

Supplementary Information

Simultaneous chemical separation of Ge and Sb from Sb-rich sulfide samples for isotopic analysis using MC-ICP-MS

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Fig. S1 to S5

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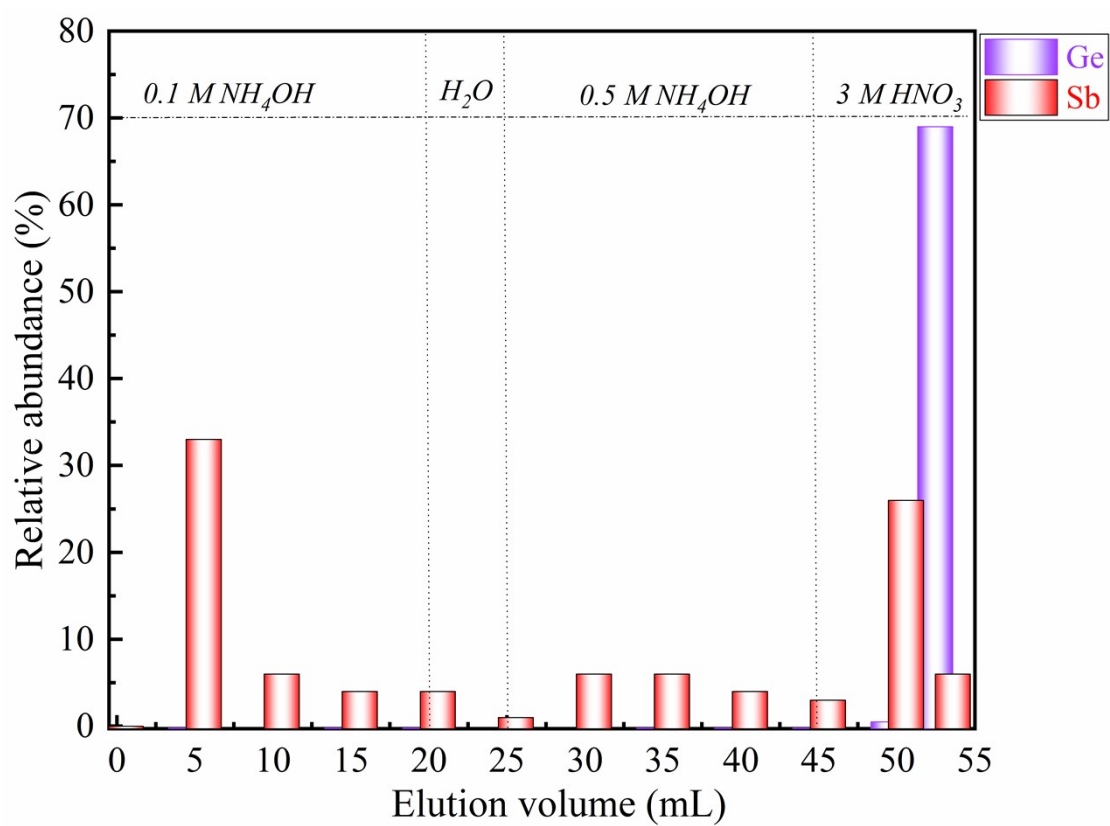


Fig. S1 Behavior of Ge and Sb on AG1-X8 resin under alkaline conditions. 2 mL of AG1-X8 resin and a synthetic solution of Ge and Sb were used in the experiment.

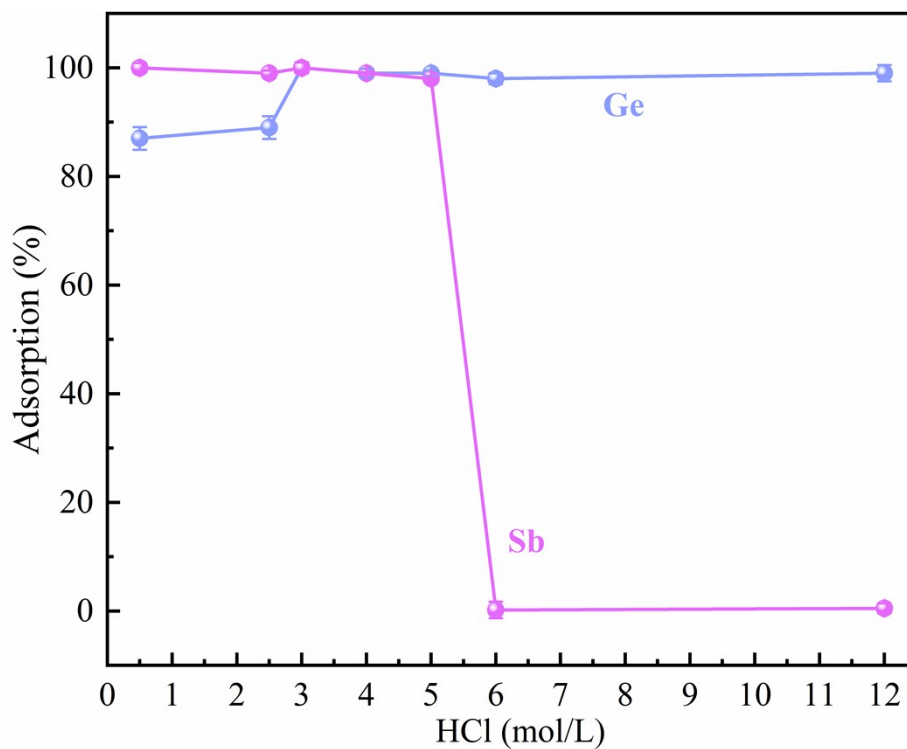


Fig. S2 The influence of HCl concentration on the adsorption of Ge and Sb on thiol silica resin. 8 mL of HCl with different concentrations were used in the experiment. Error bars indicate the standard deviation based on three independent experiments (n = 3).

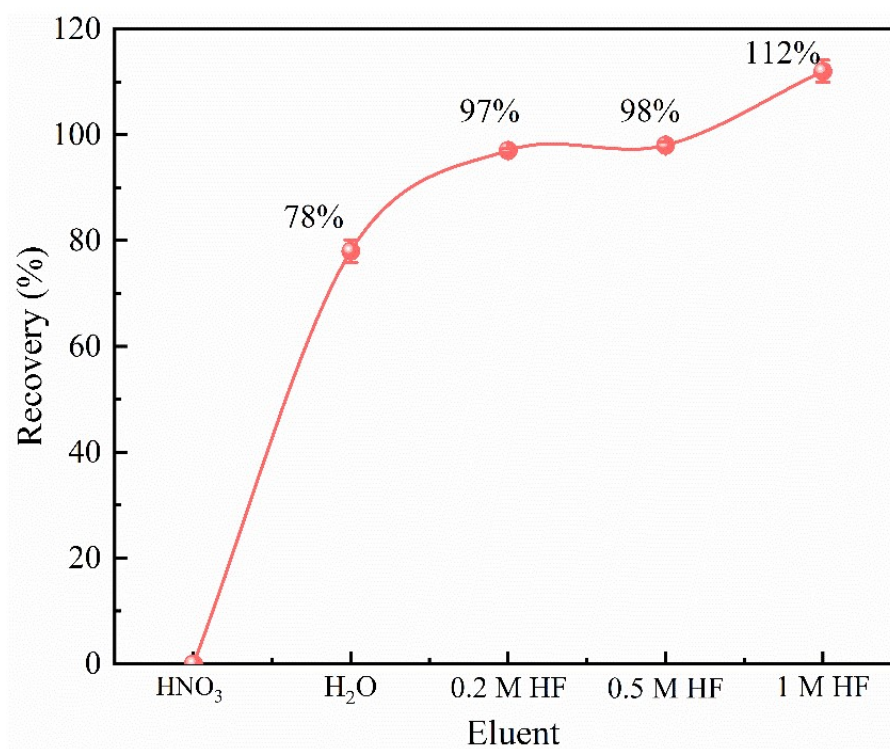


Fig. S3 The influence of different eluents on Ge recovery after elution with concentrated HNO₃. Error bars indicate the standard deviation based on three independent experiments (n = 3).

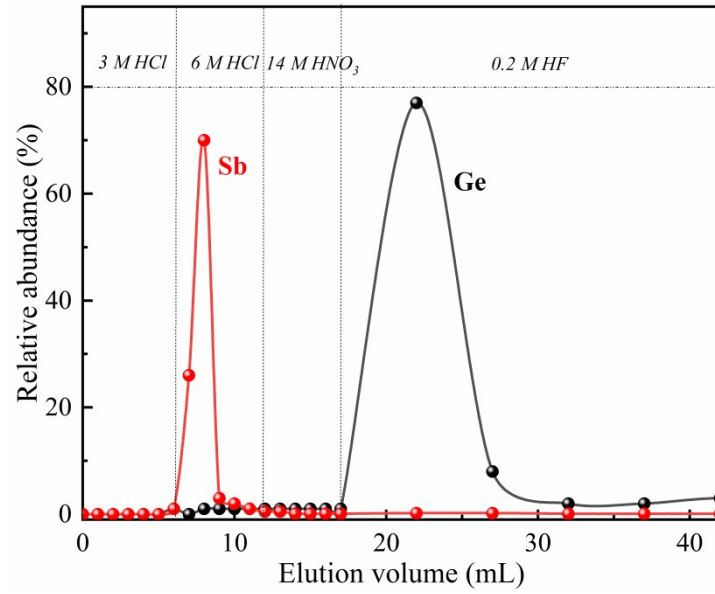


Fig. S4 The elution curves of Ge and Sb on thiol silica resin. The synthetic solution (Sb and Ge) was used to obtain the elution curve.

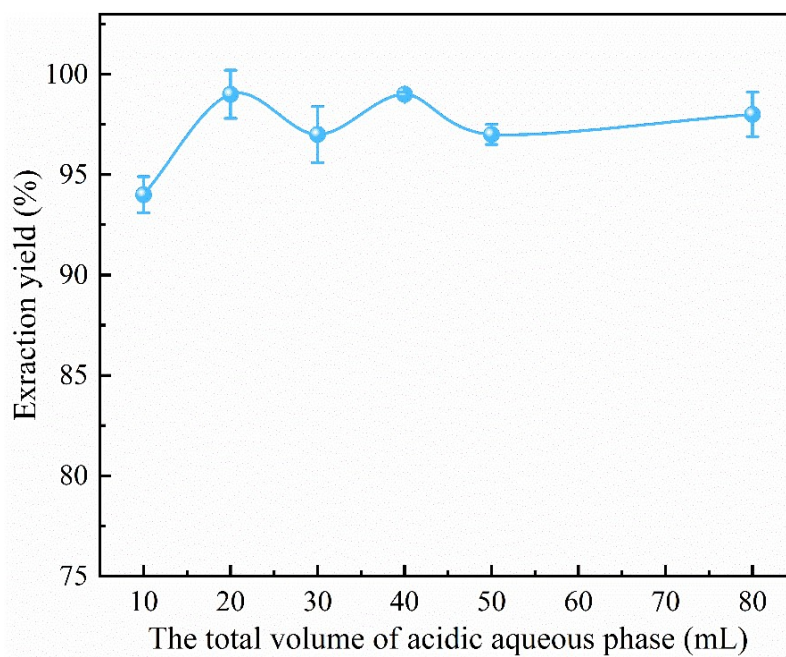


Fig. S5 Influence of the volume of acidic aqueous phases on the Ge extraction yield. Spex Ge was used as the sample for extraction, and the volume of chloroform used for single extraction was 10 mL. Error bars indicate the standard deviation based on three independent experiments ($n = 3$).

Table S1 The elemental concentration of GBW07270 Chinese sulfide reference materials

Element	Certified Value	N
Ag	5.0 ± 0.4	9
As	(3.3)	
Bi	6.1 ± 1.2	9
Cd	0.15* ± 0.01*	11
Co	491 ± 23	12
Cu	0.10* ± 0.01*	11
Fe	2.14* ± 0.14*	12
Ga	251 ± 18	7
Ge	6.0 ± 0.7	7
In	21.0 ± 1.4	6
Mn	169 ± 8.0	11
Ni	43.2 ± 4.0	8
Pb	0.099* ± 0.013*	9
S*	32.33 ± 0.17	7
Sb	249 ± 56	8
Se	(3)	
Sn	(0.2)	
Te	(0.3)	
Zn	62.51* ± 0.17*	7

Note: N represents number of sample; data marked with * mean contents in percentage and unmarked data mean contents in ppm; () represents reference value; all errors are 1 s.

Table S2 MC-ICP-MS operating conditions

Settings	Ge isotope	Sb isotope
MC-ICPMS parameters		

Settings	Ge isotope	Sb isotope
RF power (W)	1179	1300
Coolant gas (L/min)	15.1	16.5
Auxiliary flow (Ar) (L/min)	0.7	0.85
Cup configuration	L3 (⁶⁹ Ga), L2 (⁷⁰ Ge), L1 (⁷¹ Ga), C (⁷² Ge), H1 (⁷³ Ge), H2 (⁷⁴ Ge), H3 (⁷⁶ Ge)	H7 (¹²⁵ Te), H6 (¹²³ Sb), H5 (¹²² Sn), H4 (¹²¹ Sb), H3 (¹²⁰ Sn), Ax (¹¹⁷ Sn), L2 (¹¹⁵ In), L4 (¹¹³ In), L5 (¹¹¹ Cd)
Hydride generation		
“Acid” reagent	0.28 M HNO ₃	
Reducing agent	0.8% NaBH ₄ +0.4% NaOH	
Reagents and sample flow rate (mL/min)	0.25	
Additional gas flow rate	0.3	
Membrane desolvator		
Nebulization temperature	160°C	
Sweep gas (L/min)	2.1	
Sample uptake rate (μL/ min)	100	

Table S3 Germanium isotope results following thiol silica resin purification

Sample	Purification method	$\delta^{74}\text{Ge}$ (‰, mean \pm 2SD)	References
Spex Ge	/	-0.69 \pm 0.10	Qi et al. (2019) ¹⁰

Sample	Purification method	$\delta^{74}\text{Ge}$ (‰, mean \pm 2SD)	References
Spex Ge	Thiol silica resin purification	-0.32 \pm 0.08	This study
Spex Ge	Unpurified	-0.66 \pm 0.07	This study

Table S4 Average removal rates for the matrices and the residual element/Sb ratios in purified samples (GBW07270)

Element	Percentage removed (%)	Residual element/Sb ratio after purification
Ag	>99.99	<0.001
As	>99.99	<0.001
Cd	>99.99	<0.001
Co	>99.99	<0.001
Cu	>99.99	<0.001
Fe	>99.99	<0.001
Ga	>99.99	<0.001
Ge	>99.99	<0.001
In	>99.99	<0.001
Se	>99.99	<0.001
Sn	>99.99	<0.001
Te	>99.99	<0.001
Zn	>99.99	<0.001
Mn	>99.99	<0.001
Ni	>99.99	<0.001
Pb	>99.99	<0.001
