

Trace elemental analysis of distilled alcoholic beverages using the Agilent 7700x ICP-MS with octopole collision/reaction cell

Application note

Food testing

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Abstract

A method is described for the measurement of trace elements in alcoholic beverages including bourbon, rum, liqueur, sake, vodka, Irish whiskey and Scottish whisky, using an Agilent 7700x ICP-MS featuring the Octopole Reaction System (ORS³). The 7700x ensures simple operation as a single method and single set of conditions can be used to measure all sample types, following a simple dilution. Excellent spike recoveries were obtained, demonstrating the ability of the ORS³ in helium mode to remove interferences regardless of their source. The study shows that the 7700x can be used for the routine measurement of trace metals in alcoholic beverages.

Introduction

The measurement of trace elements in alcoholic beverages is required from a quality control standpoint and also to ensure that the final product complies with any regulatory requirements. Metal content can originate from the raw ingredients, such as water or grain, as well as during processing, for example from fermentation or distillation equipment. An example would be high arsenic concentration from distillation vessels manufactured from poor quality copper. The levels of trace elements can also significantly affect the taste of the product. Consequently, there is a requirement to measure elemental concentrations in the final product. While ICP-MS offers high sensitivity and excellent detection limits for many elements, interferences on key elements arising from the carbon content and required sample preparation can be problematic.

The Agilent 7700x ICP-MS features the Octopole Reaction System (ORS³) collision/reaction cell, which removes matrix-based polyatomic interferences using a single set of cell conditions (helium collision mode). For the analysis of spirits, the major interferences resulting from the sample matrix would be carbon-based (for example, ⁴⁰Ar¹²C on ⁵²Cr). Many elements are much more stable in a chloride matrix than after simple acidification using nitric acid; for this reason, hydrochloric acid (HCI) was added to the samples at a final concentration of 0.5%. New interferences are created by the addition of HCI (for example, ³⁵Cl¹6O on ⁵¹V; ⁴⁰Ar³5Cl on ⁷⁵As, and so forth) but they are also removed by the ORS³ in helium mode (He mode).

Experimental

Sample preparation and instrument conditions

Samples were prepared by a simple 5x dilution using 1% HNO $_3$ and 0.5% HCI (v/v). Using an acid mix significantly improves the stability of many elements, particularly Hg. In order to compensate for sample transport effects and solvent evaporation rates, the alcohol content of the standards was matched to that of the samples by adding $\sim 10\%$ ethanol to all standard solutions (approximately equivalent to 5x dilution of the original samples, which contained $\sim 40\%$ v/v alcohol).

This also compensates for ionization enhancement effects for As and Se in the presence of high carbon concentrations. Internal standards were added on-line and no further matrix matching was necessary. As no reference materials are available for these matrices, spike recoveries were performed on several samples.

All measurements were performed using a standard Agilent 7700x ICP-MS fitted with the standard sample introduction system consisting of a MicroMist glass concentric nebulizer, quartz Scott-type Peltier-cooled spray chamber, Ni interface cones and ORS³ operating under He mode or without cell gas (no gas mode). The optional hydrogen mode was not required. Instrument conditions are displayed in Table 1.

Table 1. Agilent 7700x ICP-MS operating conditions

Parameter	Value
Forward power	1550 W
Carrier gas flow rate	0.8 L/min
Make-up gas flow rate	0.32 L/min
Spray chamber temperature	2 °C
Sampling depth	8.0 mm
ORS ³ helium gas flow rate	5.0 mL/min

Data acquisition

Data was acquired operating the ORS³ in He mode and no gas mode. Some elements were acquired in both modes for comparison purposes to highlight the efficiency of He mode for interference removal.

He mode is the default mode of operation of the 7700x. The inert He cell gas conditions remove interferences based upon their ionic cross-section rather than relying on a reactive gas. As almost all interferences in ICP-MS are polyatomic in nature, they possess a greater ionic cross-section than the monatomic analyte ion at the same mass and therefore undergo a greater number of collisions in the cell. As each collision causes energy loss, the interfering polyatomic ions lose more energy than the analyte ions and are subsequently filtered from the mass-spectrum by discriminating between the two different energies (called kinetic energy discrimination). Since this process takes place regardless of the analyte-interferent combination, and works for multiple polyatomic ion overlaps at each analyte mass, a single set of conditions can be used for all analytes.

Results and discussion

Detection limits (DL) and background equivalent concentrations (BEC) are presented in Table 2. Some elements were acquired both without cell gas (no gas) and in He mode for comparison. For those elements that suffer from interferences in this carbon and chloride matrix, the BECs and DLs are severely compromized when operating the instrument in no gas mode (that is, conventional non-cell ICP-MS). This can be clearly observed in the data for chromium: The BEC for 52Cr without cell gas (no gas mode) was 162.8 μg/L compared to 0.0117 μg/L in He mode an improvement of more than 4 orders of magnitude. The interference is effectively reduced to background contamination levels as the BECs for both Cr isotopes are very similar. Improvements can also be observed for Mg, Al, Ca, V, Mn, Fe, As and Se — all of which were measured in He mode.

Figure 1 shows the calibration graphs for ⁹Be, ⁵¹V, ²⁴Mg, ⁵²Cr, ⁵³Cr and ²³⁸U. There are two calibration graphs for those elements that suffer from interferences (²⁴Mg, ⁵¹V, ⁵²Cr, ⁵³Cr). One was acquired in no gas mode (without cell gas) and one in He mode. The 'no gas' calibrations for Cr do not pass through the origin due to the carbon and chlorine-based interferences and this offset can be clearly seen. There is an improvement in the BEC and DL in the calibrations for ²⁴Mg, ⁵¹V, ⁵²Cr, and ⁵³Cr in He mode. Be and U are also presented to demonstrate the excellent sensitivity for these low and high mass elements.

In order to obtain the lowest possible detection limits, it is essential to maximize the ionization efficiency of the plasma. This is done through optimization of the sample introduction system (low solution and gas flow rates and wide bore injector torch, temperature controlled spray chamber) and plasma generator design (27.12 MHz, solid-state with high coupling efficiency digital drive). All of these factors combine to increase the effective central channel temperature, improving ionization efficiency. This is allied to an ion lens system designed to improve full-mass ion transmission efficiency, further improving the DLs.

Table 2. Background equivalent concentration (BEC) and 3 σ detection limits (μ g/L) for a blank matrix containing 10% ethanol, 1% HNO $_3$ and 0.5% HCl in He mode and without cell gas (no gas mode).

^{*} Some examples of plasma and matrix based interferences are also presented for information.

No. d.	B#/	luturfama **	2 - DI	DEO
Mode	Mass/ Element	Interference*	3σ DL (μg/L)	BEC (μg/L)
No gas	9Be		0.00019	0.00056
No gas	²³ Na		0.406	8.82
No gas	²⁴ Mg	$^{12}\mathbf{C}_2$	1.25	10.18
He	²⁴ Mg		0.118	0.608
No gas	²⁷ AI	¹² C ¹⁵ N; ¹³ C ¹⁴ N	0.133	1.36
He	²⁷ AI		0.023	0.558
He	³⁹ K	$^{40}Ar^{1}H$	2.393	23.09
No gas	⁴⁴ Ca	$^{12}\mathrm{C}^{16}\mathrm{O}_{2}$	152.1	1902.9
He	⁴⁴ Ca		2.36	3.40
No gas	⁵¹ V	³⁷ Cl ¹⁶ O; ³⁷ Cl ¹⁴ N; ³⁸ Ar ¹³ C	0.125	1.35
He	⁵¹ V		0.00099	0.0049
No gas	⁵² Cr	$^{40}\text{Ar}^{12}\text{C};^{36}\text{Ar}^{16}\text{O};^{35}\text{CI}^{17}\text{O};^{37}\text{CI}^{15}\text{N}$	6.49	162.8
He	⁵² Cr		0.0117	0.067
No gas	⁵³ Cr	⁴⁰ Ar ¹³ C; ³⁷ Cl ¹⁶ O	1.32	20.92
He	⁵³ Cr		0.0387	0.0461
No gas	⁵⁵ Mn	$^{40}\text{Ar}^{15}\text{N}$	0.0569	0.157
Не	⁵⁵ Mn		0.0590	0.033
No gas	⁵⁶ Fe	$^{40}Ar^{16}O$	4.55	56.17
Не	⁵⁶ Fe		0.265	0.326
Не	⁵⁹ Co		0.00088	0.00069
He	⁶⁰ Ni		0.0148	0.177
Не	⁶³ Cu		0.0106	0.098
Не	⁶⁵ Cu		0.0104	0.101
Не	⁶⁶ Zn		0.0124	0.118
No gas	⁷⁵ As	⁴⁰ Ar ³⁵ Cl	0.0064	0.412
Не	⁷⁵ As		0.0013	0.0018
No gas	⁷⁸ Se	$^{40}\text{Ar}^{38}\text{Ar}$	0.559	2.495
Не	⁷⁸ Se		0.0059	0.0038
No gas	88Sr		0.00083	0.0049
No gas	⁹⁵ Mo		0.0023	0.0047
No gas	¹⁰⁷ Ag		0.00061	0.0118
He	¹¹¹ Cd		0.0013	0.00078
No gas	¹²¹ Sb		0.00081	0.0014
No gas	¹³⁸ Ba		0.00041	0.0042
He	²⁰¹ Hg		0.0012	0.0036
No gas	²⁰⁵ TI		0.0014	0.0038
No gas	²⁰⁸ Pb		0.00086	0.0088
No gas	²³⁸ U		0.00014	0.00024

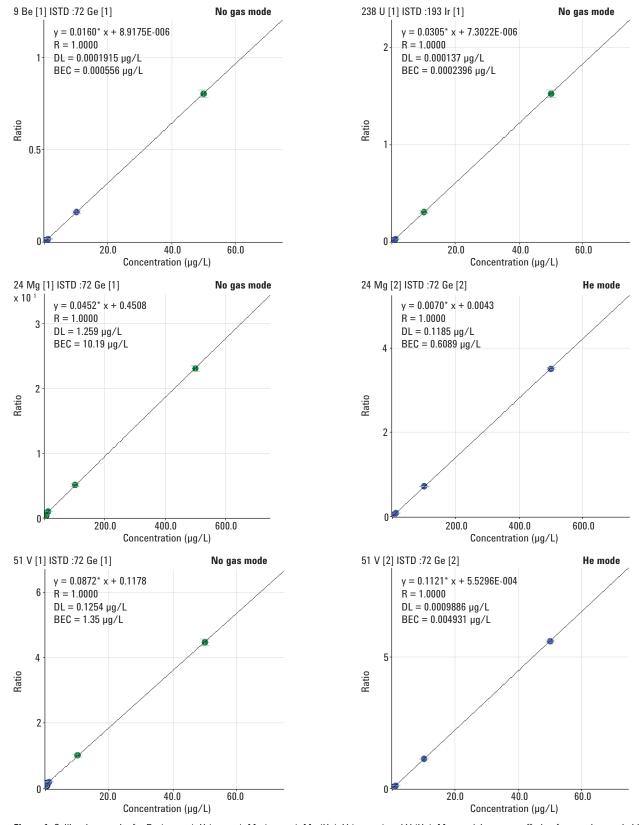


Figure 1. Calibration graphs for Be (no gas), U (no gas), Mg (no gas), Mg (He), V (no gas) and V (He). Masses/elements suffering from carbon and chlorine-based interferences can clearly be observed in no gas mode. (Continued next page)

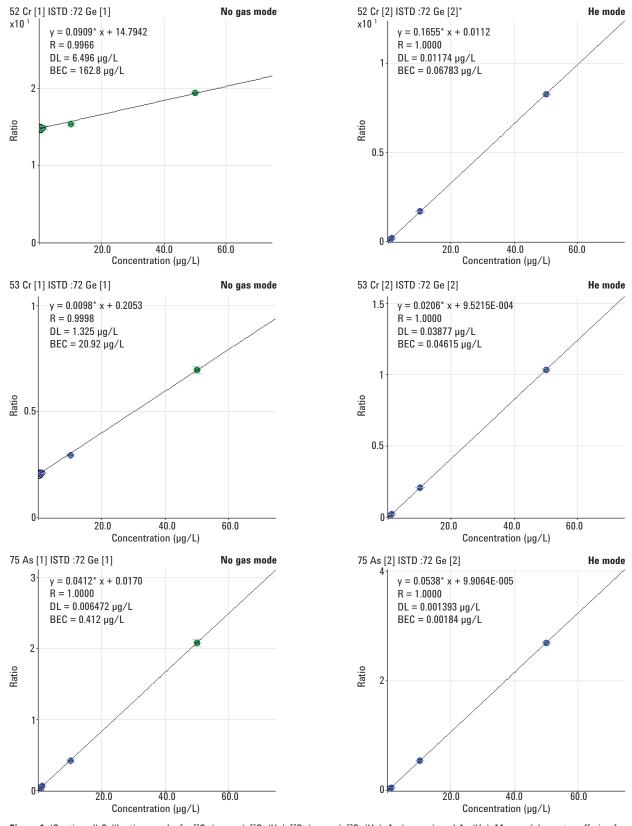


Figure 1. (Continued) Calibration graphs for 52Cr (no gas), 52Cr (He), 53Cr (no gas), 53Cr (He), As (no gas), and As (He). Masses/elements suffering from carbon and chlorine-based interferences can clearly be observed in no gas mode.

5

The elements Ge, Rh, and Ir were used as internal standards and were added on-line.

Tables 3, 4 and 5 display the quantitative data for all samples, including a spike recovery for a bourbon sample (Table 3) and spike recoveries for two of the Irish whiskey samples (Table 4). Data are displayed in the preferred cell gas mode (usually helium). The

recovery limits for all spiked elements were well within the range 80–120%, indicating good accuracy. Only the recovery for K in Sample 2 of the Irish whiskey sample set was outside of this range. Because K is present at a high natural level in the sample, a higher spike level would be preferred. Results for both Cr and Cu isotopes in all samples show good agreement, which is a good indication that all interferences on both isotopes were effectively removed.

Table 3. Analytical results (µg/L) and spike recoveries for a range of spirit beverages. Due to the distillation process many elements are present at sub-ppb concentrations.

de /no gas 0.00050 0.00143 0.00420 9.661 96.6 0.00028 0.00039 0.00080 0.00101 Na /no gas 5894.3 7109.8 297.3 408.6 111.3 162.8 625.5 962.3 200.9 Mg /He 3.9 83.6 31.8 135.2 103.4 6.8 416.2 344.8 8.0 Al /He 0.8 6.3 10.1 19.6 94.8 1.3 1.6 19.1 0.3 K /He 381.5 2109.4 2157.4 2275.4 118.0 0.7 1087.1 419.3 23.0 Ca /He 8.8 30.9 18.2 109.6 91.5 8.8 686.8 330.5 21.0 V/He 0.009 0.692 0.137 9.578 94.4 0.008 0.078 0.101 0.017 Cr/He 0.01 0.19 0.16 9.62 94.5 0.07 0.13 0.03 0.00 Gr/He 0.01 <t< th=""><th colspan="4">Bourbon</th><th></th><th>(</th><th>Other</th><th></th></t<>	Bourbon					(Other			
Na /no gas 5894.3 7109.8 297.3 408.6 111.3 162.8 625.5 962.3 200.9 Mg /He 3.9 83.6 31.8 135.2 103.4 6.8 416.2 344.8 8.0 Al /He 0.8 6.3 10.1 19.6 94.8 1.3 1.6 19.1 0.3 K /He 381.5 2109.4 2167.4 2275.4 118.0 0.7 1087.1 419.3 23.0 Ca /He 8.8 30.9 18.2 109.6 91.5 8.8 686.8 330.5 21.0 V /He 0.009 0.692 0.137 95.78 94.4 0.008 0.078 0.101 0.017 Cr /He 0.01 0.19 0.16 9.62 94.5 0.07 0.13 0.03 0.00 Cr /He 0.01 0.19 0.16 9.64 94.8 0.05 0.86 9.73 0.12 Co /He 0.016 0.020 <	Element/Mode	Sample A	Sample B	Sample C	Spike	% Recovery	Rum	Liqueur	Sake	Vodka
Mg / He	⁹ Be /no gas	0.00050	0.00143	0.00420	9.661	96.6	0.00028	0.00039	0.00080	0.00101
Al/He 0.8 6.3 10.1 19.6 94.8 1.3 1.6 19.1 0.3 1.6 K/He 381.5 2109.4 2157.4 2275.4 118.0 0.7 1087.1 419.3 23.0 Ca/He 8.8 30.9 18.2 109.6 91.5 8.8 686.8 330.5 21.0 V/He 0.009 0.692 0.137 9.578 94.4 0.008 0.078 0.101 0.017 0.17 0.17 0.14 0.009 0.692 0.137 9.578 94.4 0.008 0.078 0.13 0.03 0.00 0.00 0.00 0.00 0.00 0.00	²³ Na /no gas	5894.3	7109.8	297.3	408.6	111.3	162.8	625.5	962.3	200.9
K He 381.5 2109.4 2157.4 2275.4 118.0 0.7 1087.1 419.3 23.0 Ca He 8.8 30.9 18.2 109.6 91.5 8.8 686.8 330.5 21.0 V He 0.009 0.692 0.137 9.578 94.4 0.008 0.078 0.101 0.017 Cr He 0.01 0.21 0.17 9.62 94.5 0.07 0.13 0.03 0.00 Cr He 0.01 0.19 0.16 9.64 94.8 0.05 0.08 0.04 0.00 Mn He 0.49 1.24 8.71 18.37 96.6 0.32 0.86 9.73 0.12 Fe He 1.09 29.19 4.88 95.70 90.8 31.35 1.94 5.05 0.32 Co /He 1.09 0.021 0.025 8.936 89.1 0.006 0.017 0.105 0.024 Vi /He 0.83 1.97 32.88<	²⁴ Mg /He	3.9	83.6	31.8	135.2	103.4	6.8	416.2	344.8	8.0
Ca / He 8.8 30.9 18.2 109.6 91.5 8.8 686.8 330.5 21.0 V / He 0.009 0.692 0.137 9.578 94.4 0.008 0.078 0.101 0.017 Cr / He 0.01 0.21 0.17 9.62 94.5 0.07 0.13 0.03 0.00 Cr / He 0.01 0.19 0.16 9.64 94.8 0.05 0.08 0.04 0.00 Mn / He 0.49 1.24 8.71 18.37 96.6 0.32 0.86 9.73 0.12 Fe / He 1.09 29.19 4.88 95.70 90.8 31.35 1.94 5.05 0.32 Co / He 0.016 0.020 0.025 8.936 89.1 0.006 0.017 0.105 0.004 Ni / He 0.047 0.116 0.214 9.844 96.3 0.124 0.021 0.016 0.022 Cu / He 0.83 1.97	²⁷ Al /He	0.8	6.3	10.1	19.6	94.8	1.3	1.6	19.1	0.3
V/He 0.009 0.692 0.137 9.578 94.4 0.008 0.078 0.101 0.017 Cr /He 0.01 0.21 0.17 9.62 94.5 0.07 0.13 0.03 0.00 Cr /He 0.01 0.19 0.16 9.64 94.8 0.05 0.08 0.04 0.00 Mn /He 0.49 1.24 8.71 18.37 96.6 0.32 0.86 9.73 0.12 Fe /He 1.09 29.19 4.88 95.70 90.8 31.35 1.94 5.05 0.32 Co /He 0.016 0.020 0.025 8.936 89.1 0.006 0.017 0.105 0.004 Ni/He 0.047 0.116 0.214 9.844 96.3 0.124 0.021 0.016 0.029 Cu /He 0.83 1.97 32.88 44.23 113.5 304.54 1.59 3.33 1.90 Zh /He 0.46 1.59 <	³⁹ K /He	381.5	2109.4	2157.4	2275.4	118.0	0.7	1087.1	419.3	23.0
Cr /He 0.01 0.21 0.17 9.62 94.5 0.07 0.13 0.03 0.00 Cr /He 0.01 0.19 0.16 9.64 94.8 0.05 0.08 0.04 0.00 Mn /He 0.49 1.24 8.71 18.37 96.6 0.32 0.86 9.73 0.12 Fe /He 1.09 29.19 4.88 95.70 90.8 31.35 1.94 5.05 0.32 Co /He 0.016 0.020 0.025 8.936 89.1 0.006 0.017 0.105 0.004 Ni /He 0.047 0.116 0.214 9.844 96.3 0.124 0.021 0.016 0.029 Cu /He 0.83 1.97 32.88 44.23 113.5 304.54 1.50 3.11 1.77 Cu /He 0.89 2.11 35.06 44.75 96.9 326.49 1.59 3.33 1.90 Zh /He 0.0051 0.2312	⁴⁴ Ca /He	8.8	30.9	18.2	109.6	91.5	8.8	686.8	330.5	21.0
Cr /He 0.01 0.19 0.16 9.64 94.8 0.05 0.08 0.04 0.09 Mn /He 0.49 1.24 8.71 18.37 96.6 0.32 0.86 9.73 0.12 Fe /He 1.09 29.19 4.88 95.70 90.8 31.35 1.94 5.05 0.32 Co /He 0.016 0.020 0.025 8.936 89.1 0.006 0.017 0.105 0.004 Ni /He 0.047 0.116 0.214 9.844 96.3 0.124 0.021 0.016 0.029 Cu /He 0.83 1.97 32.88 44.23 113.5 304.54 1.50 3.11 1.77 Cu /He 0.89 2.11 35.06 44.75 96.9 326.49 1.59 3.33 1.90 Zn /He 0.46 1.59 1.75 11.70 99.5 6.64 14.63 0.90 2.36 As /He 0.0051 0.2312	⁵¹ V /He	0.009	0.692	0.137	9.578	94.4	0.008	0.078	0.101	0.017
Mn / He 0.49 1.24 8.71 18.37 96.6 0.32 0.86 9.73 0.12 Fe / He 1.09 29.19 4.88 95.70 90.8 31.35 1.94 5.05 0.32 Co / He 0.016 0.020 0.025 8.936 89.1 0.006 0.017 0.105 0.004 Ni / He 0.047 0.116 0.214 9.844 96.3 0.124 0.021 0.016 0.029 Cu / He 0.83 1.97 32.88 44.23 113.5 304.54 1.50 3.11 1.77 Cu / He 0.89 2.11 35.06 44.75 96.9 326.49 1.59 3.33 1.90 Zn / He 0.46 1.59 1.75 11.70 99.5 6.64 14.63 0.90 2.36 As / He 0.0051 0.2312 0.0346 9.609 95.7 0.0112 0.0477 0.0838 0.0022 Sr / No gas 0.11	⁵² Cr /He	0.01	0.21	0.17	9.62	94.5	0.07	0.13	0.03	0.00
Fe /He 1.09 29.19 4.88 95.70 90.8 31.35 1.94 5.05 0.32 Co /He 0.016 0.020 0.025 8.936 89.1 0.006 0.017 0.105 0.004 Ni /He 0.047 0.116 0.214 9.844 96.3 0.124 0.021 0.016 0.029 Cu /He 0.83 1.97 32.88 44.23 113.5 304.54 1.50 3.11 1.77 Cu /He 0.89 2.11 35.06 44.75 96.9 326.49 1.59 3.33 1.90 Zn /He 0.061 0.021 0.034 0.002 0.0034 0.005 0.00	⁵³ Cr /He	0.01	0.19	0.16	9.64	94.8	0.05	80.0	0.04	0.00
Co /He 0.016 0.020 0.025 8.936 89.1 0.006 0.017 0.105 0.004 Ni /He 0.047 0.116 0.214 9.844 96.3 0.124 0.021 0.016 0.029 Cu /He 0.83 1.97 32.88 44.23 113.5 304.54 1.50 3.11 1.77 Cu /He 0.89 2.11 35.06 44.75 96.9 326.49 1.59 3.33 1.90 Zn /He 0.46 1.59 1.75 11.70 99.5 6.64 14.63 0.90 2.36 As /He 0.0051 0.2312 0.0346 9.609 95.7 0.0112 0.0477 0.0838 0.0027 Se /He 0.0049 0.0518 0.0071 10.46 104.6 0.0097 0.0113 0.0433 0.0052 Sr /No gas 0.11 1.10 0.39 10.61 102.2 0.09 10.13 7.76 0.31 'Pd /no gas 0	⁵⁵ Mn /He	0.49	1.24	8.71	18.37	96.6	0.32	0.86	9.73	0.12
Ni / He	⁵⁶ Fe /He	1.09	29.19	4.88	95.70	90.8	31.35	1.94	5.05	0.32
Cu /He 0.83 1.97 32.88 44.23 113.5 304.54 1.50 3.11 1.77 Cu /He 0.89 2.11 35.06 44.75 96.9 326.49 1.59 3.33 1.90 Zn /He 0.46 1.59 1.75 11.70 99.5 6.64 14.63 0.90 2.36 As /He 0.0051 0.2312 0.0346 9.609 95.7 0.0112 0.0477 0.0838 0.0027 Se /He 0.0049 0.0518 0.0071 10.46 104.6 0.0097 0.0113 0.0433 0.0052 Sr /No gas 0.11 1.10 0.39 10.61 102.2 0.09 10.13 7.76 0.31 Pd /no gas 0.005 0.001 0.003 9.576 95.7 0.003 0.001 0.002 0.007 1°Cd /He 0.0039 0.0053 0.0193 9.811 97.9 0.0115 0.0227 0.0016 0.004 8Ba /no gas	⁵⁹ Co /He	0.016	0.020	0.025	8.936	89.1	0.006	0.017	0.105	0.004
Cu /He 0.89 2.11 35.06 44.75 96.9 326.49 1.59 3.33 1.90 Zn /He 0.46 1.59 1.75 11.70 99.5 6.64 14.63 0.90 2.36 As /He 0.0051 0.2312 0.0346 9.609 95.7 0.0112 0.0477 0.0838 0.0027 Se /He 0.0049 0.0518 0.0071 10.46 104.6 0.0097 0.0113 0.0433 0.0052 Sr /No gas 0.11 1.10 0.39 10.61 102.2 0.09 10.13 7.76 0.31 Ag /no gas 0.005 0.001 0.003 9.576 95.7 0.003 0.001 0.002 0.007 1°Cd /He 0.0039 0.0053 0.0193 9.811 97.9 0.0115 0.0227 0.0016 0.004 1°Sb /no gas 0.027 0.057 0.012 10.994 109.8 0.008 0.137 0.010 0.015 8Ba /no	⁶⁰ Ni /He	0.047	0.116	0.214	9.844	96.3	0.124	0.021	0.016	0.029
Zn /He 0.46 1.59 1.75 11.70 99.5 6.64 14.63 0.90 2.36 As /He 0.0051 0.2312 0.0346 9.609 95.7 0.0112 0.0477 0.0838 0.0027 Se /He 0.0049 0.0518 0.0071 10.46 104.6 0.0097 0.0113 0.0433 0.0052 Sr /No gas 0.11 1.10 0.39 10.61 102.2 0.09 10.13 7.76 0.31 7Ag /no gas 0.005 0.001 0.003 9.576 95.7 0.003 0.001 0.002 0.007 1Cd /He 0.0039 0.0053 0.0193 9.811 97.9 0.0115 0.0227 0.0016 0.0040 1Sb /no gas 0.027 0.057 0.012 10.994 109.8 0.008 0.137 0.010 0.015 8Ba /no gas 0.070 0.343 0.260 10.250 99.9 0.004 0.738 0.372 1.342 <	⁶³ Cu /He	0.83	1.97	32.88	44.23	113.5	304.54	1.50	3.11	1.77
As /He 0.0051 0.2312 0.0346 9.609 95.7 0.0112 0.0477 0.0838 0.0027 Se /He 0.0049 0.0518 0.0071 10.46 104.6 0.0097 0.0113 0.0433 0.0052 Sr /No gas 0.11 1.10 0.39 10.61 102.2 0.09 10.13 7.76 0.31 Ag /no gas 0.005 0.001 0.003 9.576 95.7 0.003 0.001 0.002 0.007 Cd /He 0.0039 0.0053 0.0193 9.811 97.9 0.0115 0.0227 0.0016 0.0040 Sb /no gas 0.027 0.057 0.012 10.994 109.8 0.008 0.137 0.010 0.015 Ba /no gas 0.070 0.343 0.260 10.250 99.9 0.004 0.738 0.372 1.342 Hg /He 0.0034 0.0019 0.0004 0.200 100.0 0.0038 0.0026 0.0001 0.0089 FTI /no gas 0.0007 0.0009 0.0013 10.224 102.2 0.0016 0.0008 0.0021 0.0004 BPb /no gas 0.021 0.088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	⁶⁵ Cu /He	0.89	2.11	35.06	44.75	96.9	326.49	1.59	3.33	1.90
Se /He 0.0049 0.0518 0.0071 10.46 104.6 0.0097 0.0113 0.0433 0.0052 Sr /No gas 0.11 1.10 0.39 10.61 102.2 0.09 10.13 7.76 0.31 7Ag /no gas 0.005 0.001 0.003 9.576 95.7 0.003 0.001 0.002 0.007 1Cd /He 0.0039 0.0053 0.0193 9.811 97.9 0.0115 0.0227 0.0016 0.0040 1Sb /no gas 0.027 0.057 0.012 10.994 109.8 0.008 0.137 0.010 0.015 8Ba /no gas 0.070 0.343 0.260 10.250 99.9 0.004 0.738 0.372 1.342 1Hg /He 0.0034 0.0019 0.0004 0.200 100.0 0.0038 0.0026 0.0001 0.0008 FTI /no gas 0.007 0.008 0.862 10.022 91.6 0.776 0.062 0.054 0.013 <td>⁶⁶Zn ∕He</td> <td>0.46</td> <td>1.59</td> <td>1.75</td> <td>11.70</td> <td>99.5</td> <td>6.64</td> <td>14.63</td> <td>0.90</td> <td>2.36</td>	⁶⁶ Zn ∕He	0.46	1.59	1.75	11.70	99.5	6.64	14.63	0.90	2.36
Sr /No gas 0.11 1.10 0.39 10.61 102.2 0.09 10.13 7.76 0.31 ⁷ Ag /no gas 0.005 0.001 0.003 9.576 95.7 0.003 0.001 0.002 0.007 ¹ Cd /He 0.0039 0.0053 0.0193 9.811 97.9 0.0115 0.0227 0.0016 0.0040 ¹ Sb /no gas 0.027 0.057 0.012 10.994 109.8 0.008 0.137 0.010 0.015 ⁸ Ba /no gas 0.070 0.343 0.260 10.250 99.9 0.004 0.738 0.372 1.342 ¹ Hg /He 0.0034 0.0019 0.0004 0.200 100.0 0.0038 0.0026 0.0001 0.0008 ⁶ TI /no gas 0.0007 0.0088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	⁷⁵ As /He	0.0051	0.2312	0.0346	9.609	95.7	0.0112	0.0477	0.0838	0.0027
Pb /no gas 0.005 0.001 0.003 9.576 95.7 0.003 0.001 0.002 0.007 1°Cd /He 0.0039 0.0053 0.0193 9.811 97.9 0.0115 0.0227 0.0016 0.0040 1°Sb /no gas 0.027 0.057 0.012 10.994 109.8 0.008 0.137 0.010 0.015 8Ba /no gas 0.070 0.343 0.260 10.250 99.9 0.004 0.738 0.372 1.342 1'Hg /He 0.0034 0.0019 0.0004 0.200 100.0 0.0038 0.0026 0.0001 0.0089 5TI /no gas 0.0007 0.0088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	⁷⁸ Se /He	0.0049	0.0518	0.0071	10.46	104.6	0.0097	0.0113	0.0433	0.0052
Ocd / He 0.0039 0.0053 0.0193 9.811 97.9 0.0115 0.0227 0.0016 0.0040 Ocd / He 0.027 0.057 0.012 10.994 109.8 0.008 0.137 0.010 0.015 Ba / no gas 0.070 0.343 0.260 10.250 99.9 0.004 0.738 0.372 1.342 Hg / He 0.0034 0.0019 0.0004 0.200 100.0 0.0038 0.0026 0.0001 0.0089 Tl / no gas 0.0007 0.0009 0.0013 10.224 102.2 0.0016 0.0008 0.0021 0.0004 Pb / no gas 0.021 0.088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	88Sr /No gas	0.11	1.10	0.39	10.61	102.2	0.09	10.13	7.76	0.31
Sb /no gas 0.027 0.057 0.012 10.994 109.8 0.008 0.137 0.010 0.015 Ba /no gas 0.070 0.343 0.260 10.250 99.9 0.004 0.738 0.372 1.342 1Hg /He 0.0034 0.0019 0.0004 0.200 100.0 0.0038 0.0026 0.0001 0.0089 FTI /no gas 0.0007 0.0099 0.0013 10.224 102.2 0.0016 0.0008 0.0021 0.0004 *Pb /no gas 0.021 0.088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	¹⁰⁷ Ag /no gas	0.005	0.001	0.003	9.576	95.7	0.003	0.001	0.002	0.007
Ba /no gas 0.070 0.343 0.260 10.250 99.9 0.004 0.738 0.372 1.342 Hg /He 0.0034 0.0019 0.0004 0.200 100.0 0.0038 0.0026 0.0001 0.0089 TI /no gas 0.0007 0.0009 0.0013 10.224 102.2 0.0016 0.0008 0.0021 0.0004 BPb /no gas 0.021 0.088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	¹¹¹ Cd /He	0.0039	0.0053	0.0193	9.811	97.9	0.0115	0.0227	0.0016	0.0040
Hg /He 0.0034 0.0019 0.0004 0.200 100.0 0.0038 0.0026 0.0001 0.0089 FTI /no gas 0.0007 0.0009 0.0013 10.224 102.2 0.0016 0.0008 0.0021 0.0004 *Pb /no gas 0.021 0.088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	¹²¹ Sb /no gas	0.027	0.057	0.012	10.994	109.8	0.008	0.137	0.010	0.015
*FI /no gas 0.0007 0.0009 0.0013 10.224 102.2 0.0016 0.0008 0.0021 0.0004 *Pb /no gas 0.021 0.088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	¹³⁸ Ba /no gas	0.070	0.343	0.260	10.250	99.9	0.004	0.738	0.372	1.342
*Pb /no gas 0.021 0.088 0.862 10.022 91.6 0.776 0.062 0.054 0.013	²⁰¹ Hg /He	0.0034	0.0019	0.0004	0.200	100.0	0.0038	0.0026	0.0001	0.0089
	²⁰⁵ TI /no gas	0.0007	0.0009	0.0013	10.224	102.2	0.0016	0.0008	0.0021	0.0004
⁸ U /no gas 0.001 0.011 0.003 10.223 102.2 0.000 0.047 0.063 0.002	²⁰⁸ Pb /no gas	0.021	0.088	0.862	10.022	91.6	0.776	0.062	0.054	0.013
	²³⁸ U /no gas	0.001	0.011	0.003	10.223	102.2	0.000	0.047	0.063	0.002

Table 4. Analytical results ($\mu g/L$) and spike recoveries for three Irish whiskey samples. Due to the distillation process many elements are present at sub-ppb concentrations.

Element/Mode Sample A Spike % Recovery Sam	nple B Spike % Re	ecovery Sample C
⁹ Be /no gas 0.00085 9.227 92.3 0.00	94.3 94.3	0.00369
²³ Na /no gas 778.6 887.2 108.6 101	8.0 1114.3 96.3	623.6
²⁴ Mg /He 5.4 103.9 98.4 21.	120.5 99.5	47.3
²⁷ Al /He 2.0 11.7 97.6 6.1	15.0 89.8	8.5
³⁸ K /He 381.2 485.5 104.4 931	.8 1004.2 72.4	1529.3
⁴⁴ Ca /He 6.8 106.1 99.3 22.3	2 117.2 95.1	32.7
⁵¹ V /He 0.025 9.824 98.0 0.04	9.467 94.2	0.063
⁵² Cr /He 0.68 10.49 98.2 0.69	7 10.10 94.3	0.82
⁵³ Cr /He 0.65 10.40 97.5 0.66	5 10.05 93.9	0.81
⁵⁵ Mn /He 0.63 10.42 97.9 2.56	11.84 93.0	2.74
⁵⁶ Fe /He 1.53 100.38 98.9 6.04	99.19 93.1	10.81
⁵⁹ Co /He 0.007 9.136 91.3 0.04	8.870 88.2	0.032
⁶⁰ Ni /He 0.028 9.798 97.7 0.04	9.510 94.6	0.002
⁶³ Cu /He 0.90 10.19 92.8 3.33	3 12.27 89.4	3.51
⁶⁵ Cu /He 0.97 10.88 99.1 3.54	13.03 95.0	3.76
⁶⁶ Zn /He 0.10 10.43 103.3 0.3	10.10 97.8	0.76
⁷⁵ As /He 0.0069 9.5975 95.9 0.00	9.2482 92.3	0.0140
⁷⁸ Se / He 0.0035 9.6230 96.2 0.00	9.7909 97.9	0.0050
⁸⁸ Sr /no gas 0.10 9.71 96.1 0.40	3 10.19 97.3	1.09
¹⁰⁷ Ag /no gas 0.001 9.056 90.6 0.00	9.337 93.3	0.001
111Cd /He 0.0011 9.9280 99.3 0.00	9.6625 96.6	0.0022
¹²¹ Sb /no gas 0.011 8.903 88.9 0.01	8.899 88.8	0.013
138Ba /no gas 0.069 9.653 95.8 1.70	02 11.496 97.9	0.386
²⁰¹ Hg /He 0.0021 0.1886 93.3 0.00	040 0.1967 96.4	0.0022
²⁰⁵ TI /no gas 0.0010 9.3196 93.2 0.00	9.9106 99.1	0.0002
		0.100
²⁰⁸ Pb /no gas 0.030 8.660 86.3 0.00	9.044 89.8	0.132

Table 5. Analytical results (μ g/L) for four Scottish whisky samples. Due to the distillation process many elements are present at sub-ppb concentrations.

Element/Mode	Sample A	Sample B	Sample C	Sample D
⁹ Be /no gas	0.01417	0.00574	0.00345	0.00103
²³ Na /no gas	935.6	1333.2	1070.6	883.9
²⁴ Mg /He	41.2	30.3	16.0	18.8
²⁷ Al /He	13.9	19.5	6.4	6.8
³⁹ K /He	668.0	673.3	474.6	607.0
⁴⁴ Ca /He	36.4	24.0	12.4	16.5
⁵¹ V /He	0.156	0.038	0.056	0.028
⁵² Cr /He	0.11	0.14	0.11	0.07
⁵³ Cr /He	0.11	0.14	0.10	0.07
⁵⁵ Mn /He	5.01	3.01	1.39	1.02
⁵⁶ Fe /He	9.56	7.43	5.73	11.14
⁵⁹ Co /He	0.102	0.035	0.019	800.0
⁶⁰ Ni ∕He	0.261	0.125	0.056	0.004
⁶³ Cu ∕He	52.49	31.84	46.23	24.05
⁶⁵ Cu ∕He	52.39	33.91	45.10	25.60
⁶⁶ Zn ∕He	1.93	1.68	0.82	1.38
⁷⁵ As /He	0.0467	0.0393	0.0265	0.0214
⁷⁸ Se /He	0.0262	0.0312	0.0179	0.0093
88Sr /no gas	0.86	0.63	0.19	0.26
¹⁰⁷ Ag /no gas	0.005	0.003	0.002	0.000
¹¹¹ Cd /He	0.0038	0.0022	0.0014	0.0020
¹²¹ Sb /no gas	0.018	0.011	0.011	0.010
¹³⁸ Ba /no gas	0.404	0.318	0.219	0.152
²⁰¹ Hg /He	0.0026	0.0014	0.0005	0.0019
²⁰⁵ TI /no gas	0.0004	0.0010	0.0014	0.0015
²⁰⁸ Pb /no gas	0.131	0.107	0.111	0.167
238U /no gas	0.030	0.005	0.006	0.002

Conclusions

Routine analysis of alcoholic spirit beverages using the Agilent 7700x ICP-MS was performed following a simple sample dilution/acidification. No sample-specific method development or customized cell modes were required, as the use of helium gas mode in the ORS³ of the 7700x efficiently removed the plasma-based and matrix-based interferences from all analytes. He mode improves detection limits and ensures accurate and reliable results with a simple, consistent set of conditions for all interfered elements, regardless of the sample composition. He mode provides improvements in detection limits of around 4 orders of magnitude and is applicable to multielement analysis in a wide range of sample types.

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