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Selective Alkaline Leaching of Copper from Copper Flotation Tailings Using Monosodium Glutamate

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ABSTRACT

Monosodium glutamate (MSG) was evaluated for the first time as a chelating agent for selective alkaline leaching of copper from porphyry copper flotation tailings containing 0.33% Cu. The tailings are composed predominantly of quartz, feldspar, chlorite, and calcite, with chalcopyrite occurring as microinclusions enclosed within the silicate gangue matrix. The effects of MSG concentration (0.25–1.0 M), oxidant type (H₂O₂ and KMnO₄), and temperature (25–60 °C) on copper extraction and selectivity were investigated at pH 9.5. KMnO₄ was found to be a more effective oxidant than H₂O₂ under alkaline conditions, attributed to its greater stability and higher redox potential at this pH. Under optimal conditions (0.75 M MSG, 0.03 M KMnO₄, 60 °C, 24 h), copper extraction reached 78.6% while iron co-dissolution was limited to 0.85%, yielding a Cu/Fe separation factor of 92. Kinetic analysis using the shrinking core model indicated mixed control with an apparent activation energy of 24.6 kJ·mol⁻¹. XRD analysis of the leaching residue showed a significant decrease in chalcopyrite reflections, while pyrite peaks remained essentially unchanged. SEM-EDS imaging revealed intact cubic pyrite crystals in the residue with no evidence of surface corrosion, providing direct morphological confirmation of the process selectivity.

1. Introduction

Flotation tailings generated during porphyry copper ore processing commonly retain approximately 0.1–0.5 wt.% Cu, predominantly as fine-grained, poorly liberated chalcopyrite and other copper-bearing phases associated with or enclosed within silicate gangue particles [1–3]. These sulfide grains may escape conventional flotation because of their ultrafine size and incomplete liberation, remaining finely disseminated or physically locked within quartz, K-feldspar, muscovite, clay, and other silicate gangue minerals. Although regrinding and advanced flotation may improve their recovery, the low copper grade and complex mineral associations of such tailings also provide a rationale for investigating direct hydrometallurgical treatment [4–6].

Conventional acid leaching of copper tailings is generally characterized by limited selectivity, as copper dissolution may be accompanied by the solubilization of iron-bearing phases and other ac-

id-consuming gangue minerals. Consequently, the resulting pregnant leach solutions may contain substantially higher concentrations of iron than copper, complicating downstream copper separation and purification [7]. Moreover, the generation of acidic, sulfate-rich effluents and the associated mobilization of potentially toxic metal(loid)s impose additional wastewater-treatment and residue-management requirements, which may substantially reduce the economic attractiveness of tailings reprocessing [8–10]. These limitations have motivated the search for selective lixiviants capable of dissolving copper sulfides while leaving iron minerals intact.

Alkaline leaching with amino acid-based ligands offers a fundamentally different selectivity mechanism: copper dissolution is promoted through the formation of stable, soluble Cu-amino acid complexes, while the dissolution of iron-bearing and silicate gangue phases is largely suppressed under alkaline conditions [11–13]. At pH 9–11, Fe(III) has very low aqueous solubility and tends to precipitate

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as ferric hydroxide or oxyhydroxide phases, thereby suppressing the accumulation of dissolved iron. In contrast, Cu(II) is stabilized in solution through the formation of soluble bis(glycinato)copper(II), $\text{Cu}(\text{Gly})_2$, complexes [14]. Glycine has received the greatest attention among amino acid lixiviants. Under alkaline and oxidizing conditions, it can promote selective copper dissolution from chalcopyrite and rapidly leachable oxide minerals such as malachite at near-ambient temperatures [15–17]. Chrysocolla, however, is considerably more refractory and generally exhibits slower and substantially lower copper extraction in alkaline glycine media [18].

Monosodium glutamate (MSG, $\text{C}_5\text{H}_8\text{NNaO}_4$) represents an industrially attractive alternative to glycine because of its large-scale fermentative production, widespread commercial availability, and comparatively low cost. Global production of L-glutamate and MSG has been estimated at more than 3 million tonnes annually, with the food industry remaining its principal market [19]. Under alkaline conditions, glutamate coordinates Cu(II) through its nitrogen- and oxygen-donor groups, forming soluble complexes predominantly represented as $\text{Cu}(\text{Glu})_2^{2-}$. This complexation behavior is broadly analogous to that of copper-glycinate systems, although the additional carboxylate group of glutamate affects its coordination and solubility characteristic [20]. At pH 9.5, the conditional stability constant for copper remains high, whereas the effective stability of the iron-glutamate complex is negligible due to competing hydroxide precipitation.

The application of MSG as a lixiviant has so far been investigated for only a limited range of primary and secondary materials. An early study by Prasetyo et al. demonstrated highly selective extraction of zinc and copper from electric arc furnace dust using 1.0 M MSG at pH 9, with maximum extractions of approximately 99% and 86%, respectively, while Fe, Al, Ca, and Mg remained predominantly in the solid residue [21]. Perea-Solano et al. (2021) applied MSG to waste printed circuit boards, achieving 92% Cu recovery with minimal iron dissolution [22]. More recently, alkaline MSG leaching has been applied to chalcopyrite, achieving approximately 90% Cu dissolution after 10 h at 60 °C using KMnO_4 as an oxidant [23]. In all cases, the Cu/Fe separation fac-

tor exceeded 50, confirming the intrinsic selectivity of the system.

Despite these advances, all published studies on MSG leaching have employed relatively pure or concentrated feed materials. No work has addressed flotation tailings, which present a distinct set of challenges. Low copper grades, a complex polymineral gangue, and the physical entrapment of target sulfide phases within rock-forming minerals. It remains unclear whether the MSG system can achieve adequate copper extraction from such a dilute and texturally complex material, and how the presence of carbonates, chlorites, and multiple iron phases (pyrite, hematite, iron-bearing silicates) affects the leaching selectivity.

The present study addresses this gap by evaluating the alkaline leaching of copper from porphyry copper flotation tailings using monosodium glutamate. The effects of MSG concentration, oxidant type, and temperature on copper extraction kinetics and selectivity are systematically investigated. The selectivity of the process is assessed by chemical analysis of the leach solutions, XRD characterization of the residue mineralogy, and direct SEM-BSD observation of sulfide mineral preservation in the leaching residue.

2. Materials and Methods

2.1. Tailings characterization

Copper ore tailings were sampled from the tailings storage facility of the Balkhash processing plant (Karaganda region, Kazakhstan). The chemical composition, determined by inductively coupled plasma optical emission spectrometry (iCAP PRO XP DUO), is presented in Table 1.

The phase composition was determined by X-ray diffraction (DW-27 mini Drawell, Cu $K\alpha$ radiation, $2\theta = 10\text{--}70^\circ$, step size 0.02° , scan rate $2^\circ/\text{min}$). Particle size distribution was measured by laser diffraction (Malvern Mastersizer 3000) in wet dispersion mode. The morphology and microstructure of the tailings and leaching residues were examined by scanning electron microscopy in backscattered electron mode (SEM-BSD, Phenom XL G2 Desktop SEM), accelerating voltage 15 kV, chamber pressure 0.10 Pa).

Table 1. Chemical composition of the sample

Element	Si	Al	Fe	Ca	Mg	S	Cu	Zn
wt.%	35.22	3.47	2.23	1.42	0.85	1.18	0.33	0.82

2.2. Reagents

Monosodium glutamate ($C_5H_8NNaO_4$, $\geq 99\%$, food grade) was used as the chelating agent. Potassium permanganate ($KMnO_4$, analytical grade) and hydrogen peroxide (H_2O_2 , 30%, analytical grade) were used as oxidants. Sodium hydroxide ($NaOH$, analytical grade) was used for pH adjustment. All solutions were prepared with distilled water.

2.3. Leaching procedure

Leaching experiments were conducted in 500 mL Erlenmeyer flasks placed in a thermostated orbital shaker (400 rpm). In each experiment, 30 g of tailings was suspended in 300 mL of MSG solution (solid-to-liquid ratio 1:10, w/v). The pH was adjusted to 9.5 with $NaOH$ and maintained throughout the experiment. The oxidant was added at the beginning of each run.

The following parameters were varied systematically:

- MSG concentration: 0.25, 0.50, 0.75, and 1.00 M;
- oxidant type and concentration: H_2O_2 (0.03, 0.05, 0.10 M), $KMnO_4$ (0.01, 0.03, 0.05 M), and a control without oxidant;
- temperature: 25, 40, and 60 °C;
- leaching time: 0.5, 1, 2, 4, 8, and 24 h.

Aliquots of 5 mL were withdrawn at predetermined intervals, filtered through 0.45 μm membrane filters, and analyzed by ICP-OES for Cu, Fe, Zn, Al, Ca, and Mg. The extraction of each element was calculated from the solution concentration, solution volume, initial solid mass, and the corresponding element content in the feed material. Solid residues obtained after 24 h were washed with deionized water, dried at 60 °C for 12 h, and characterized by XRD and SEM-BSD.

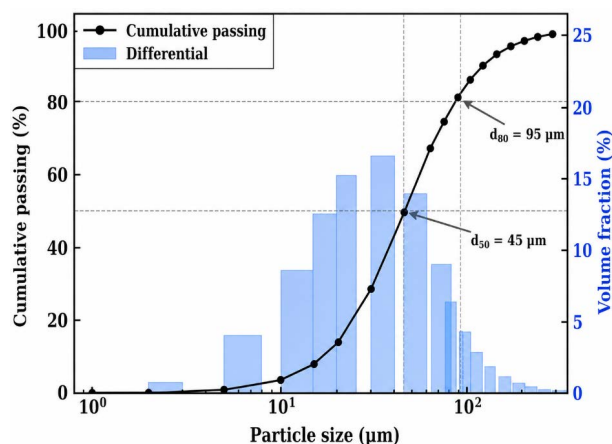


Fig. 1. Particle size distribution of the copper ore tailings.

All leaching experiments were performed in triplicate under identical conditions, and the reported extraction values represent the mean of three independent experiments ($n = 3$).

3. Results and Discussion

XRD analysis of the initial flotation tailings identified quartz, albite, chlorite, calcite, pyrite, chalcopryite, and hematite as the principal crystalline phases (Fig. 7). The gangue is dominated by silicate and carbonate minerals, whereas pyrite and chalcopryite represent the sulfide phases relevant to the subsequent leaching behavior. SEM-BSD observations further revealed that chalcopryite occurs as fine microinclusions embedded within the silicate gangue matrix, indicating incomplete liberation of the copper-bearing phase. Such textural association may restrict the accessibility of chalcopryite to the leaching solution and contribute to incomplete copper extraction. Since quantitative phase analysis was not performed, the mineralogical characterization is interpreted qualitatively.

The particle size distribution of the tailings, obtained by laser diffraction, is shown in Fig. 1.

The material exhibits a median particle size $d_{50} = 45 \mu m$ and $d_{80} = 95 \mu m$, with a broadly unimodal distribution. Approximately 30% of the particles are finer than 20 μm . This relatively fine grind is inherited from the original flotation circuit and is favorable for leaching, as it provides a high specific surface area without requiring additional comminution.

The influence of sodium glutamate concentration on the extraction of Cu, Zn, and Fe is presented in Fig. 2 (25 °C, pH 9.5, 0.03 M H_2O_2 , 24 h).

From a process-development perspective, the relatively high MSG concentration used in the present system makes reagent management an im-

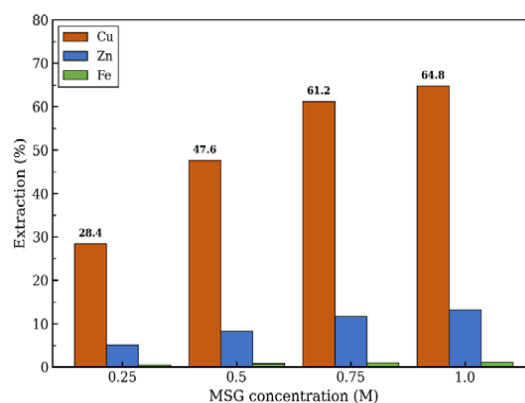


Fig. 2. Effect of MSG concentration on the extraction of Cu, Zn, and Fe (25 °C, pH 9.5, 0.03 M H_2O_2 , 24 h).

portant consideration. Recovery and reuse of the glutamate-containing leach solution after copper separation could potentially reduce fresh MSG consumption and improve the economic and environmental performance of the process. However, MSG recycling was not investigated experimentally in the present study, and the effects of repeated solution reuse, accumulation of dissolved species, and changes in complexing capacity should be evaluated in future work.

Copper extraction increased markedly with increasing MSG concentration, rising from 28.4% at 0.25 M to 47.6% at 0.50 M and 61.2% at 0.75 M. A further increase to 1.0 M resulted in only a modest improvement, to 64.8%, indicating a diminishing effect of increasing ligand concentration above 0.75 M. This behavior suggests that, once sufficient glutamate is available for copper complexation, the overall extraction may become increasingly controlled by mineral accessibility, chalcopryrite oxidation, and mass transfer through reaction-product or gangue layers. A comparable diminishing influence of MSG concentration has been observed during the leaching of complex copper sulfide concentrates, for which high copper extraction was achieved using 0.5 M MSG under oxygenated conditions [24]. Iron extraction remained below 1.2% across all concentrations (12–25 mg/L Fe), confirming the inherent selectivity of the glutamate- Cu^{2+} chelation at pH 9.5: iron precipitates as $\text{Fe}(\text{OH})_3$, while copper forms the soluble bis(glutamato)copper(II) complex $\text{Cu}(\text{Glu})_2^{2-}$. Zinc extraction increased gradually from 5.1% to 13.2%, reflecting the moderate affinity of glutamate for Zn^{2+} at alkaline pH. A concentration of 0.75 M MSG was selected as optimal for subsequent experiments, balancing high copper recovery against reagent consumption.

The dissolution of chalcopryrite under alkaline conditions requires oxidation of sulfide sulfur and ferrous iron; accordingly, the choice of oxidant is critical. Figure 3 presents the kinetics of copper extraction using H_2O_2 and KMnO_4 at various concentrations, compared with a control experiment without oxidant (0.5 M MSG, pH 9.5, 25 °C).

Without oxidant, copper extraction reached only 12.3% after 24 h, confirming that direct dissolution of chalcopryrite by glutamate alone is severely limited. Addition of 0.03 M H_2O_2 enhanced extraction to 47.6%, with further increases to 52.1% and 54.8% at 0.05 and 0.10 M, respectively. The relatively modest improvement upon increasing H_2O_2 concentration is attributed to its rapid catalytic decomposition under alkaline conditions, which limits its effective lifetime in solution. KMnO_4 proved more effective: at

0.03 M, copper extraction reached 58.7%, exceeding that of 0.05 M H_2O_2 , despite the lower molar concentration. At 0.05 M KMnO_4 , extraction reached 62.4%. The superior performance of permanganate is attributed to its thermodynamic stability at pH 9.5 and its higher redox potential ($E^\circ = +0.58$ V for $\text{MnO}_4^-/\text{MnO}_2$ at this pH) compared with H_2O_2 ($E^\circ = +0.15$ V). Additionally, the MnO_2 reduction product does not consume glutamate and may passivate pyrite surfaces, further suppressing iron dissolution (16 mg/L Fe with KMnO_4 versus 18 mg/L with H_2O_2 at identical concentrations). Although 0.05 M KMnO_4 resulted in a slightly higher copper extraction (62.4%) than 0.03 M KMnO_4 (58.7%), increasing the oxidant concentration from 0.03 to 0.05 M represents an approximately 67% increase in oxidant concentration while improving copper extraction by only 3.7 percentage points. Therefore, 0.03 M KMnO_4 was selected as the preferred concentration for subsequent temperature experiments as a compromise between copper extraction and oxidant consumption.

The effect of temperature on copper extraction kinetics under optimized conditions (0.75 M MSG, 0.03 M KMnO_4 , pH 9.5) is presented in Fig. 4.

At all temperatures, the extraction curves exhibit a rapid initial phase during the first 2–4 h, followed by gradual deceleration. At 25 °C, copper extraction reached 18.5% after 2 h and 61.2% after 24 h. Increasing the temperature to 40 °C yielded 37.1% at 2 h and 72.4% at 24 h. At 60 °C, the maximum extraction of 78.6% was achieved within 24 h, with 48.2% recovered after only 2 h. The incomplete extraction at 60 °C is attributed to the occlusion of a portion of chalcopryrite microinclusions within dense silicate particles, rendering them inaccessible with-

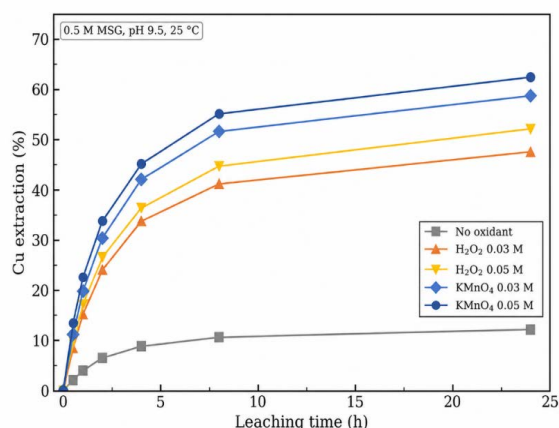


Fig. 3. Kinetics of copper extraction with different oxidants: H_2O_2 and KMnO_4 at various concentrations compared with a control without oxidant (0.5 M MSG, pH 9.5, 25 °C).

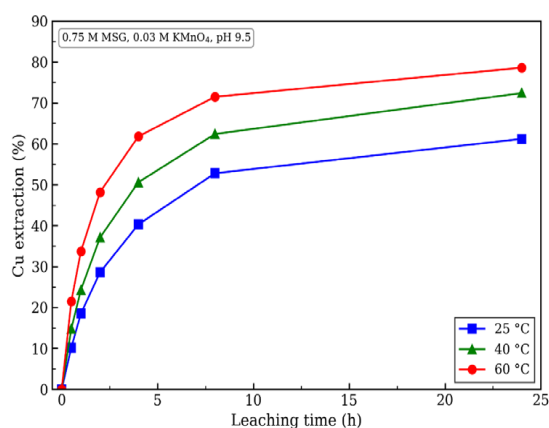


Fig. 4. Effect of temperature on the kinetics of copper extraction (0.75 M MSG, 0.03 M KMnO_4 , pH 9.5).

out mechanical activation. The kinetic data were analysed using the shrinking core model (SCM), which assumes that leaching proceeds from the external surface of a solid particle toward its unreacted core. As the reaction progresses, the radius of the unreacted core decreases, while a reacted or product layer develops around it. Depending on the relative rates of the interfacial chemical reaction and mass transfer through this layer, the overall process may be controlled by the surface reaction, diffusion through the product layer, or a combination of both mechanisms. For chemical-reaction-controlled leaching, the experimental data were fitted using the following SCM expression:

$$1 - (1 - X)^{1/3} = k_r t \quad (1)$$

where: X is the fractional extraction of copper at time t (dimensionless, from 0 to 1), t is the leaching time (h), and k_r is the apparent rate constant for chemical-reaction control (h^{-1}).

In this model, the rate-limiting step is the chemical reaction occurring at the interface between the unreacted solid core and the leaching solution. A linear relationship between $1 - (1 - X)^{1/3}$ and t therefore indicates that the interfacial reaction makes the dominant contribution to the overall leaching rate.

The chemical-reaction-control equation provided a good fit during the initial 0–8 h of leaching, with coefficients of determination exceeding 0.98 at all investigated temperatures. This result indicates that, during the early stage, the reactive mineral surface remained readily accessible to the leaching solution and the overall rate was governed mainly by reactions at the solid-liquid interface.

To evaluate the later stage of the process, the data were also fitted to the product-layer diffusion equation:

$$1 - 3(1 - X)^{2/3} + 2(1 - X) = k_d t \quad (2)$$

where: k_d is the apparent rate constant associated with diffusion through the product layer (h^{-1}). The other symbols have the same meanings as defined above.

This expression describes a situation in which dissolved reactants must diffuse through an increasingly thick reacted layer to reach the unreacted core, while soluble reaction products must diffuse in the opposite direction into the bulk solution.

The product-layer diffusion model described the experimental data more accurately during the 8–24 h interval. The improved fit at longer leaching times is consistent with the progressive accumulation of elemental sulfur and manganese dioxide (MnO_2) on the particle surface. MnO_2 formation may therefore have a dual effect on the leaching process. While MnO_2 may contribute to the suppression of pyrite dissolution and thus enhance Cu/Fe selectivity, its progressive accumulation on particle surfaces may partially cover reactive sites, increase the effective diffusion path, and restrict the transport of leaching species to the remaining copper-bearing phases. This effect may contribute to the gradual decrease in the copper leaching rate observed at longer reaction times. However, manganese distribution between the liquid and solid phases was not quantified in the present study; therefore, the proposed role of MnO_2 should be regarded as a mechanistic interpretation that requires further experimental verification.

Taken together, the fitting results suggest a change in the dominant kinetic regime during leaching. The initial stage is primarily controlled by the interfacial chemical reaction, whereas the later stage is increasingly affected by diffusion through the developing product layer. The process may therefore be described as undergoing a transition from chemical-reaction control to mixed control rather than an abrupt change to purely diffusion-controlled kinetics. Under mixed control, both the surface reaction and mass transfer through the product layer contribute appreciably to the observed overall rate.

The apparent rate constants (k) were obtained from the slopes of the corresponding linearized shrinking-core-model plots at 25, 40, and 60 °C. These rate constants were subsequently used to construct the Arrhenius plot of $\ln k$ versus $1/T$ (Fig. 5). The apparent activation energy was calculated from the slope of the Arrhenius relationship according to the equation $\ln k = \ln A - E_a/RT$. Since the kinetic analysis indicated a transition from predominantly

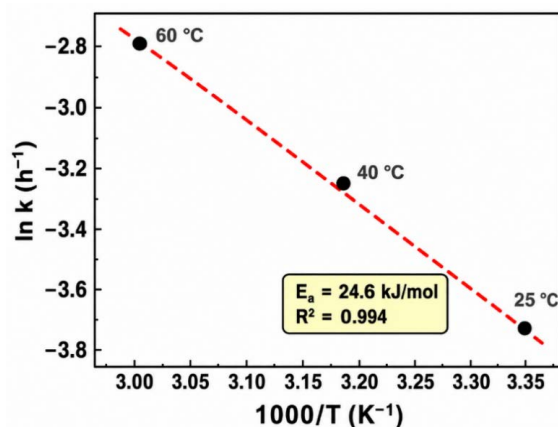


Fig. 5. Arrhenius plot for copper leaching from tailings with MSG: $\ln k$ versus $1000/T$ based on the shrinking core model.

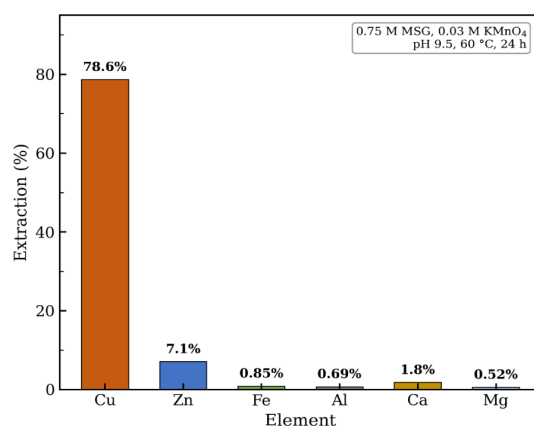


Fig. 6. Extraction of individual elements under optimal leaching conditions (0.75 M MSG, 0.03 M KMnO_4 , pH 9.5, 60 °C, 24 h).

chemical-reaction control at the initial stage to an increasing contribution of product-layer diffusion at longer leaching times, the calculated activation energy is interpreted as an apparent activation energy characterizing the overall mixed-control leaching process rather than a single elementary rate-controlling step.

The Arrhenius plot showed a strong linear relationship ($R^2 = 0.994$), yielding an apparent activation energy of $24.6 \text{ kJ} \cdot \text{mol}^{-1}$. This relatively low value suggests that copper dissolution is not controlled exclusively by the surface chemical reaction but involves a substantial mass-transfer contribution. Accordingly, the process may be described as mixed-controlled, with diffusion through the gangue or reaction-product layer contributing to the overall rate. This interpretation is broadly consistent with recent kinetic studies of chalcopyrite leaching in alkaline MSG media, which identified product-layer diffusion as an important rate-limiting mechanism [25].

The selectivity of the leaching system is an important aspect of the proposed process. Fig. 6 presents the extraction of individual elements under optimal conditions (0.75 M MSG, 0.03 M KMnO_4 , pH 9.5, 60 °C, 24 h).

Copper was selectively extracted at 78.6% (259 mg/L), while iron extraction was negligible at 0.85% (19 mg/L), corresponding to a Cu/Fe separation factor of approximately 92. Aluminum (0.69%), calcium (1.8%), and magnesium (0.52%) dissolution was similarly minimal, confirming that silicate and carbonate gangue minerals remain largely unaffected. Zinc showed a moderate extraction of 7.1% (58 mg/L), reflecting partial Zn-glutamate complexation; however, its concentration relative to Cu would not complicate downstream recovery.

The selectivity is explained by the thermodynamics of metal-glutamate complexation at pH 9.5. The stability constant of $\text{Cu}(\text{Glu})_2^{2-}$ ($\log \beta_2 \approx 15.2$) greatly exceeds that of $\text{Fe}(\text{Glu})_2$ ($\log \beta_2 \approx 8.7$), and at pH 9.5 ferric iron is overwhelmingly precipitated as $\text{Fe}(\text{OH})_3$ ($K_{\text{sp}} = 2.8 \times 10^{-39}$), effectively preventing its complexation. This thermodynamic selectivity is the principal advantage over sulfuric acid leaching, where iron dissolution from pyrite and chalcopyrite can exceed 30–50%.

The XRD patterns before and after leaching (Fig. 7) provide direct phase-level evidence of selectivity.

In the residue pattern, reflections attributed to chalcopyrite are significantly diminished, while quartz, albite, chlorite, and pyrite peaks remain essentially unchanged. The persistence of pyrite confirms that the MSG system at pH 9.5 does not attack iron disulfide, consistent with the near-zero iron extraction.

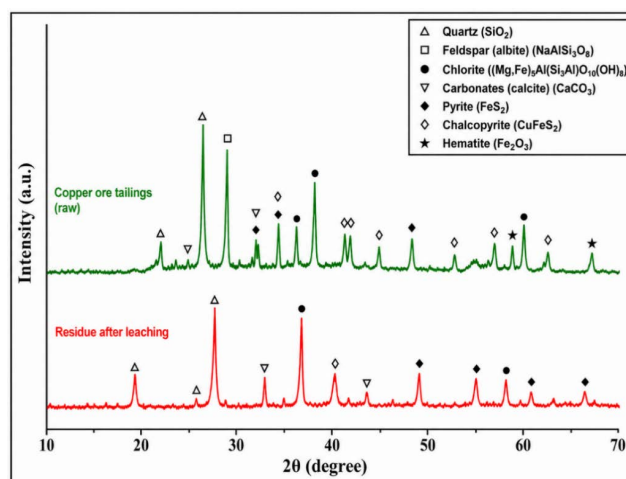


Fig. 7. XRD patterns of copper ore tailings and leaching residue.

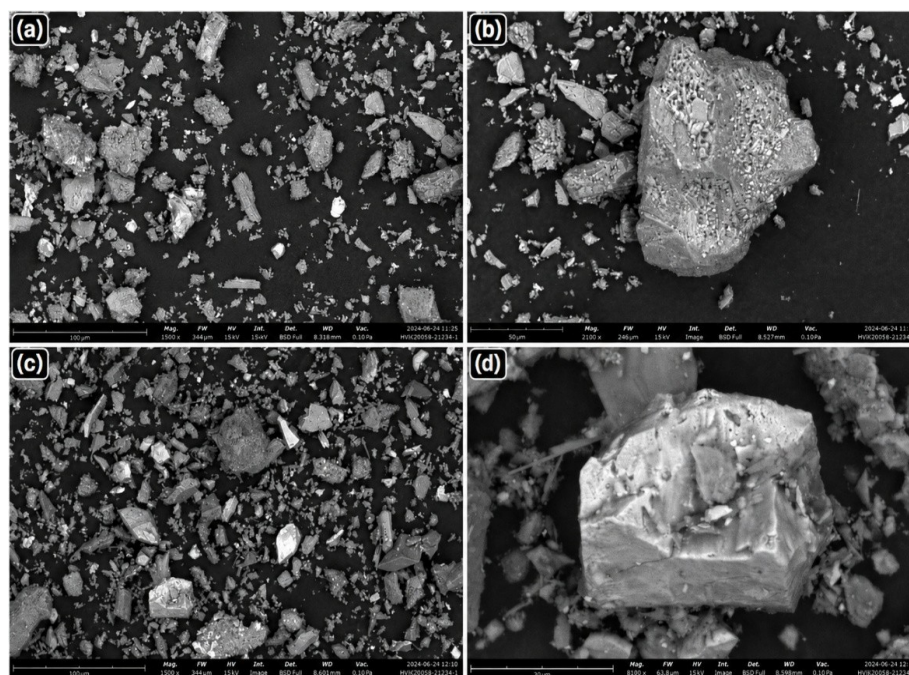


Fig. 8. SEM-BSD images: (a) raw tailings, general view, 1500 $\times$; (b) composite particle with sulfide microinclusions in the silicate matrix, 2100 $\times$; (c) leaching residue, general view, 1500 $\times$; (d) intact pyrite crystal preserved in the residue after MSG leaching, 8100 $\times$.

SEM-BSD observations (Fig. 8) further corroborate these findings. In the raw tailings (Fig. 8a), angular to sub-angular particles of 5–150 μm are observed; bright inclusions in BSD contrast correspond to high-Z sulfide phases. At higher magnification (Fig. 8b), composite particles reveal chalcopyrite microinclusions (bright) embedded in the silicate matrix (dark), confirming the micro-enclosed nature of the mineralization. After leaching (Fig. 8c), the overall particle morphology is preserved, but the frequency and brightness of sulfide inclusions are visibly reduced, indicating dissolution of accessible chalcopyrite. The most compelling evidence is provided by Fig. 8d: a pyrite crystal with well-preserved cubic morphology (~ 20 μm edge length) in the leaching residue at 8100 $\times$ magnification. The crystal surfaces are smooth, with no pitting, etching, or corrosion, demonstrating that pyrite remained completely inert during 24 h of MSG leaching at 60 $^{\circ}\text{C}$. Combined with XRD and ICP-OES data, this establishes that the alkaline glutamate system achieves selective dissolution of chalcopyrite while leaving pyrite and gangue minerals intact.

4. Conclusion

This study demonstrates the first application of monosodium glutamate as a chelating agent for selective copper extraction from flotation tailings

of porphyry copper ores (Balkhash, Kazakhstan, 0.33% Cu).

Under optimal conditions (0.75 M MSG, 0.03 M KMnO_4 , pH 9.5, 60 $^{\circ}\text{C}$, 24 h), copper extraction reached 78.6% with exceptional selectivity: iron co-dissolution was only 0.85% (Cu/Fe separation factor ≈ 92). XRD and SEM-BSD analyses indicated that pyrite was largely preserved in the leaching residue, with intact cubic crystals showing no evident signs of surface corrosion.

Kinetic modeling yielded an apparent activation energy of 24.6 kJ/mol, indicating mixed control by chemical reaction and diffusion through the product layer. The residual unextracted copper is attributed to chalcopyrite microinclusions occluded within the silicate matrix.

The alkaline MSG system combines high selectivity with environmental advantages making it a promising approach for copper recovery from technogenic deposits in ecologically sensitive regions.

Author Contributions

Lyazzat Mussapurova – Writing – Original Draft, Visualization, Writing – Review & Editing. **Aisulu Batkal** – Writing – Original Draft, Writing – Review & Editing, Investigation. **Kaster Kamunur** – Data Curation, Writing – Review & Editing. **Timur Osserov** – Methodology, Visualization. **Olesya Tumentseva** – Conceptualization, Methodology, Supervision.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Селективное щелочное выщелачивание меди из хвостов медной флотации с использованием глутамата натрия

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АННОТАЦИЯ

Впервые исследовано применение глутамата натрия в качестве комплексообразующего реагента для селективного щелочного выщелачивания меди из хвостов флотации порфировых медных руд, содержащих 0,33% Cu. Изучено влияние концентрации глутамата натрия, типа окислителя и температуры при pH 9,5. В оптимальных условиях (0,75 М глутамат натрия, 0,03 М KMnO_4 , 60 °C, 24 ч) извлечение меди достигло 78,6%, тогда как сорастворение железа составило 0,85%. Кинетический анализ показал смешанный режим контроля с кажущейся энергией активации 24,6 кДж·моль. Данные рентгенофазового анализа и СЭМ подтвердили селективное растворение халькопирита при сохранении пирита и минералов пустой породы.

Ключевые слова: хвосты флотации, глутамат натрия, щелочное выщелачивание, извлечение меди, халькопирит, селективное растворение, модель сжимающегося ядра

Натрий глутаматын пайдаланып мыс флотациясы қалдықтарынан мысты селективті сілтілі шаймалау

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АҢДАТПА

Құрамында 0,33% Cu бар порфирлі мыс кендерін флотациялау қалдықтарынан мысты селективті сілтілі шаймалау үшін натрий глутаматын кешен түзуші реагент ретінде қолдану алғаш рет зерттелді. pH 9,5 жағдайында натрий глутаматы концентрациясының, тотықтырғыш түрінің және температураның әсері анықталды. Оңтайлы жағдайда (0,75 М натрий глутаматы, 0,03 М KMnO_4 , 60 °C, 24 с) мыстың алынуы 78,6%-ға жетті, ал темірдің қатар еруі 0,85% болды. Кинетикалық талдау 24,6 кДж·моль көрінерлік активтену энергиясымен аралас бақылау режимін көрсетті. Рентгенфазалық және СЭМ деректері пирит пен бос жыныс минералдары сақталған кезде халькопириттің селективті ерігенін растады.

Түйін сөздер: флотация қалдықтары, натрий глутаматы, сілтілі шаймалау, мысты алу, халькопирит, селективті еріту, кішірейетін өзек моделі