Electronic Supplementary Material (ESI) for Nanoscale.

Supporting Information for

A Henry's Law Method for Generating Bulk Nanobubbles

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FT-IR analysis

FT-IR is a non-destructive, quantitative, and quick method for identifying a wide range of chemical constituents and elucidating compound structures in various forms in real-world samples according to the vibrational modes of their molecular functional groups. FT-IR spectroscopic measurements were used here to investigate the purity of bulk nanobubble suspensions produced in pure water. Spectroscopic measurements were performed on a Tensor 27 instrument (Bruker, Germany) coupled with an ATR accessory. The scanned spectral range was from 400−4000 cm^{-1}, with a resolution of 2 cm^{-1} and a wavenumber accuracy of 0.01 cm^{-1}.

Raman analysis

Raman spectroscopy data for pure water and bulk nanobubble suspensions were collected using an inVia Qontor Confocal Raman microscope (Renishaw, UK). Each scan had a 30 s acquisition time using a 532 nm laser at 10% power achieved using a pinhole aperture. Each spectrum was obtained using the average of three acquisitions between 100−4000 cm^{-1}.

GC analysis

GC analysis of water and BNB suspensions was performed with an Agilent 7890A gas chromatograph (Agilent Technology, UK) equipped with ZB-WAX column (30 m × ϕ 0.25 mm, thickness 0.25 μm, Phenomenex, UK). Helium was used as a carrier and make-up gas passed through the column at a constant flow rate of 1.0 $mL.min^{-1}$. The injection volume was 1 μL, which was used with a split ratio of 1:10. The column temperature programme was as follows: temperature was held at 50 ˚C for 2 min, increased to 250 ˚C at 5 ˚$C.min^{-1}$ and then held at 250 ˚C for 18 min. The GC operating parameters are summarized in Table S1.

Table S1. GC operating parameters.

Gas chromatography	
Instrument	7809A (Agilent)
Column	ZB–WAX 30 m × ϕ 0.25 mm, 0.25 μm (Phenomenex, UK)
Injection method	Split (1:10)
Injection volume	1 μL
Carrier gas	Helium
Flow rate	1 $mL.min^{-1}$
Injection temperature	250 ˚C
Oven temperature program	50 ˚C (2 min) → 5 ˚C/min → 250 ˚C (18 min)
Transfer line temperature	250 ˚C

ICP-MS analysis

A NexION 300X ICP-MS spectrometer (Perkin-Elmer, UK) equipped with a cyclonic spray chamber and a SeaSpray concentric nebulizer was used to analyse pure water and BNB suspensions for the presence of any trace metal/nonmetal particles. The ICP-MS operating parameters are summarised in Table S2. In order to quantify the analytical results of ICP-MS, the internal and external standard additions modes were used. All standards were prepared in a 2% aqueous solution of HNO_3. Single element stock solutions (Sigma Aldrich, UK) of 20 metal/nonmetal elements, namely Na, Mg, Al, Si, P, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Rb, Sr, Zr, and Hg at a 1000 ppm concentration were used to prepare the standards for external calibration. The calibration curve and corresponding correlation coefficient ($R^2 > 0.99$) for each element used are presented in the Figures S2−S3. Indium at 1 ppm was employed as internal standard. Pure water and BNB suspensions were acidified using 2 % HNO_3 prior to ICP-MS sampling. Samples were supplied to the nebulizer in continuous mode with the spectrometer peristaltic pump using flared end PVC-based tubing of 0.19 mm internal diameter.

Table S2. ICP-MS operating parameters.

Parameter	Value
RF applied power (kW)	1.6 kW
Auxiliary gas flow rate (Argon)	1.2 $L.min^{-1}$
Plasma gas flow (Argon)	18 $L.min^{-1}$
Nebulizer gas flow (Argon)	0.95 $L.min^{-1}$
Sample flow rate	0.3 $mL.min^{-1}$
KED Gas Flow (Helium)	4 $mL.min^{-1}$
Nebulizer type	Sea Spray concentric
Interface cone material	Nickel
Analog stage voltage	-1675
Pulse stage voltage	1050 V
Discriminator threshold	12 mV
Deflector voltage	- 10 V
Quadrupole rod offset	- 12 V
Cell entrance voltage	- 9 V
Cell exit voltage	- 20 V
Cell rod offset	- 15 V
Axial field voltage	475 V

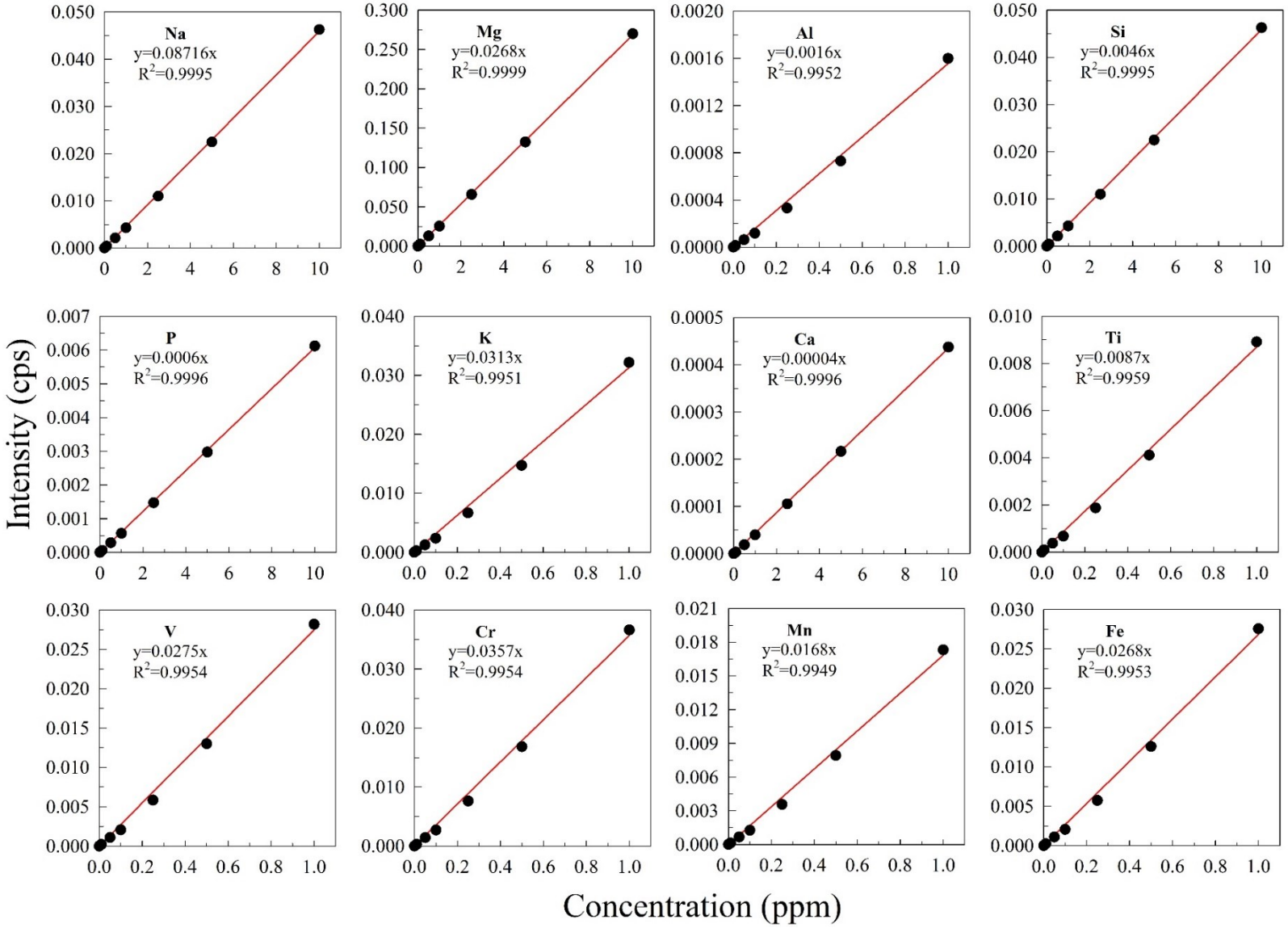

Figure S1. Calibration curves for individual elements (Na, Mg, Al, Si, P, K, Ca, Ti, V, Cr, Mn, Fe) measured by ICP-MS with solution-based calibration (standard additions mode).

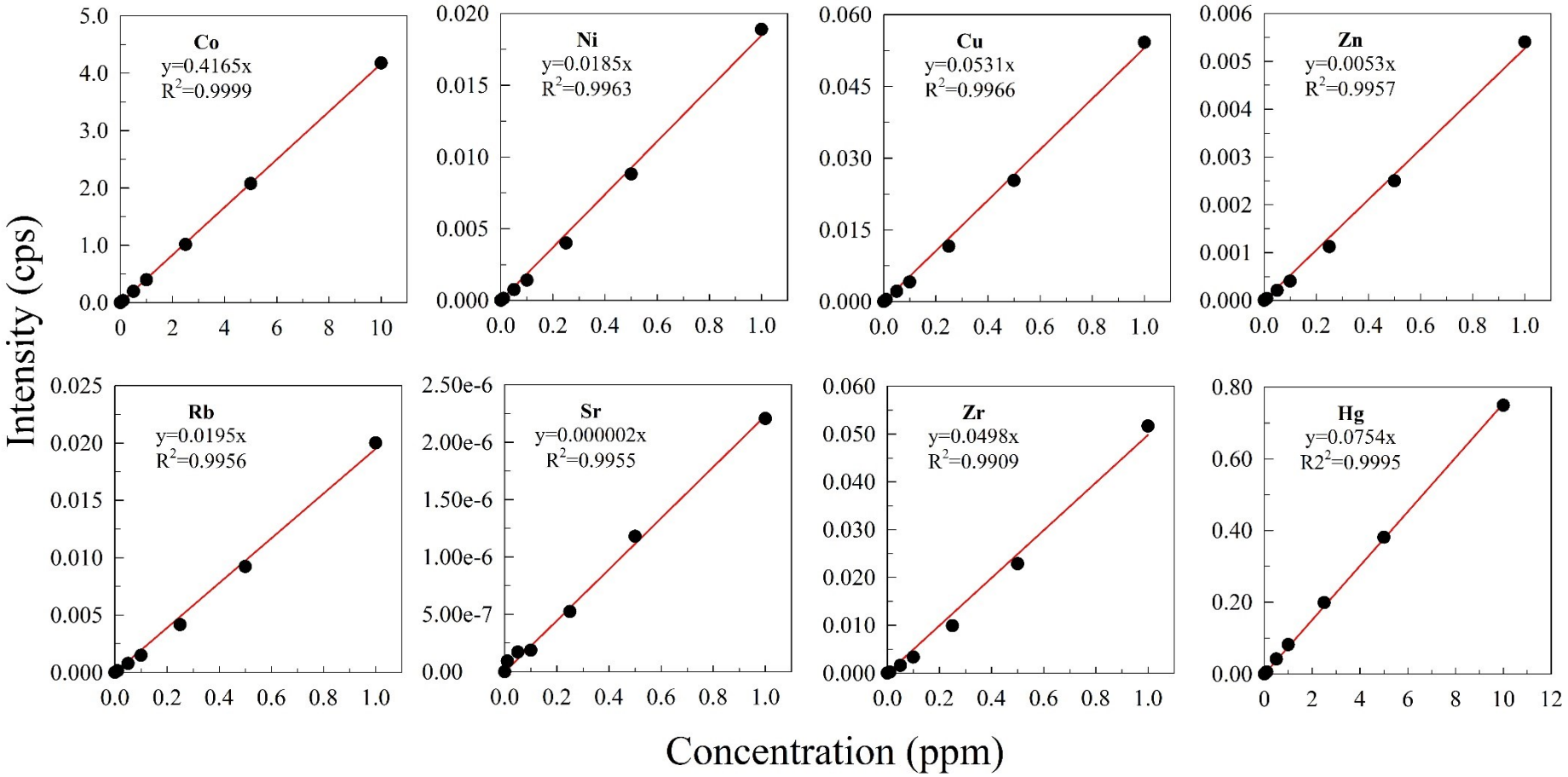

Figure S2. Calibration curves for individual elements (Co, Ni, Cu, Zn, Rb, Sr, Zr, Hg) measured by ICP-MS with solution-based calibration (standard additions mode).

Table S3. Concentration (in ppm) of detected elements in pure water and in BNB suspensions measured using ICP-MS.

Element	System	
	Pure water	Bulk nanobubble suspension
Na	0.001721	0.004647
Mg	0.003409	0.004647
Al	0.001494	0.002780
Si	0.006619	0.726000
P	0.000187	0.001482
K	0.000831	0.001480
Ca	0.001951	0.018370
Ti	0.000023	0.000346
V	0.000136	0.000084
Cr	0.000011	0.000131
Mn	0.000042	0.000106
Fe	0.004652	0.001010
Co	0.000405	0.000033
Ni	0.000113	0.002780
Cu	0.000010	0.001480
Zn	0.000207	0.000346
Rb	0.000146	0.000084
Sr	0.000169	0.000131
Zr	0.000165	0.000106
Hg	0.037039	0.009754