 L/min would be used to maximize sensitivity while keeping the UO^+/U^+ signal ratio at or below 0.1.

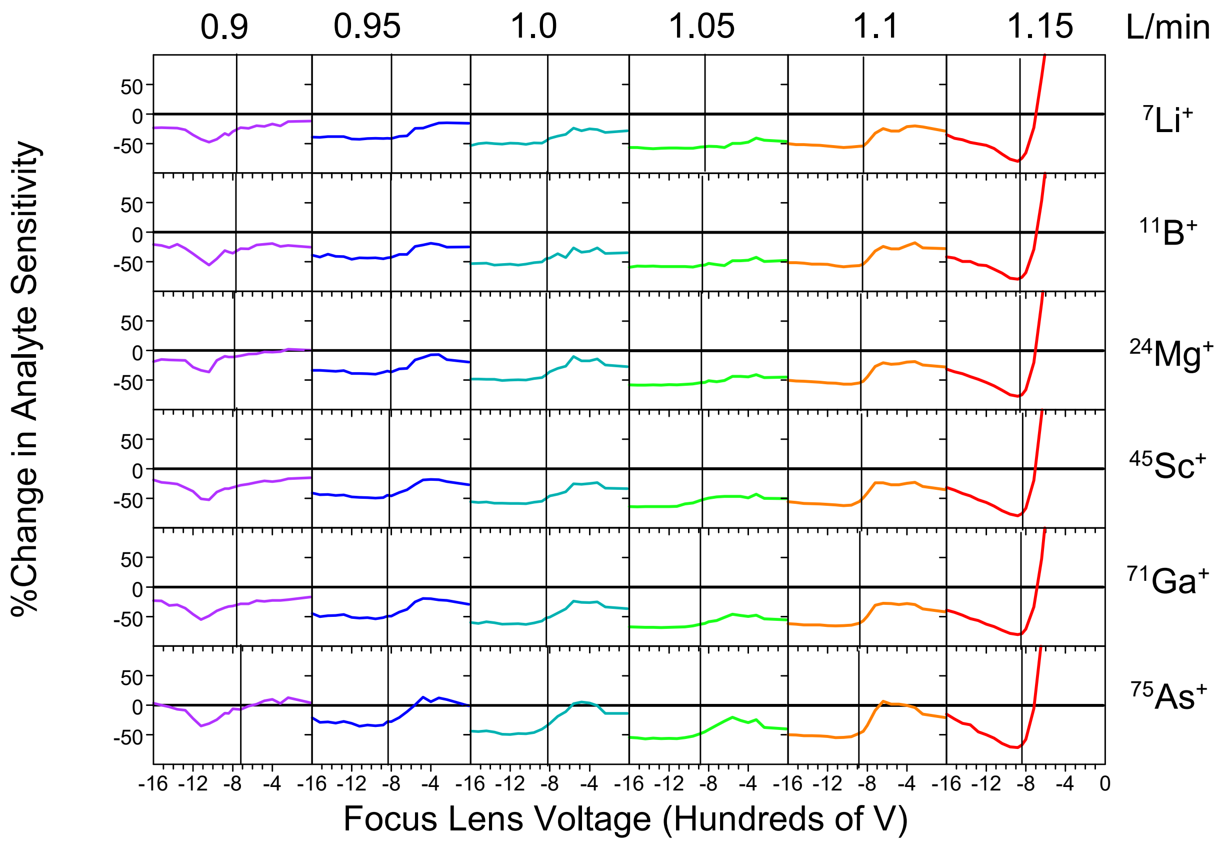

Figure S21. Matrix-induced change in analyte ion sensitivity due to the presence of 5 mM Tl in solution at nebulizer gas flow rates of 0.90, 0.95, 1.00, 1.05, 1.10, and 1.15 L/min. The y-axis scale is the same for each particular analyte ion (within a row of plots), independent of nebulizer gas flow rate with the exception of the first column (0.90 L/min). All signals measured at 0.90 L/min were multiplied by 4 in order to allow the signals to be more easily seen in the plots. Typically a nebulizer gas flow rate of 1.05 L/min would be used to maximize sensitivity while keeping the UO^{+}/U^{+} signal ratio at or below 0.1.

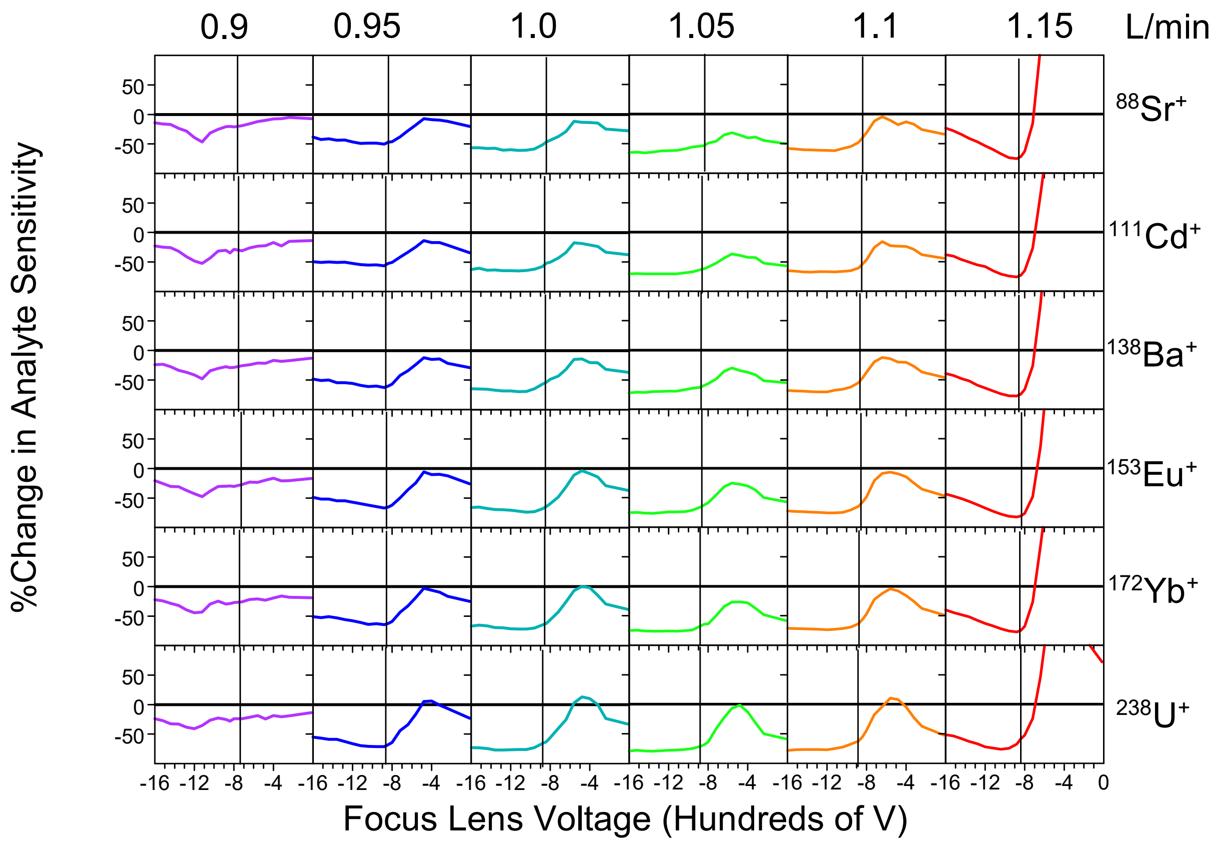

Figure S22. Matrix-induced change in analyte ion sensitivity due to the presence of 5 mM Tl in solution at nebulizer gas flow rates of 0.90, 0.95, 1.00, 1.05, 1.10, and 1.15 L/min. The y-axis scale is the same for each particular analyte ion (within a row of plots), independent of nebulizer gas flow rate with the exception of the first column (0.90 L/min). All signals measured at 0.90 L/min were multiplied by 4 in order to allow the signals to be more easily seen in the plots. Typically a nebulizer gas flow rate of 1.05 L/min would be used to maximize sensitivity while keeping the UO^+/U^+ signal ratio at or below 0.1.

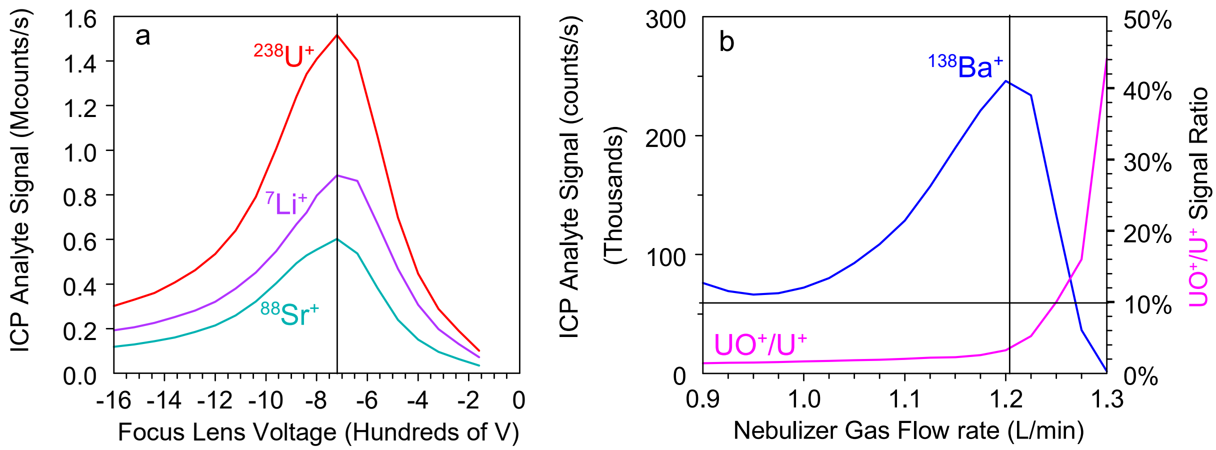

Figure S23. (a) Analyte signal ($^{7}Li^{+}$, $^{88}Sr^{+}$, $^{238}U^{+}$) from a 20 ng/mL no matrix solution as a function of focus lens voltage. (b) $^{138}Ba^{+}$ signal intensity, UO^{+}/U^{+} signal ratio as a function of nebulizer gas flow rate. Guard electrode was ungrounded.

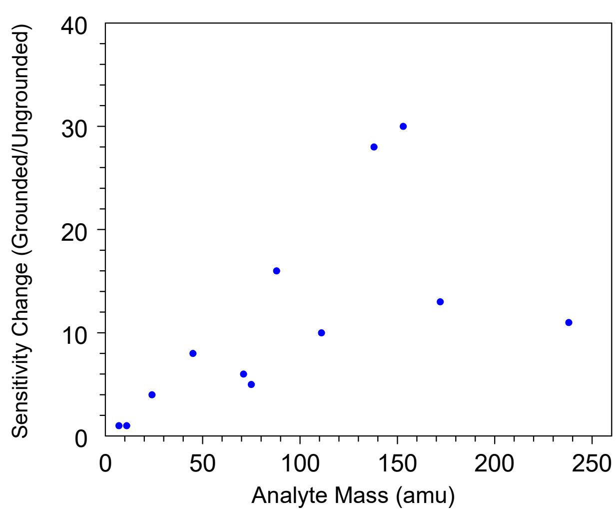

Figure S24. Analyte sensitivity ratio with guard electrode grounded/ungrounded at the optimum operating conditions without the presence of a matrix element.

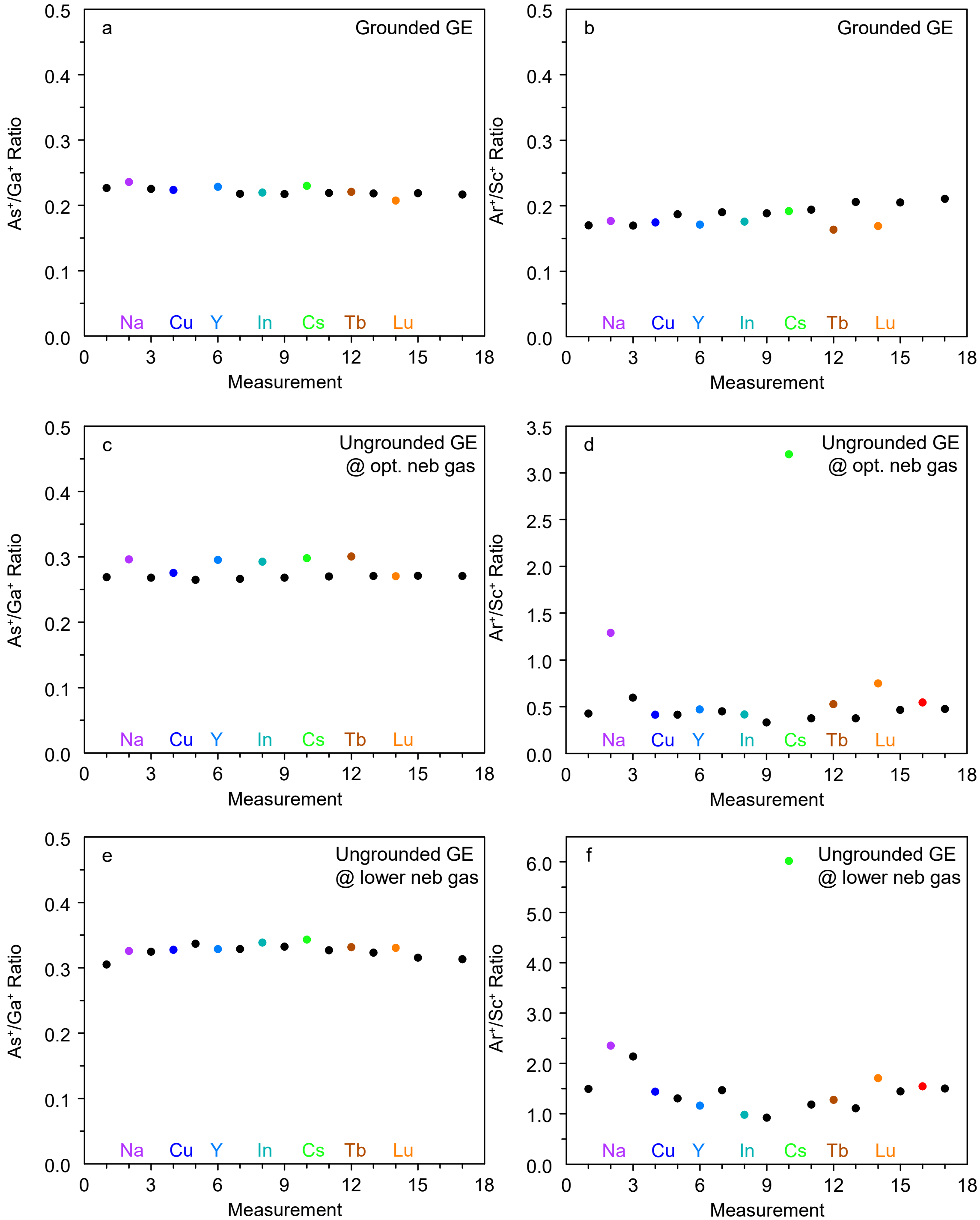

Figure S25. (a) As^+/Ga^+ and (b) Ar^+/Sc^+ signal ratio when GE was grounded, (c) As^+/Ga^+ and (d) Ar^+/Sc^+ signal ratio when GE was ungrounded at the optimum nebulizer gas flow rate, (e) As^+/Ga^+ and (f) Ar^+/Sc^+ signal ratio when GE was ungrounded at the optimum nebulizer gas flow rate when GE was grounded (1.05 L/min), which was lower than the optimum nebulizer gas flow rate when GE was ungrounded (1.2 L/min). Black symbols indicate signals produced from solutions without an added matrix element.

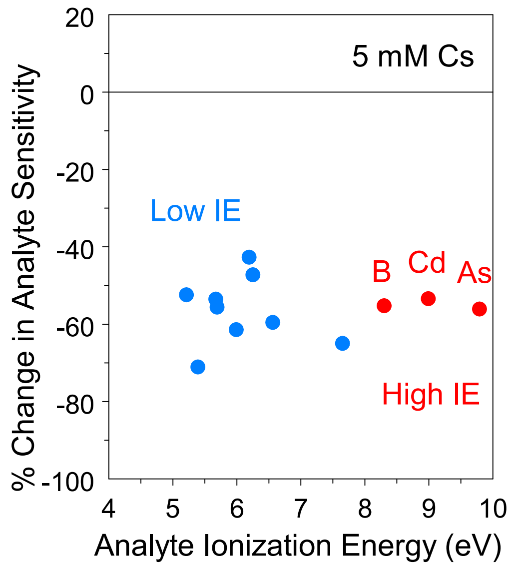

Figure S26. Change in analyte ion sensitivity in the presence of 5 mM Cs as a function of analyte ionization energy (IE) with a fixed lens voltage (−720 V) that was near optimum for all analytes at the optimum nebulizer gas flow rate (1.2 L/min). The guard electrode was ungrounded.

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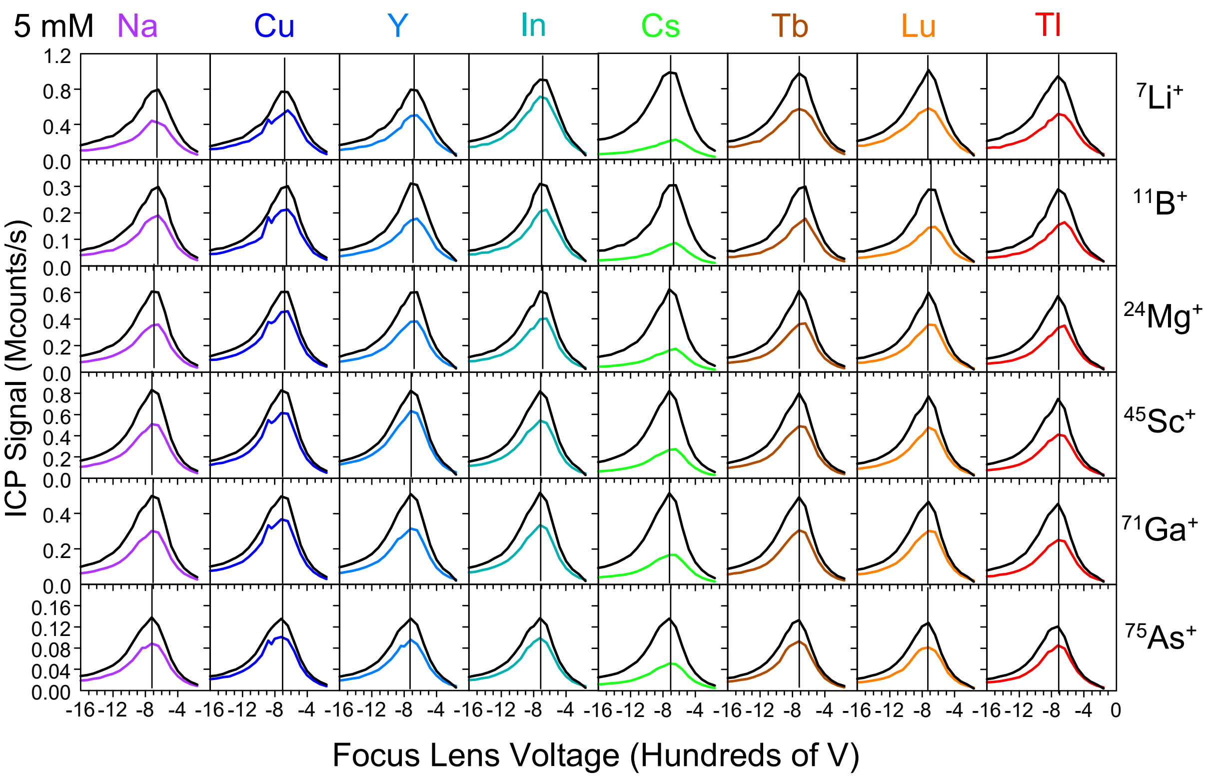

Figure S27. Analyte ion signals in the absence or presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltage. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^{+}/U^{+} signal ratio was 0.1 or less. The vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was ungrounded.

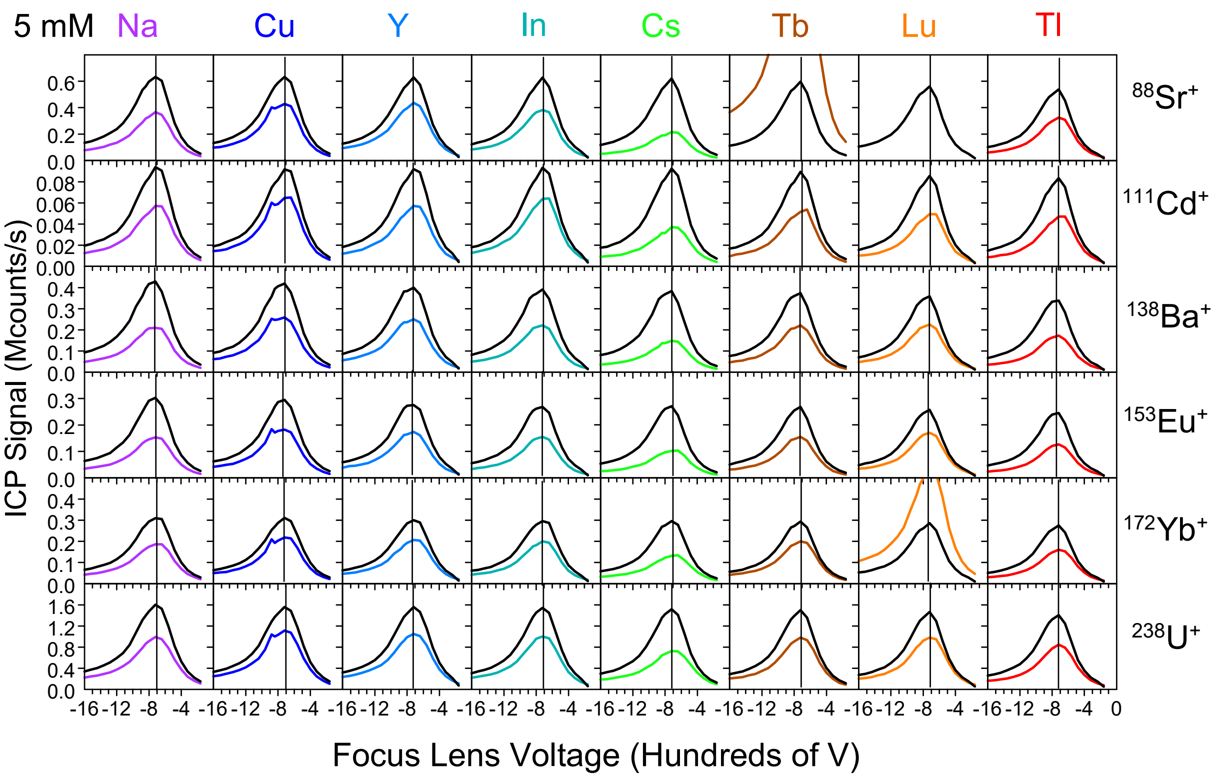

Figure S28. Analyte ion signals in the absence or presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltage. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^+/U^+ signal ratio was 0.1 or less. The vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was ungrounded. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

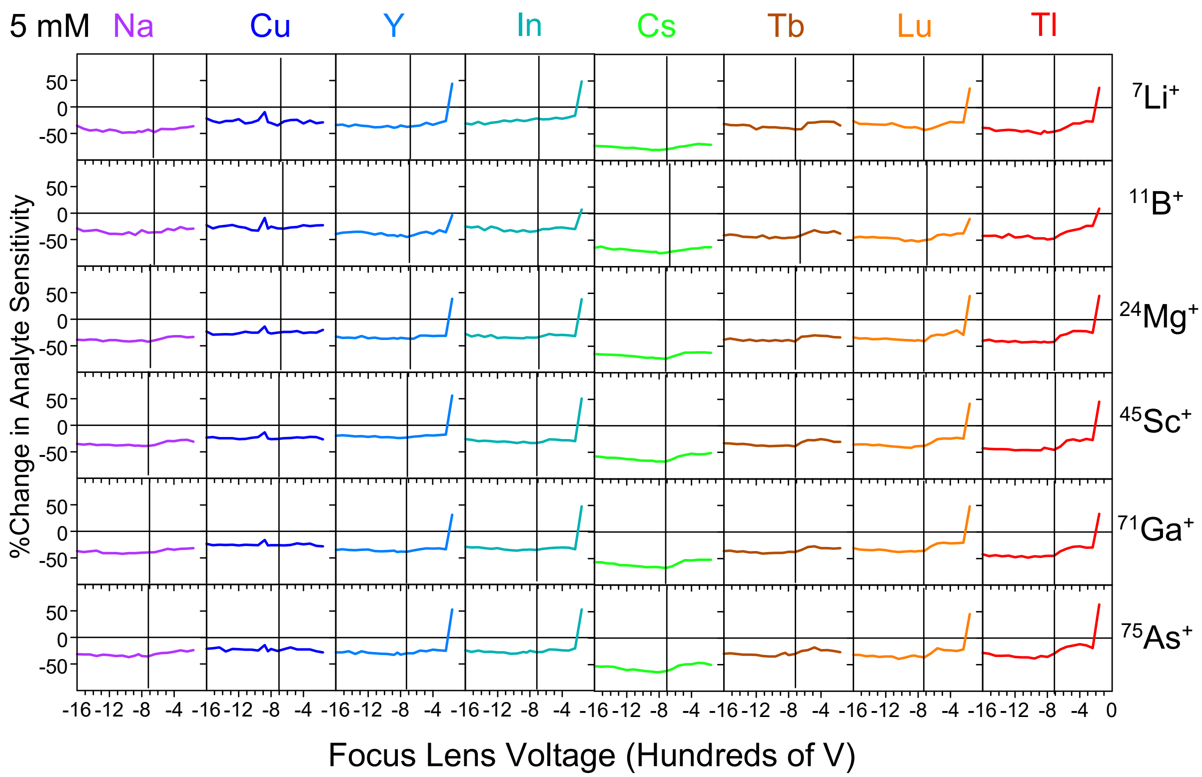

Figure S29. Matrix-induced change in analyte ion sensitivity ($^{7}Li^{+}$, $^{45}Sc^{+}$, $^{71}Ga^{+}$, $^{111}Cd^{+}$, $^{138}Ba^{+}$, $^{153}Eu^{+}$, $^{238}U^{+}$) due to the presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltage. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^{+}/U^{+} signal ratio was 0.1 or less. Vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was ungrounded.

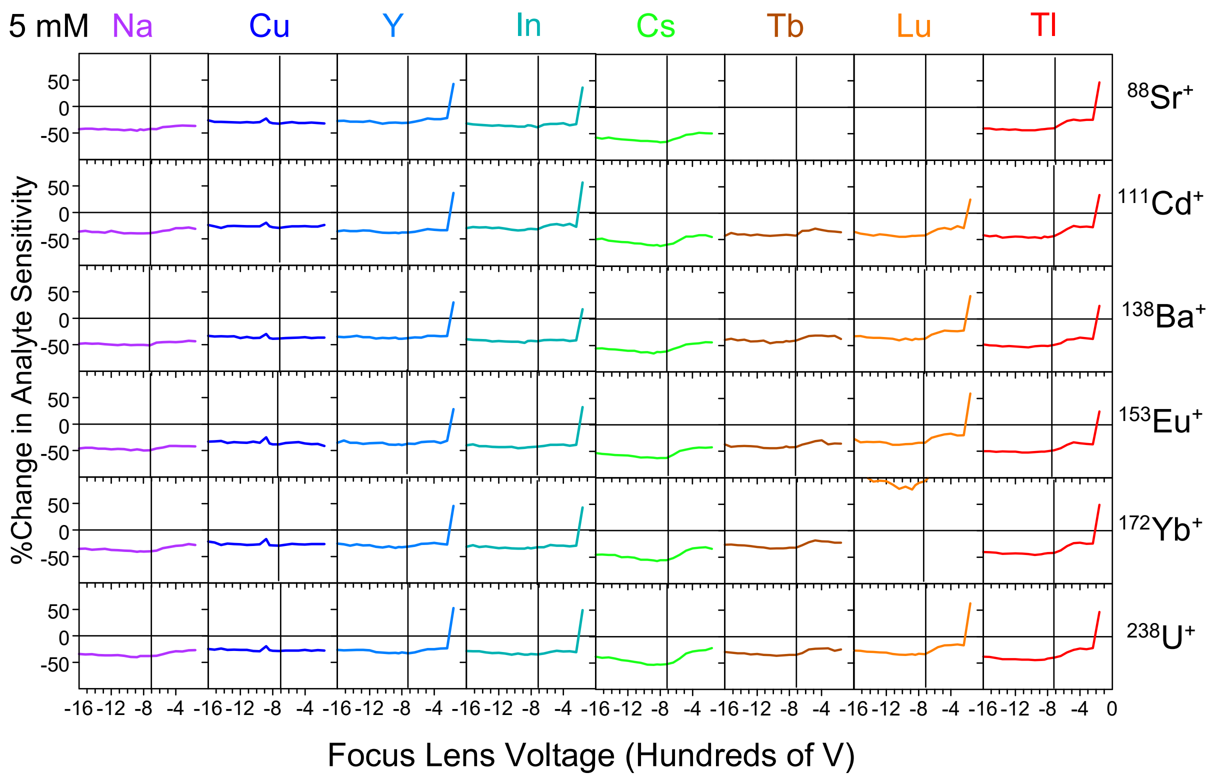

Figure S30. Matrix-induced change in analyte ion sensitivity ($^{7}Li^{+}$, $^{45}Sc^{+}$, $^{71}Ga^{+}$, $^{111}Cd^{+}$, $^{138}Ba^{+}$, $^{153}Eu^{+}$, $^{238}U^{+}$) due to the presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of lens voltage. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^{+}/U^{+} signal ratio was 0.1 or less. Vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was ungrounded. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

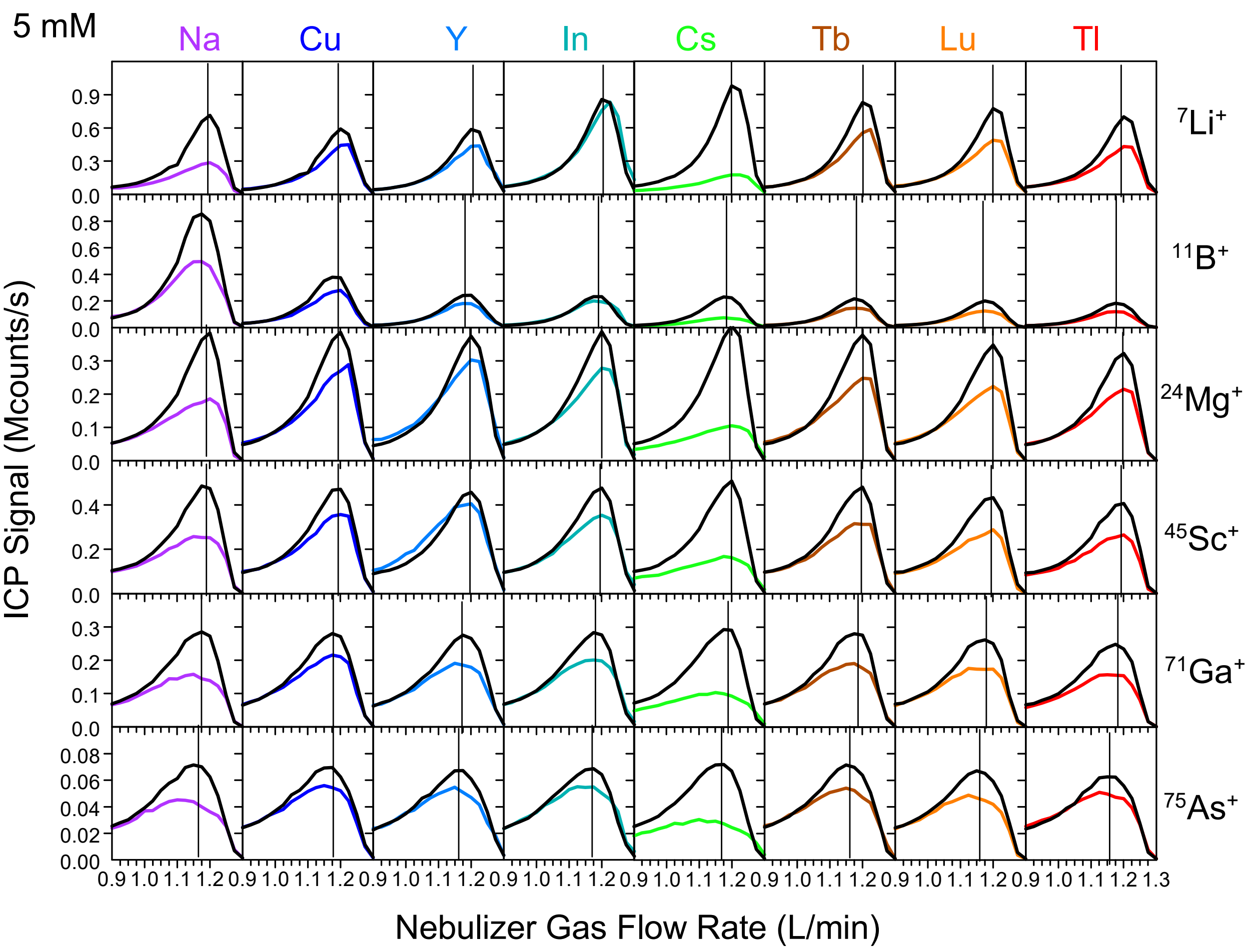

Figure S31. Analyte ion signals in the absence or presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of nebulizer gas flow rate. Optimum lens voltage (−720 V) for maximum sensitivity in the absence of a matrix element while the UO^{+}/U^{+} signal ratio was 0.1 or less. The guard electrode inserted between torch and coil was ungrounded.

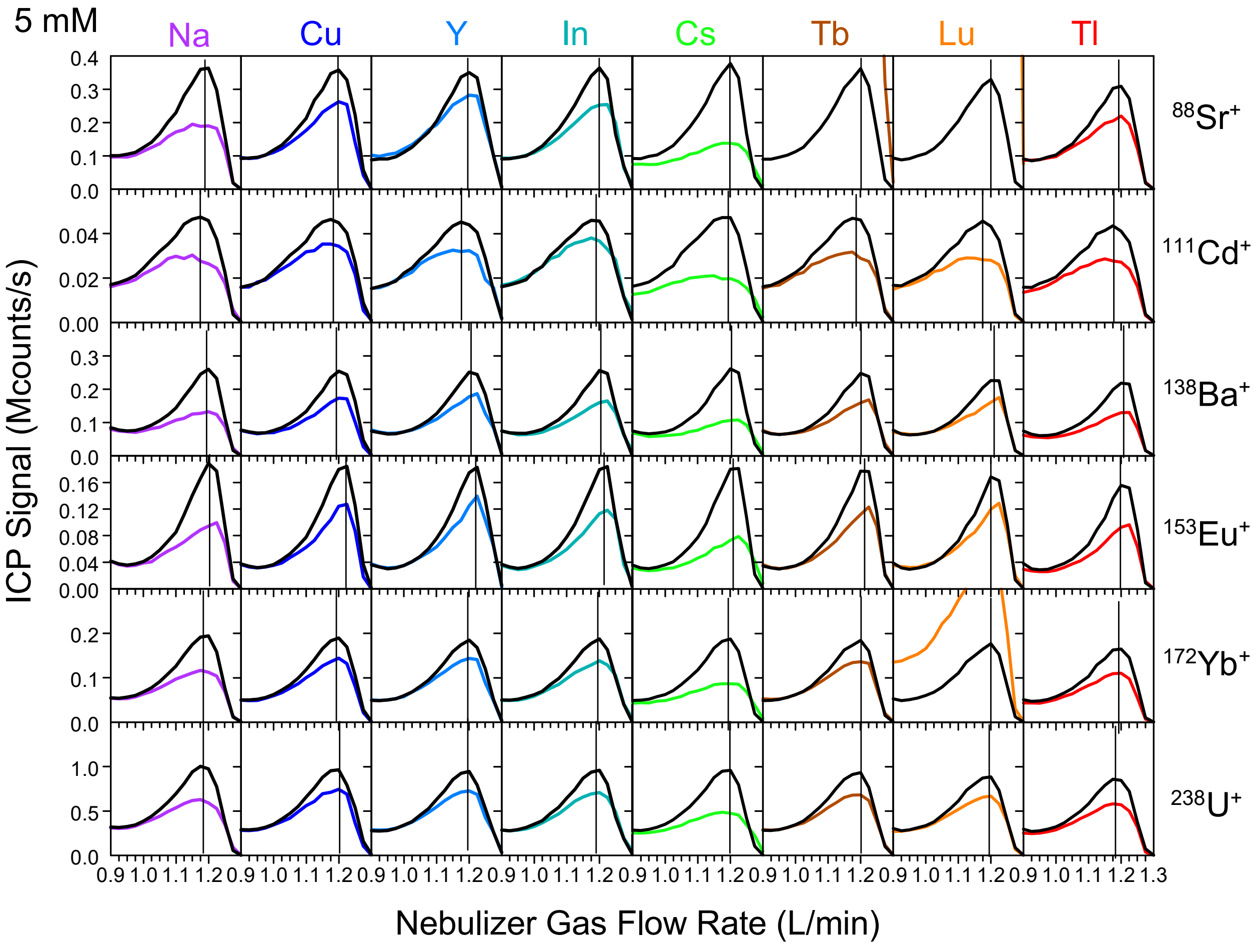

Figure S32. Analyte ion signals in the absence or presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of nebulizer gas flow rate. Optimum lens voltage (−720 V) for maximum sensitivity in the absence of a matrix element while the UO^+/U^+ signal ratio was 0.1 or less. The guard electrode inserted between torch and coil was ungrounded. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

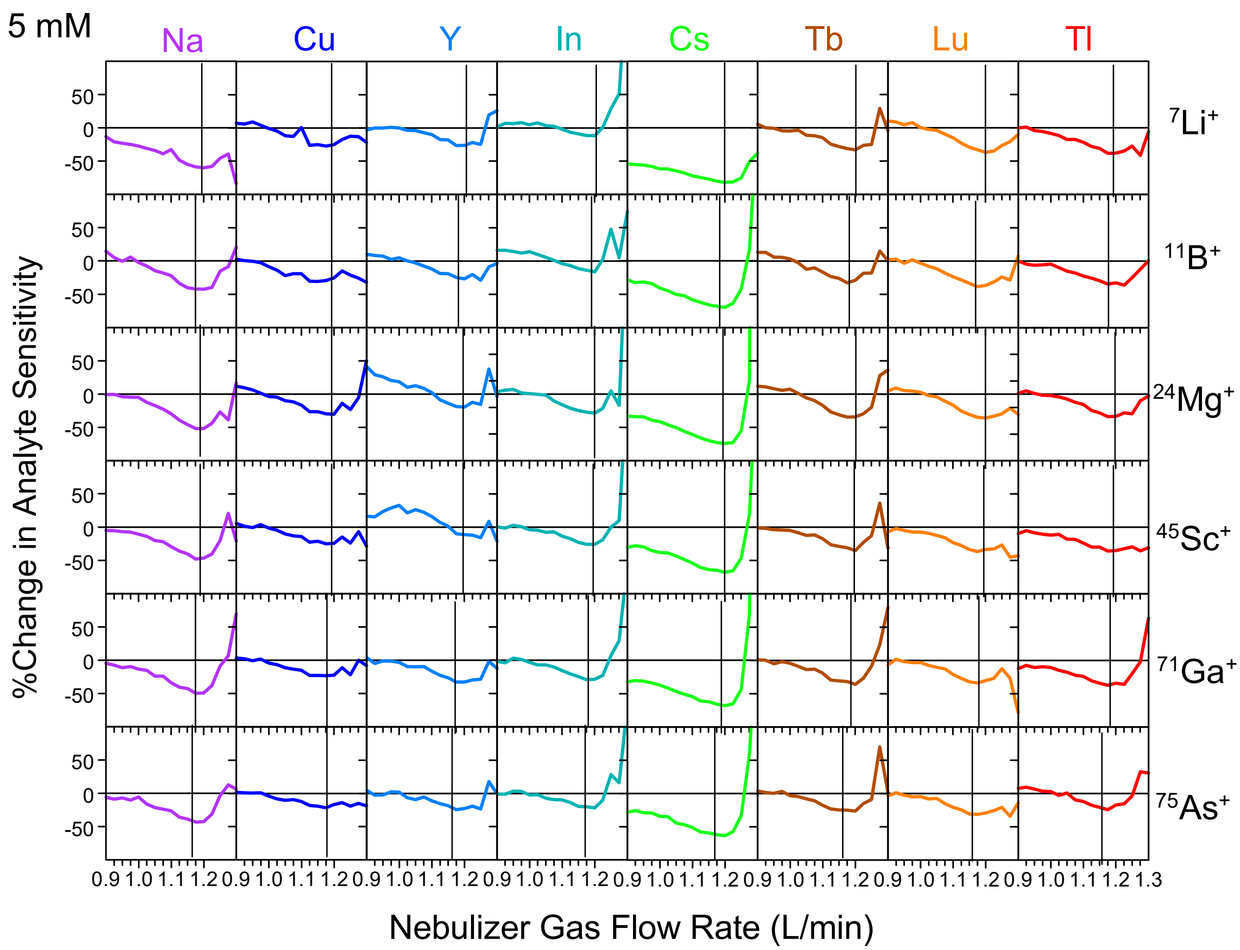

Figure S33. Matrix-induced change in analyte ion sensitivity due to the presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of nebulizer gas flow rate. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^+/U^+ signal ratio was 0.1 or less. Vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was ungrounded.

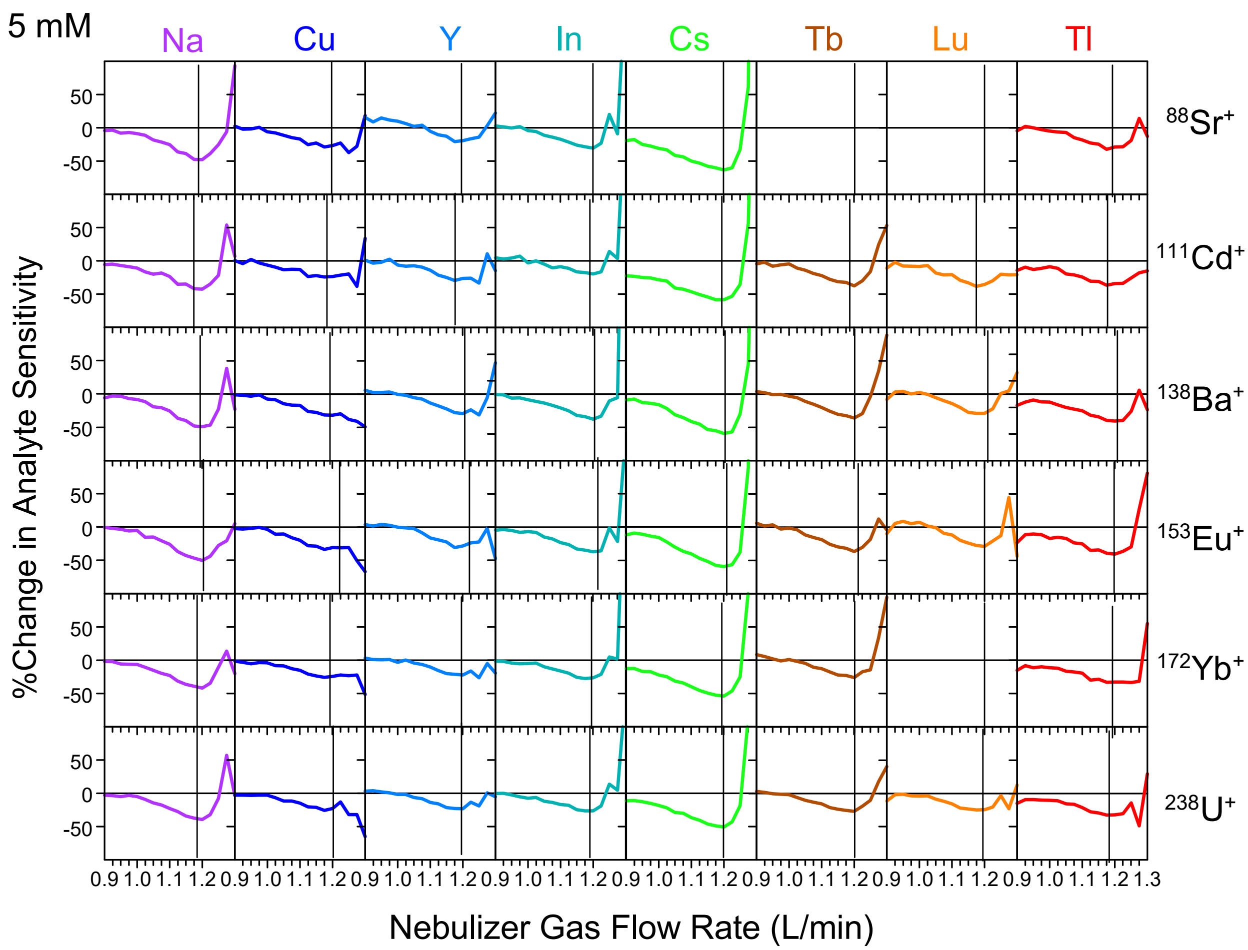

Figure S34. Matrix-induced change in analyte ion sensitivity due to the presence of 5 mM matrix element (Na, Cu, Y, In, Cs, Tb, Lu, or Tl; lowest to highest matrix ion mass) in solution as a function of nebulizer gas flow rate. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^+/U^+ signal ratio was 0.1 or less. Vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was ungrounded. The Lu solution produced a significant Lu^{2+} signal at same m/z as Sr^{2+}. The Lu solution contained Yb contamination that contributes a significant signal at m/z 172.

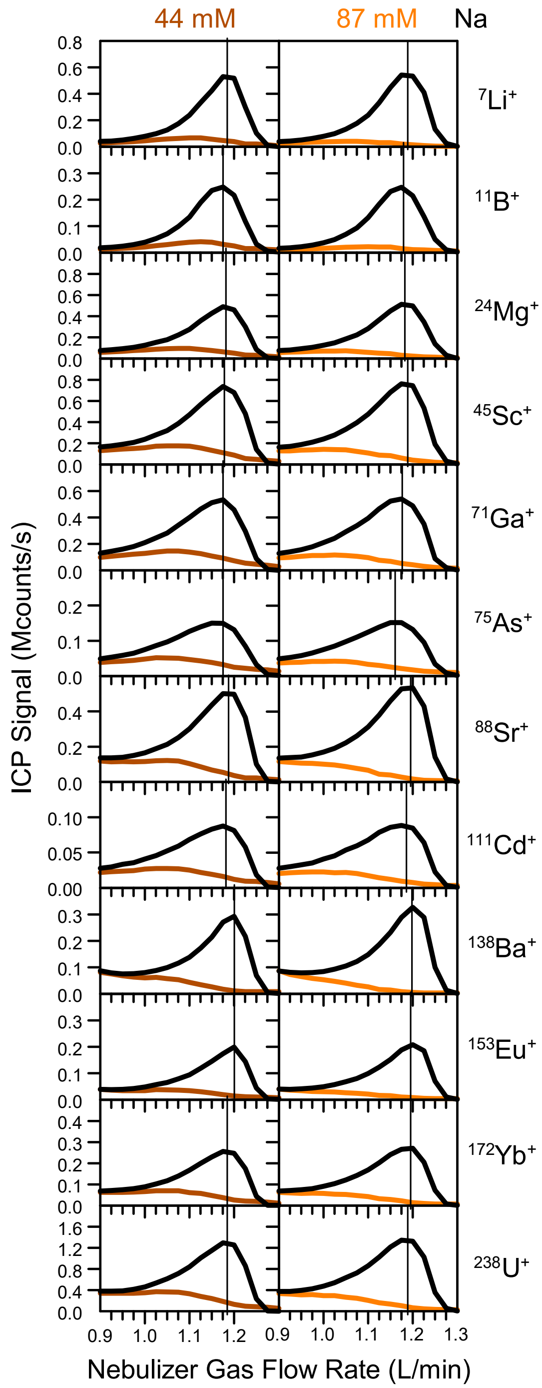

Figure S35. Matrix-induced change in analyte ion sensitivity due to the presence of 44mM and 87 mM Na in solution as a function of nebulizer gas flow rate. Optimum nebulizer gas flow rate for maximum sensitivity in the absence of a matrix element while the UO^{+}/U^{+} signal ratio was 0.1 or less. Vertical line in each plot indicates the optimum lens voltage for maximum sensitivity in the absence of a matrix element. The guard electrode was ungrounded.