Challenge
Determination of 28 elements, mostly in trace concentrations, in samples with high matrix load and various interferences

Solution
Integrated collision reaction cell for targeted removal of interferences, patented 3D focusing of ions for high sensitivity

Intended audience
Clinical diagnostics laboratories, research, pharma

Determination of Trace Elements in Blood Serum and Plasma Using ICP-MS Applying Ready-to-Use IVD Kits

Introduction

The determination of trace elements in human samples has become a standard method in medical diagnostics. The most common applications are analyses of whole blood, serum, plasma, and urine for various elements. The information that can be obtained from the elemental concentration varies depending on the element and sample type.

Essential trace elements such as copper, zinc, selenium, or iodine are mainly used as biomarkers. Certain diseases are known to cause deficiency or excess of certain trace elements, thus, if the concentration is outside the reference range, this could be a valuable indication for diagnosis. On the other hand, occupational medicine regularly analyzes clinical samples to monitor occupational exposure to toxic elements such as lead, chromium, cadmium, nickel, or mercury. Further possible applications include the monitoring of treatments (e.g., platinum determination after administration of platinum-based cytostatics) and implants (e.g., potential migration of titanium, chromium, or cobalt from implants into the human body).

Due to the high number of elements and sometimes very low concentrations that must be determined in human samples, inductively coupled plasma-mass spectrometry (ICP-MS) is the method of choice for this application. Its main advantages are multi-element capability, which allows short measurement times, and thus, high sample throughput and better sensitivity for most elements compared to other techniques for elemental analysis.

The determination of trace elements in human samples by ICP-MS in medical laboratories is subject to the guidelines of the EU regulation (EU) 2017/746 on *in vitro* diagnostic medical devices[1], IVDR, which has become active in May 2022. While no standardized methods dedicated to ICP-MS exist for this application, the IVDR requires laboratories to

use kits certified for the respective analysis in accordance with IVDR wherever possible.
The use of so-called in-house IVD or laboratory developed tests (LDT), i.e., test methods developed in the respective laboratory itself, is only permitted for analyses for which no certified kit is available or existing kits do not offer an equivalent performance level. This must be justified in the laboratory's documentation from May 26, 2028 on.[2]

This work describes the application of a „Kit for trace element analysis in serum and plasma by ICP-MS/MS", which carries CE and IVDR-ready labels, using the PlasmaQuant MS ICP-MS from Analytik Jena. It will be shown that the applicability of the kit is not limited to instruments with MS/MS technology. The patented integrated collision reaction cell allows effective interference management, while the patented 3D focusing of the ion beam by means of the ReflexION ion mirror provides the necessary sensitivity to accurately determine even the lowest elemental concentrations.

The IVD kit contains all solutions and calibrators that are needed for the analysis of 28 trace elements in serum and plasma using ICP-MS equipped with a rapid sample introduction system. The only preparation steps needed are the reconstitution of the calibrators and the dilution of samples and calibrators with the diluent.

Materials and Methods

Samples and reagents

- Ultrapure water type I (>18.2 MΩ cm, ELGA Purelab®, Veolia Water Technologies Germany GmbH, Celle)
- ClinMass® ICP-MS/MS Complete Kit (RECIPE Chemicals + Instruments GmbH, Munich, Germany), consisting of:
  - Serum Calibrator Set Lot 2131 (Level 1–4)
  - Diluting Solution D
  - Autosampler Washing Solution
  - FAST Carrier Solution
  - Internal Standard IS
  - Sample Preparation Vials
  - Manual
- Injector Washing Solution (RECIPE Chemicals + Instruments GmbH, Munich, Germany)
- ClinChek® Serum Control Level I, II Lot 2062 (RECIPE Chemicals + Instruments GmbH, Munich, Germany)
- ClinChek® Plasma Control Level I, II Lot 2461 (RECIPE Chemicals + Instruments GmbH, Munich, Germany)
- Seronorm™ Trace Elements Serum L-1 Lot 1309438, L-2 Lot 1309416 (SERO AS, Billingstad, Norway)
- Serum samples, prepared from different sample pools

Sample preparation

The lyophilized control materials were reconstituted with ultrapure water following the manufacturers' information. Reconstituted and fresh samples were diluted tenfold with Diluting Solution D prior to the measurement in accordance with the manual.

Calibration

The lyophilized serum calibrators were reconstituted with ultrapure water following the manufacturer's information and subsequently diluted tenfold with Diluting solution D prior to the measurement in accordance with the manual. Diluting Solution D was also used as the calibration blank.

Instrumentation

A PlasmaQuant MS Q ICP-MS (Analytik Jena GmbH+Co. KG, Jena, Germany) was used for the analyses. Further details on the configuration of the system are listed in Table 1.

Table 1: Instrument configuration

Parameter	Specification
Nebulizer	SeaSpray (0.4 mL/min)
Spray chamber	Scott double-pass, Peltier cooled
Torch	Fassel torch with 2.4 mm injector
Cones	Nickel sampler and skimmer
Autosampler	ASX-560 (CETAC) with enclosure, HEPA filter, and ASXpress Plus (CETAC) rapid sample introduction system

The rinse solution of the autosampler, the carrier solution of the rapid sample introduction system, and the internal standard solution were provided with the IVD kit. The internal standard solution was added on-line to the sample solution via the peristaltic pump of the PlasmaQuant MS. Black/black PVC tubings (0.76 mm ID) were used to introduce sample and internal standard solutions, diluting the samples further by a factor of 2 and resulting in an effective dilution factor of 20.

Method parameters

The method parameters used are given in Table 2.

Table 2: General method parameters

Parameter	Specification
Plasma gas flow	9.0 L/min
Auxiliary gas flow	1.20 L/min
Sheath gas flow	0.00 L/min
Nebulizer gas flow	1.01 L/min
RF power	1.30 kW
Sampling depth	5.5 mm
Pump rate	12 rpm
iCRC gas, flow	Hydrogen: 80 mL/min (H_2 mode); 200 mL/min (H_2B) Helium: 120 mL/min (He120); 180 mL/min (He180)
Stabilization delay	40 s (H_2); 15 s (H_2B); 15 s (nG); 10 s (He120); 10 s (He180)*
Spray chamber temperature	3 °C
Skimmer bias (BOOST)	4 V (H_2B)
Points per peak	1 (Peak hopping)
Scans per replicate	10
Replicates	3

* Switching times of < 5 s can be chosen between different measurement modes. To obtain the best measuring precision possible, longer stabilization delays were used achieving an average RSD of < 2%.
H_2 – hydrogen mode; H_2B – hydrogen boost mode; nG – no gas; He120 – helium mode 120 mL/min; He180 – helium mode 180 mL/min

To eliminate matrix- or plasma-based polyatomic interferences, helium as a collision gas and hydrogen as a reaction gas were introduced into Analytik Jena's patented integrated collision reaction cell (iCRC). To achieve maximum sensitivity and lowest limits of detection for elements measured in reaction mode, the patented BOOST technology was used. In BOOST mode, a positive voltage is applied to the back of the skimmer cone. This enables compensating for the loss of sensitivity by collision of analytes with gas molecules in reaction gas modes with high flow rates. Isotopes which are not interfered by polyatomic interferences were measured in no gas mode. In total, five different measurement modes were used in this method: hydrogen, hydrogen boost, no gas, and two helium modes with flow rates of 120 mL/min and 180 mL/min, respectively.

Evaluation parameters

The choice of isotopes, measurement modes, and dwell times is shown in Table 3. For Hg, the sum of the isotopes ^{199}Hg, ^{200}Hg, ^{201}Hg, and ^{202}Hg was used to achieve a higher sensitivity. This can be done because no interferences are expected on any of these isotopes. For internal standards, dwell times of 20 ms in hydrogen- and no gas modes, and 50 ms in helium modes were chosen. The isotopes chosen were ^{45}Sc, ^{74}Ge, ^{103}Rh, and ^{187}Re.
Using the ASXPress Plus sample introduction system, a total measuring time of approx. 2.5 min for all elements listed in Table 3 could be achieved including sample uptake, measurement, and rinsing.

Table 3: Element specific method parameters

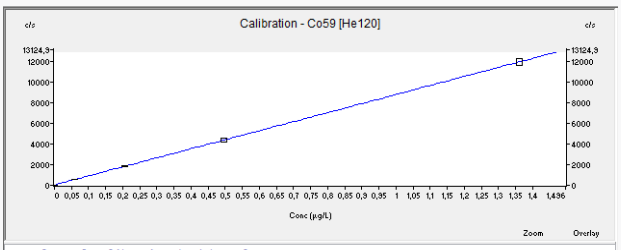
Element	Isotope	Expected polyatomic interferences	Mode	Correction equation	Dwell time [ms]	Internal standard
Aluminum	^{27}Al	$^{13}C^{14}N^+$, $^{11}B^{16}O^+$	He120		50	^{45}Sc
Antimony	^{121}Sb		nG		20	Interpolate
Arsenic	^{75}As	$^{40}Ar^{35}Cl^+$, $^{74}Ge^1H^+$	H_2		50	^{74}Ge
Barium	^{137}Ba		nG		20	Interpolate
Beryllium	^{9}Be		nG		50	^{45}Sc
Bismuth	^{209}Bi		nG		20	^{187}Re
Cadmium	^{114}Cd		nG	- 0.0268 * ^{118}Sn	20	Interpolate
Chromium	^{52}Cr	$^{40}Ar^{12}C^+$, $^{36}Ar^{16}O^+$, $^{38}Ar^{14}N^+$	H_2B		50	^{74}Ge
Cobalt	^{59}Co	$^{24}Mg^{35}Cl^+$, $^{43}Ca^{16}O^+$, $^{45}Sc^{14}N^+$	He120		50	Interpolate
Copper	^{65}Cu	$^{40}Ar^{25}Mg^+$	He120		50	^{74}Ge
Gold	^{197}Au		nG		20	^{187}Re
Iodine	^{127}I		nG		20	Interpolate
Iron	^{56}Fe	$^{40}Ar^{16}O^+$	H_2B		20	^{74}Ge
Lithium	^{7}Li		nG		20	^{45}Sc
Magnesium	^{25}Mg	$^{12}C^{13}C^+$	He120		50	^{45}Sc
Manganese	^{55}Mn	$^{39}K^{16}O^+$, $^{40}Ar^{15}N^+$, $^{37}Cl^{18}O^+$	He120		50	Interpolate
Mercury	$^{199\text{-}202}Hg$		nG		20 each	^{187}Re
Molybdenum	^{98}Mo		nG	- 0.1111 * ^{101}Ru	20	Interpolate
Nickel	^{60}Ni	$^{24}Mg^{36}Ar^+$, $^{44}Ca^{16}O^+$, $^{23}Na^{37}Cl^+$	He120		50	Interpolate
Palladium	^{108}Pd		nG	- 0.07031 * ^{111}Cd	20	Interpolate
Platinum	^{195}Pt		nG		20	^{187}Re
Selenium	^{78}Se	$^{40}Ar^{38}Ar^+$, $^{38}Ar^{40}Ca^+$	H_2B	- 0.03043 * ^{83}Kr	50	^{74}Ge
Silver	^{107}Ag		nG		20	Interpolate
Thallium	^{205}Tl		nG		20	^{187}Re
Tin	^{120}Sn		nG	- 0.01429 * ^{125}Te	20	Interpolate
Titanium	^{49}Ti	$^{35}Cl^{14}N^+$, $^{37}Cl^{12}C^+$, $^{33}S^{16}O^+$, $^{31}P^{18}O^+$	He180		200	Interpolate
Vanadium	^{51}V	$^{35}Cl^{16}O^+$, $^{38}Ar^{13}C^+$, $^{40}Ar^{11}B^+$	He180		200	Interpolate
Zinc	^{66}Zn	$^{35}Cl^{31}P^+$	He120		50	^{74}Ge

H_2 – hydrogen mode; H_2B – hydrogen boost mode; nG – no gas; He120 – helium mode 120 mL/min; He180 – helium mode 180 mL/min

Results and Discussion

Calibration

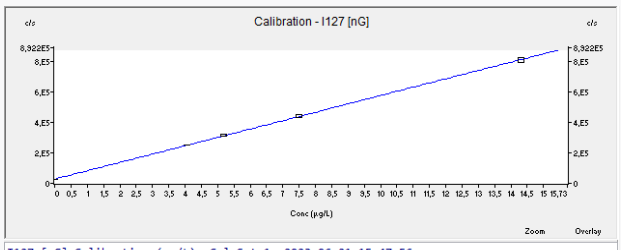
Examples of calibration curves and parameters of Co, I, Hg, and Se are shown in Figure 1. Correlation coefficients were > 0.999 for all isotopes with deviations of less than 5% between the calculated and the expected concentrations for all calibration levels (%Error).



Co59 [He120] Calibration (µg/L), Cal Set 1, 2023-06-21 15:47:56

Soln Type	c/s	SD(c/s)	%RSD	Std Conc	Calc Conc	Error	%Error	Flags
Blank	8	2,5	32,83	0,0000	-0,0038	-0,0038	-	
Level 1	633	18,5	2,93	0,0601	0,0598	-0,0003	-0,57	
Level 2	2400	64,5	2,69	0,2050	0,2098	0,0048	2,33	
Level 3	6232	180,8	2,90	0,4960	0,4960	0,0000	0,01	
Level 4	18222	313,4	1,72	1,3600	1,3593	-0,0007	-0,05	

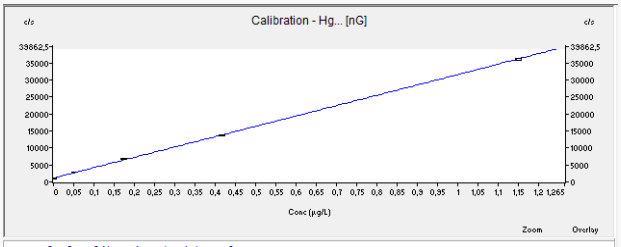
Curve Fit: Linear, Weighted Fit: No, Thru Blank: No
Correlation Coefficient: 0,999985
Limit of detection: 0,0009 µg/L
Limit of quantitation: 0,0029 µg/L
Blank Equivalent Concentration: 0,0009 µg/L
Calibration Equation: c/s = (7,7 + 32,91 + 8748*conc)*[I/S Ratio]



I127 [nG] Calibration (µg/L), Cal Set 1, 2023-06-21 15:47:56

Soln Type	c/s	SD(c/s)	%RSD	Std Conc	Calc Conc	Error	%Error	Flags
Blank	23825	64,4	0,27	0,0000	-0,0683	-0,0683	-	
Level 1	247677	1410,6	0,57	4,0700	4,0621	-0,0079	-0,19	
Level 2	324908	4345,8	1,34	5,1900	5,2721	0,0821	1,58	
Level 3	468986	9539,9	2,03	7,4800	7,5255	0,0455	0,61	
Level 4	875346	13548,9	1,55	14,3000	14,2487	-0,0513	-0,36	

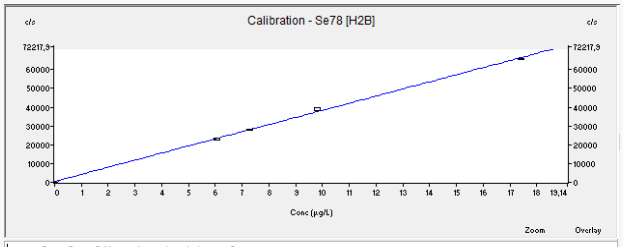
Curve Fit: Linear, Weighted Fit: No, Thru Blank: No
Correlation Coefficient: 0,999927
Limit of detection: 0,0035 µg/L
Limit of quantitation: 0,0117 µg/L
Blank Equivalent Concentration: 0,4328 µg/L
Calibration Equation: c/s = (23824,7 + 3757 + 54990*conc)*[I/S Ratio]



Hg... [nG] Calibration (µg/L), Cal Set 1, 2023-05-15 16:04:51

Soln Type	c/s	SD(c/s)	%RSD	Std Conc	Calc Conc	Error	%Error	Flags
Blank	1010	15,0	1,49	0,0000	-0,0055	-0,0055	-	
Level 1	2669	85,6	3,21	0,0527	0,0545	0,0018	3,45	
Level 2	6532	56,5	0,87	0,1740	0,1826	0,0086	4,94	
Level 3	13412	58,3	0,43	0,4180	0,4124	-0,0056	-1,35	
Level 4	34833	278,5	0,80	1,1500	1,1507	0,0007	0,06	

Curve Fit: Linear, Weighted Fit: No, Thru Blank: No
Correlation Coefficient: 0,999922
Limit of detection: 0,0015 µg/L
Limit of quantitation: 0,0049 µg/L
Blank Equivalent Concentration: 0,0330 µg/L
Calibration Equation: c/s = (1010,3 + 166,1 + 30470*conc)*[I/S Ratio]



Se78 [H2B] Calibration (µg/L), Cal Set 1, 2023-06-22 16:57:32

Soln Type	c/s	SD(c/s)	%RSD	Std Conc	Calc Conc	Error	%Error	Flags
Blank	72	6,8	9,48	0,0000	-0,1096	-0,1096	-	
Level 1	22198	305,3	1,38	6,0600	5,9624	-0,0976	-1,61	
Level 2	25260	462,9	1,83	7,2700	7,2624	-0,0076	-0,11	
Level 3	33299	772,0	2,32	9,8100	10,2172	0,4072	4,15	
Level 4	56770	227,3	0,40	17,4000	17,2076	-0,1924	-1,11	

Curve Fit: Linear, Weighted Fit: No, Thru Blank: No
Correlation Coefficient: 0,999299
Limit of detection: 0,0054 µg/L
Limit of quantitation: 0,0181 µg/L
Blank Equivalent Concentration: 0,0191 µg/L
Calibration Equation: c/s = (72,1 + 414,9 + 3787*conc)*[I/S Ratio]

Figure 1: Calibration of Co, I, Hg, and Se by ICP-MS using serum matrix calibrators

Limits of detection and quantification

The instrumental limits of detection (LOD) and quantification (LOQ) of the calibration were determined using the blank in accordance with DIN 32645[3] and are shown in Table 4. The method detection and quantification limits (MDL, MQL) were calculated considering the dilution factor of the sample preparation.

Table 4: Limits of detection and quantification of the calibration (LOD, LOQ) and method (MDL, MQL) determined in accordance with DIN 32645[3]

Element	Unit	LOD	LOQ	MDL	MQL
Aluminum	µg/L	0.0698	0.2327	0.698	2.327
Antimony	µg/L	0.0003	0.0009	0.003	0.009
Arsenic	µg/L	0.0035	0.0117	0.035	0.117
Barium	µg/L	0.0153	0.0511	0.153	0.511
Beryllium	µg/L	0.0001	0.0005	0.001	0.005
Bismuth	µg/L	0.0002	0.0008	0.002	0.008
Cadmium	µg/L	0.0012	0.0039	0.012	0.039
Chromium	µg/L	0.0049	0.0164	0.049	0.164
Cobalt	µg/L	0.0009	0.0029	0.009	0.029
Copper	µg/L	0.0027	0.0091	0.027	0.091
Gold	µg/L	0.0006	0.0020	0.006	0.020
Iodine	µg/L	0.0035	0.0117	0.035	0.117
Iron	µg/L	0.1285	0.4283	1.285	4.283
Lithium	µg/L	0.0484	0.1613	0.484	1.613
Magnesium	mg/L	0.0011	0.0037	0.011	0.037
Manganese	µg/L	0.0035	0.0116	0.035	0.116
Mercury	µg/L	0.0015	0.0049	0.015	0.049
Molybdenum	µg/L	0.0022	0.0074	0.022	0.074
Nickel	µg/L	0.0044	0.0146	0.044	0.146
Palladium	µg/L	0.0004	0.0014	0.004	0.014
Platinum	µg/L	0.0003	0.0010	0.003	0.010
Selenium	µg/L	0.0054	0.0181	0.054	0.181
Silver	µg/L	0.0008	0.0026	0.008	0.026
Thallium	µg/L	0.0001	0.0004	0.001	0.004
Tin	µg/L	0.0009	0.0028	0.009	0.028
Titanium	µg/L	0.0575	0.1917	0.575	1.917
Vanadium	µg/L	0.0034	0.0112	0.034	0.112
Zinc	µg/L	0.0233	0.0777	0.233	0.777

Validation

To validate the method, the reference materials ClinChek® Serum, ClinChek® Plasma, and Seronorm™ Serum were analyzed. The concentrations of all elements were within the control range specified by the manufacturer and most of the results were within a range of +/- 10% of the reference value. The results are shown in Tables 5, 6, and 7. No concentrations of the elements Bi and Ag were specified in the certificate of ClinChek® Plasma Level I and II (2. update). In Seronorm™ Serum L-1 and L-2, only certified concentrations of the elements Al, Cr, Co, Cu, Fe, Li, Mn, Mg, Hg, Ni, Se, and Zn were given out of the 28 elements specified in the serum calibrators.

Table 5: Elemental concentrations and recoveries of Seronorm™ Serum L-1 and L-2

Element	Unit	Seronorm™ Trace Elements Serum L-1			Seronorm™ Trace Elements Serum L-2		
		Result	Control range	Recovery [%]	Result	Control range	Recovery [%]
Aluminum	µg/L	47.4	36.9–55.4	103	123	94–141	105
Chromium	µg/L	2.60	1.30–3.05	119	5.74	4.0–7.5	101
Cobalt	µg/L	1.06	0.67–1.57	95	2.94	2.13–3.97	97
Copper	µg/L	1121	999–1176	103	1847	1700–2000	100
Iron	mg/L	1.39	1.17–1.77	94	2.06	1.72–2.58	96
Lithium	µg/L	4816	4202–6320	92	9260	7739–11639	96
Magnesium	mg/L	17.1	13.4–20.1	102	34.5	27.1–40.7	102
Manganese	µg/L	9.84	7.9–11.9	99	14.7	11.6–17.4	101
Mercury	µg/L	1.06	0.53–1.60	99	1.94	1.44–2.67	94
Nickel	µg/L	5.84	3.38–7.90	104	9.13	7.9–11.9	101
Selenium	µg/L	85.9	76–99	99	137	120–157	99
Zinc	µg/L	1075	952–1242	98	1632	1404–1831	101

Table 6: Elemental concentrations and recoveries of ClinChek® Serum Level I and II

Element	Unit	ClinChek® Serum trace elements Level I			ClinChek® Serum trace elements Level II		
		Result	Control range	Recovery [%]	Result	Control range	Recovery [%]
Aluminum	µg/L	15.8	11.4–21.1	97	59.2	44.7–74.6	99
Antimony	µg/L	1.74	1.37–2.05	102	6.94	5.54–8.31	100
Arsenic	µg/L	9.52	7.58–11.4	100	19.3	15.4–23.2	100
Barium	µg/L	24.0	19.6–29.5	98	62.1	49.1–73.7	101
Beryllium	µg/L	1.91	1.45–2.42	99	9.77	7.31–12.2	100
Bismuth	µg/L	1.49	1.08–1.79	103	5.37	4.15–6.92	97
Cadmium	µg/L	1.93	1.56–2.35	98	5.81	4.75–7.13	98
Chromium	µg/L	1.63	1.18–1.97	103	5.89	4.73–7.10	99
Cobalt	µg/L	2.04	1.60–2.41	102	5.65	4.53–6.79	100
Copper	mg/L	0.743	0.632–0.855	100	1.41	1.19–1.61	100
Gold	µg/L	96.9	72.2–120	101	471	376–565	100
Iodine	µg/L	40.8	32.5–48.8	100	77.1	62.9–94.3	98
Iron	mg/L	0.831	0.730–0.988	97	1.49	1.26–1.71	101
Lithium	mg/L	3.65	3.19–4.32	97	7.66	6.44–8.71	101
Magnesium	mg/L	16.0	14.4–17.6	100	21.9	19.6–24.0	100
Manganese	µg/L	2.38	1.81–3.01	99	6.32	4.99–7.49	100
Mercury	µg/L	2.10	1.58–2.63	100	7.86	6.41–9.61	98
Molybdenum	µg/L	1.79	1.36–2.27	99	5.71	4.62–6.92	99
Nickel	µg/L	1.90	1.43–2.38	100	6.07	4.84–7.27	100
Palladium	µg/L	4.88	3.86–5.78	101	19.3	15.6–23.4	99
Platinum	mg/L	0.258	0.214–0.322	96	0.924	0.712–1.07	104
Selenium	µg/L	56.3	46.1–69.2	98	102	83.7–126	97
Silver	µg/L	4.89	3.85–5.77	102	18.9	15.5–23.3	98
Thallium	µg/L	1.90	1.52–2.29	100	7.63	6.18–9.27	99
Tin	µg/L	2.03	1.62–2.43	100	9.31	7.57–11.4	98
Titanium	µg/L	9.13	6.90–12.8	93	37.0	28.1–46.8	99
Vanadium	µg/L	2.06	1.47–2.45	105	7.63	6.13–9.19	100
Zinc	mg/L	1.23	1.04–1.40	101	1.70	1.45–1.96	100

Table 7: Elemental concentrations and recoveries of ClinChek® Plasma Level I and II

Element	Unit	ClinChek® Plasma trace elements Level I			ClinChek® Plasma trace elements Level II		
		Result	Control range	Recovery [%]	Result	Control range	Recovery [%]
Aluminum	µg/L	7.11	4.82–8.94	103	46.6	33.6–56.0	104
Antimony	µg/L	1.40	1.04–1.73	102	5.00	3.79–5.68	105
Arsenic	µg/L	8.56	6.32–10.5	102	34.4	27.1–40.7	101
Barium	µg/L	302	257–347	100	409	331–448	105
Beryllium	µg/L	1.06	0.792–1.32	100	8.49	6.76–10.1	100
Cadmium	µg/L	2.26	1.71–2.86	99	7.39	5.76–8.64	103
Chromium	µg/L	3.09	2.36–3.94	98	10.3	8.52–12.8	96
Cobalt	µg/L	2.03	1.58–3.28	102	9.16	7.24–10.9	101
Copper	mg/L	0.831	0.715–0.967	99	1.39	1.18–1.60	100
Gold	µg/L	2.03	1.54–2.57	99	8.01	6.45–9.68	99
Iodine	µg/L	41.2	33.4–50.1	99	79.4	62.3–93.5	102
Iron	mg/L	0.766	0.660–0.893	99	1.16	0.959–1.30	103
Lithium	mg/L	2.86	2.60–3.52	93	8.17	7.82–9.56	94
Magnesium	mg/L	17.0	15.4–18.8	99	23.2	20.8–25.4	100
Manganese	µg/L	2.83	2.29–3.43	99	7.25	5.93–8.89	98
Mercury	µg/L	2.01	1.49–2.49	101	9.28	7.41–11.1	100
Molybdenum	µg/L	1.70	1.37–2.28	93	6.44	5.21–7.81	99
Nickel	µg/L	1.87	1.24–2.30	106	7.06	5.64–8.46	100
Palladium	µg/L	2.03	1.55–2.59	98	8.23	6.46–9.68	102
Platinum	µg/L	1.87	1.49–2.23	100	7.28	5.87–8.80	99
Selenium	µg/L	67.0	52.4–778.6	102	111	92.9–139	96
Thallium	µg/L	0.971	0.796–1.19	98	7.77	5.79–8.68	108
Tin	µg/L	1.15	0.833–1.55	96	7.63	6.10–9.14	100
Titanium	µg/L	9.34	6.64–12.3	99	36.3	27.1–45.2	100
Vanadium	µg/L	1.21	0.749–1.39	113	8.70	6.86–10.3	101
Zinc	mg/L	1.56	1.32–1.78	101	1.90	1.63–2.21	99

Stability

To evaluate the stability of the system, a measurement series of 60 serum samples and reference materials was conducted. The intensities of the internal standard isotopes were normalized to the second calibration standard and are shown in Figure 2. This shows that the internal standard recovery is mostly in a range of +/- 20% underlining the stability of the measurement. It should be noted that despite the twentyfold dilution (factor of 10 during sample preparation and additional factor of 2 during sample introduction by dilution with internal standard), the matrix load is still considerably high. This is also indicated by the distinct difference in internal standard recovery between blanks and samples/standards showing the matrix effect.

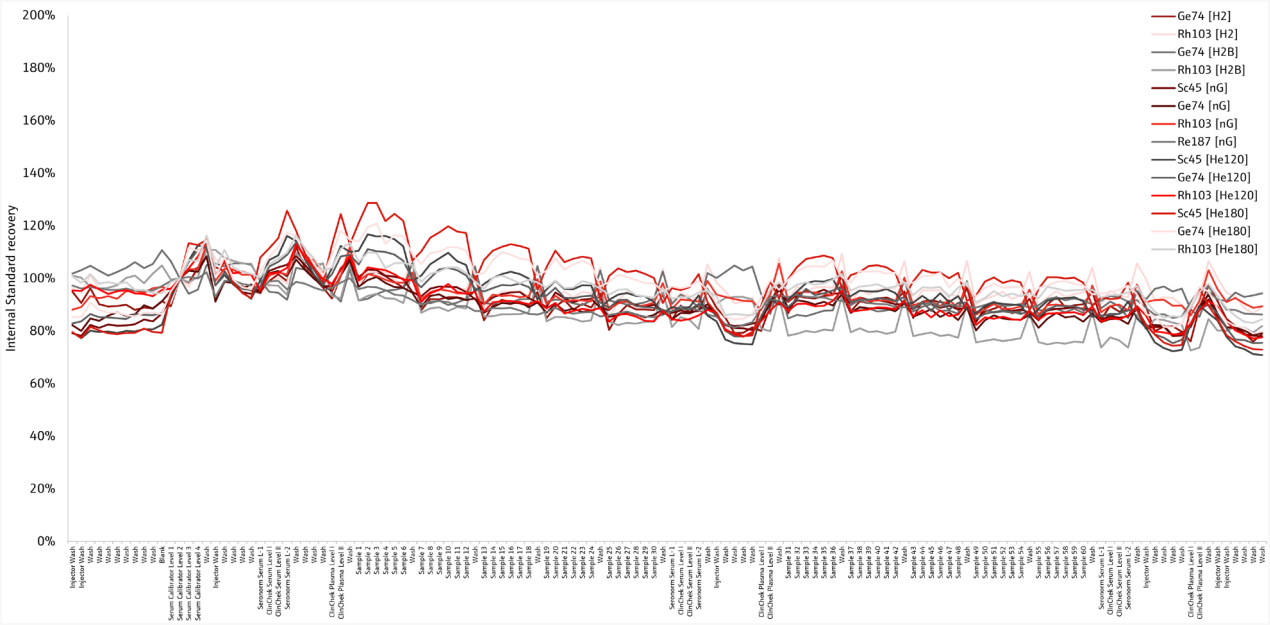


Figure 2: Internal standards recovery during a measuring sequence of 133 samples

Summary

Achieving recoveries between 90% and 110% for most and recoveries within the control range for all of the 28 investigated elements demonstrates that ready-to-use IVD kits validated for ICP-MS/MS analysis of serum and plasma can also be used with the PlasmaQuant MS, a single-quadrupole ICP-MS. Using the patented integrated collision reaction cell (iCRC), polyatomic interferences on strongly interfered isotopes could be eliminated. With the patented ReflexION ion mirror for 90° deflection and 3D focusing of the ion beam, high sensitivity could be achieved allowing low method limits of detection in the ng/L range in no gas and iCRC measurement modes. This work can serve as a basis for the validation of the IVD kit for trace elemental analysis of serum and plasma using single-quadrupole ICP-MS.
With the IVD kit and PlasmaQuant MS, users benefit from easier and less tedious workflows in combination with low running costs considering that the ICP-MS is consuming only 11.21 L/min argon in total.

Figure 3: PlasmaQuant MS Q

Recommended device configuration

Table 8: Overview of devices, accessories, and consumables

Article	Article number	Description
	Initial configuration	
PlasmaQuant MS Q	818-08011-2	ICP-MS with integrated collision reaction cell (iCRC)
Starter Kit PQMS STANDARD	810-88518-0	Basic sample introduction components for aqueous samples
Hydrogen generator	810-88026-0	Generator producing H_2 on-demand from ultrapure water
Autosampler ASX-560	810-88015-0	Autosampler with up to 370 positions
ASXPress Plus for PQMS	810-88017-0	Rapid sample introduction system for ICP-MS
Enclosure ENC-560 DC for ASX-560	810-88063-0	Dust protection cover for autosampler
HEPA filter for enclosure ENC-560 DC	810-88064-0	For using the enclosure in combination with exhaust
Seaspray nebulizer	418-88092-0	For aqueous samples with high matrix load
Sample loop 1.25 mL for ASXPress Plus	418-88172-0	1.25 mL sample loop with 1 mm inner diameter
	Consumables	
Consumables kit ICP-MS all inclusive	810-88117-0	Consumables for PlasmaQuant MS Q
Consumables kit autosampler	810-88126-0	Consumables for ASX-560 autosampler
Consumables kit valve	810-88127-0	Consumables for ASXPress Plus
Maintenance kit hydrogen generator	810-88421-0	Consumables for hydrogen generator

References

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[2] European Commission: *Progressive roll-out of the In Vitro Diagnostic Medical Devices Regulation*, December 20, 2021, updated on February 02, 2023, Press Release IP/21/6965

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