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Gallium and germanium in metallurgical slags: mineralogy and potential recovery

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Gallium (Ga) and germanium (Ge) are technologically essential critical elements. This study focuses on old metallurgical slags generated by processing non-ferrous metallic ores in Tsumeb, northern Namibia, containing interestingly high concentrations of these elements (up to 156 ppm Ga and 441 ppm Ge). Mineralogical investigation indicated that the slags were composed of olivine-, melilite- and spinel-group phases, metal(loid)-rich glass, and sulfide/metallic inclusions. The FEG-EPMA and LA-ICP-MS data confirmed that major carriers of Ga were Zn-Fe-Al spinels (up to 1370 ppm), and Ge was primarily bound in a glassy phase (up to 470 ppm), especially in the case of granulated slags. The abiotic extraction tests, simulating a hydrometallurgical recovery via agitation leaching, were carried out in sulfuric, nitric, and hydrochloric acids (pH = 0.2-0.3, 25 °C and 70 °C, pulp density of 1%) to determine the release of Ga and Ge from slags. Their leaching attained a steady state after 6 hours for granulated slags and 2 hours for finely ground slags. The extractability of both Ga and Ge was slightly higher for the high-temperature trials. The overall recovery was the best for the sulfuric acid extractions and attained 100% and 96% for Ga and Ge, respectively. Our investigation indicates that understanding the specific binding of critical elements is crucial for their potential recovery from slags. This study was supported by the Czech Science Foundation project (GAČR 19-18513S).