

Supplementary material for: **Analysis of the Lead Refining Method Using Aluminum**

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Table S-I. Element composition of pure lead used for the first laboratory research (wt. %).

Element	Sb	As	Bi	Sn
Content	0.00004±0.00002	0.00002±0.00002	0.0121±0.0005	0.00001±0.00002

Element	Cu	Ag	Zn	Se
Content	0.00041±0.00008	0.0018±0.0002	0.00005±0.00003	0.00001±0.00004

Element	Ni	Fe	Cd	S
Content	0.00006±0.00003	0.00001±0.00002	0.00001±0.00002	0.00001±0.00004

Element	Tl	Mn	Te	Ca
Content	0.0012±0.0001	0.00001±0.00002	0.00001±0.00002	0.00001±0.00002

Element	Al	Ba	Co	Cr
Content	0.00003±0.00004	0.00002±0.00002	0.00001±0.00003	0.00001±0.00005

Element	Na	Hg	Mg	Pt
Content	0.00003±0.00007	0.00001±0.00002	0.00001±0.00004	0.00003±0.00003

Element	Pd	Li	Au	Ge
Content	0.00001±0.00002	0.00001±0.00002	0.00003±0.00003	0.00001±0.00002

Element	Pb
Content	99.98

Table S-II. Element composition of secondary lead used for the second laboratory research (wt. %).

Element	Sb	As	Bi	Sn
Content	1.66±0.09	0.053±0.008	0.0151±0.0006	1.52±0.09

Element	Cu	Ag	Zn	Se
Content	0.0024±0.0007	0.0026±0.0002	0.00009±0.00003	0.012±0.002

Element	Ni	Fe	Cd	S
Content	0.00023±0.0009	0.00001±0.00002	0.00006±0.00002	0.00005±0.00004

Element	Tl	Mn	Te	Ca
Content	0.0018±0.0001	0.00001±0.00002	0.0008±0.0001	0.00001±0.00002

Element	Al	Ba	Co	Cr
Content	0.00002±0.00004	0.00003±0.00002	0.00003±0.00003	0.00009±0.00005

Element	Na	Hg	Mg	Pt
Content	0.00016±0.00008	0.00001±0.00002	0.00001±0.00004	0.00004±0.00003

Element	Pd	Li	Au	Ge
Content	0.00002±0.00002	0.00002±0.00002	0.00005±0.00003	0.00002±0.00002

Element	Pb
Content	96.73

Table S-III. Elemental composition of metallic antimony used for laboratory research (wt. %).

Element	As	Bi	Zn	Cu	Ni
Content	0.21±0.04	0.02±0.01	0.001±0.001	0.017±0.003	0.002±0.02

Element	Se	Pb	S	Sb
Content	0.3±0.1	0.2±0.1	0.001±0.001	>99.0

Table S-IV. Elemental composition of arsenic used for laboratory research (wt. %).

Element	Pb	Sb	Sn	Cu	Fe
Content	0.18±0.09	0.2±0.1	0.003±0.001	0.001±0.001	0.003±0.002

Element	Bi	Se	S	As
Content	0.004±0.001	0.009±0.002	< 0.001	>99.0

Table S-V. Elemental composition of selenium used for laboratory research (wt. %).

Element	Pb	Sb	Te	Cu	Fe
Content	0.02±0.01	0.2±0.1	0.012±0.008	< 0.001	0.002±0.001

Element	Cd	As	Sn	Se
Content	0.002±0.001	0.002±0.001	< 0.001	>99.5

Table S-VI. Elemental composition of metallic copper used for laboratory research (wt. %).

Element	Ag	As	Bi	Pb	Fe
Content	0.002±0.001	< 0.001	< 0.001	< 0.001	< 0.001

Element	Cd	S	Sn	Cu
Content	< 0.001	0.002±0.001	< 0.001	>99.5

Table S-VII. Elemental composition of metallic nickel used for laboratory research (wt. %).

Element	Cu	Fe	Mn	Pb	Si
Content	0.09±0.02	0.3±0.1	0.2±0.1	< 0.001	0.3±0.1

Element	Cd	S	Sn	Ni
Content	< 0.001	0.005±0.002	< 0.001	>99.0

Table S-VIII. Elemental composition of metallic aluminum used for laboratory research (wt. %).

Element	Fe	Si	Zn	Cu	Ni
Content	0.15±0.04	0.02±0.01	0.011±0.007	0.002±0.001	0.002±0.001

Element	Mg	Cr	S	Pb
Content	0.001±0.001	0.001±0.001	0.001±0.001	0.001±0.001

Element	As	Sn	Al
Content	< 0.001	< 0.001	>98.8

Table S-IX. Elemental composition of metallic calcium used for laboratory research (wt. %).

Element	Al	Mg	Mn	Fe	Cu
Content	0.25±0.05	0.65±0.08	0.009±0.003	0.007±0.001	0.008±0.001

Element	Ni	Na	As	Sn
Content	0.0004±0.002	0.02±0.01	< 0.001	< 0.001

Element	Pb	Se	Ca
Content	< 0.001	< 0.001	>98.7

(a) Al-Sb

- LIQUID + FCC_A1
- B3_ZINCBLENDE + FCC_A1
- LIQUID + B3_ZINCBLENDE
- LIQUID + RHOMBOHEDRAL_A7
- B3_ZINCBLENDE + RHOMBOHEDRAL_A7

(b) Al-As

- LIQUID + FCC_A1
- B3_ZINCBLENDE + FCC_A1
- LIQUID + B3_ZINCBLENDE
- LIQUID + RHOMBOHEDRAL_A7
- B3_ZINCBLENDE + RHOMBOHEDRAL_A7

(c) Al-Cu

- LIQUID + FCC_A1
- C16_AL2CU + FCC_A1
- LIQUID + C16_AL2CU
- LIQUID + ALCU_ETA
- LIQUID + D81_ALCU
- LIQUID + BCC_A2
- LIQUID + GAMMA_H
- BCC_A2 + FCC_A1
- BCC_A2 + D83_ALCU
- BCC_A2 + GAMMA_H
- D83_ALCU + GAMMA_H
- D83_ALCU + D81_ALCU
- D83_ALCU + ALCU_DELTA
- D81_ALCU + ALCU_DELTA
- D81_ALCU + ALCU_ZETA
- D81_ALCU + ALCU_ETA
- ALCU_ZETA + ALCU_ETA
- ALCU_DELTA + ALCU_ZETA
- BCC_A2 + D81_ALCU
- FCC_A1 + D83_ALCU
- C16_AL2CU + ALCU_ETA

(d) Al-Ni

- FCC_L12#2 + FCC_L12
- FCC_L12#2 + LIQUID
- FCC_L12#2 + BCC_B2
- FCC_L12#2 + AL3NI5
- BCC_B2 + AL3NI5
- LIQUID + BCC_B2
- LIQUID + D513_AL3NI2
- LIQUID + D011_AL3NI1
- LIQUID + FCC_L12
- D011_AL3NI1 + FCC_L12
- D513_AL3NI2 + D011_AL3NI1
- BCC_B2 + D513_AL3NI2

(e) Al-Pb

- LIQUID + FCC_A1
- FCC_A1#2 + FCC_A1
- LIQUID#2 + FCC_A1
- LIQUID + LIQUID#2

(f) Al-Sn

- LIQUID + FCC_A1
- LIQUID + BCT_A5
- FCC_A1 + BCT_A5

Fig. S-1. Legend with line labels for two-component phase diagrams created in Thermo-Calc 2024a: (a) Legend with line labels for the Al-Sb phase diagram (Fig. 2); (b) Legend with line labels for the Al-As phase diagram (Fig. 3); (c) Legend with line labels for the Al-Cu phase diagram (Fig. 4); (d) Legend with line labels for the Al-Ni phase diagram (Fig. 5); (e) Legend with line labels for the Al-Pb phase diagram (Fig. 6); (f) Legend with line labels for the Al-Sn phase diagram (Fig. 7);

Table S-X. Change of Al/Ca concentration in three-component lead alloys. (Because of the limited solubility of Al in Pb, the analysis of the aluminum content in lead was very problematic. When stopping the alloy stirring in order to take a metal sample, it was visible that there was a layer of aluminum on the surface of the lead. This caused the analysis of this element to be characterized by a huge standard deviation).

	Pb- Sb -Al	Pb- As -Al	Pb- Se -Al	Pb- Cu -Al	Pb- Ni -Al	Pb- Sb -Ca
Time (min)	Obtained Al conc. (wt. %)	Obtained Al conc. (wt. %)	Obtained Al conc. (wt. %)	Obtained Al conc. (wt. %)	Obtained Al conc. (wt. %)	Obtained Ca conc. (wt. %)
20	0.19±0.11	0.10±0.05	0.13±0.06	0.17±0.10	0.15±0.08	0.52±0.10
40	0.18±0.11	0.07±0.02	0.11±0.05	0.15±0.08	0.12±0.05	0.31±0.10
60	0.17±0.10	0.07±0.02	0.09±0.03	0.16±0.11	0.12±0.05	0.12±0.04