metals

Supplementary Material

1. Leaching experimental method

Experiments were performed in a 250 mL volumetric flask using a stirrer at a rotating speed of 250 rpm. Two hundred mL of solution was added to desired amounts of nickel-bearing pyrite samples. The gold foil（99.99% Au）surfaces were polished by 2000-grid sand paper, washed with acetone twice and rinsed 8 times with de-ionised water before each test. The gold foil was suspended in the upper part of the leaching reactor with a nylon thread, ensuring no contact with the volumetric flask wall during leaching. All experiments were performed at room temperature (25±1 °C). Samples were taken continuously at certain intervals during a total retention time of 34 h. The samples were centrifuged and filtered for the subsequent iodine titration, polythionate determination and oxidation for ICP analysis. The gold dissolution rate was calculated based on the dissolved gold mass per m^2 of the gold plate surface. All the experiments were conducted with reagent dosages of 0.1 M $Na_2S_2O_3$, 0.005 M $CuSO_4{\cdot}5H_2O$, 0.01 M en at 9.8 - 10.

2. Analysis of gold concentration in leaching solution containing pyrite

First, 5 mL of the immersion solution was removed with a pipet and diluted twice with water; 3 mL hydrogen peroxide was slowly added, and it was left for half an hour so that the thiosulfate in the sample solution completely oxidized to sulfate. Then, 2 mL hydrochloric acid with a volume ratio of 1:1 was added to acidify the solution. In order to eliminate the interference of metal ions (especially Fe3+) in the analysis of the sample, the acidified solution was adsorbed with activated carbon pulp (the mass ratio of activated carbon to paper is 1:2) for three cycles of extraction, filtration and adsorption, and a mixture of 10% ammonium hydrogen fluoride and 50% citric acid was used. A solution of 1:3 hydrochloric acid and distilled water was used to wash the activated carbon adsorption column several times to remove impurities; the activated carbon adsorption column was removed, and the ash was carried out in the Muffle furnace at 645°C. After complete ashing, it was taken out and cooled down. A few drops of 10% potassium chloride solution were added, along with 5 mL 1:1 aqua regia. After heating slightly for 30 min, it was transferred to a beaker, and then, 5% aqua regia was used to determine the concentration of gold by atomic absorption. The concentration of gold was calculated according to the following equation.

$$R=(1-\frac{c_t}{c_0})\times 100\%$$

3. Analysis of thiosulfate consumption

The concentration of thiosulfate was analysed by iodimetry. In the actual analysis process, before titrating with iodine solution, an appropriate amount of leached solution was diluted 10 times with deionized water. To 2 mL of diluted solution, a certain amount of distilled water was added, followed by 5 drops of EDTA saturated solution, 3 drops of formaldehyde solution (volume ratio 1:1) and 1-2 drops of methyl red as colour indicators. The sample solution to be tested was adjusted to be bright blue (pH 6-7) with the pH of the acetate–sodium acetate buffer solution. At the beginning of the test, the volume of iodine solution consumed by sample titration was recorded as V0, and after the leaching experiment was conducted for some time, the volume of iodine solution consumed by sample titration was recorded as Vt. The concentration was calculated by the following formula:

$$C_{S_2O_3^{2-}}=\frac{2C_{I_2}\times(V_t-V_0)}{V_{S_2O_3^{2-}}}$$