

## 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. Then, 200 mL of solution was added to desired amounts of the quartz–pyrite samples. The gold foil (99.99% Au) surfaces were polished using 2000-grit sandpaper, 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 ( $25 \pm 1$  °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  $\text{m}^2$  of the gold plate surface. All the experiments were conducted with reagent dosages of 0.1 M  $\text{Na}_2\text{S}_2\text{O}_3$ , 0.005 M  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ , 0.01 M en at pH 10.

### 2. Analysis of gold concentration in leaching solution containing pyrite

First, we removed 5 mL of the immersion solution with a pipet, diluted it twice with water, slowly added 3 mL hydrogen peroxide, left it for half an hour so that the thiosulfate in the sample solution was completely oxidized to sulphate, and then added 2 mL hydrochloric acid at a volume ratio of 1:1 to acidify the solution. In order to eliminate the interference of metal ions (especially  $\text{Fe}^{3+}$ ) in the analysis of the sample, the acidified solution was adsorbed with activated carbon pulp (mass ratio of activated carbon to paper was 1:2) for extraction, filtration, and adsorption, and a mixture of 10% ammonium hydrogen fluoride and 50% citric acid was used. And 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 ashing was carried out in the Muffle furnace at  $645^\circ\text{C}$ . After the ashing was completed, it was removed and cooled. Then, a few drops of 10% potassium chloride solution and 5 mL 1:1 aqua regia were added, it was heated slightly for 30 min, transferred to a beaker, and then 5% aqua regia was used to determine the concentration of gold via

atomic absorption. The concentration of gold is calculated according to the following equation.

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

### 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 diluted 10 times with deionized water was taken; then, 2 mL of diluted solution was measured, a certain amount of distilled water and 5 drops of EDTA-saturated solution were added, with 3 drops of formaldehyde solution (volume ratio 1:1) and 1-2 drops of methyl red as colour indicators. The sample solution was adjusted until maintaining a bright blue (pH 6-7) colour with 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  $V_0$ , and after the leaching experiment had been conducted for some time, the volume of iodine solution consumed by sample titration was recorded as  $V_t$ , and the concentration is calculated by the following formula:

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