

**LEACHING OF GOLD FROM OXIDIZED GOLD ORES
USING GLYCINE****Rakhmonova, U.T.****Instructor****Rakhmanova4302@gmail.com****Akhmedova Dilshodakhon Abdukodir kizi****Student****Ahmedovadilshoda405@gmail.com****Jizzakh State Pedagogical University****<https://doi.org/10.5281/zenodo.18845281>****ARTICLE INFO**Received: 26th February 2026Accepted: 27th February 2026Online: 28th February 2026**KEYWORDS**

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Gold; Silver; Oxidized gold ore

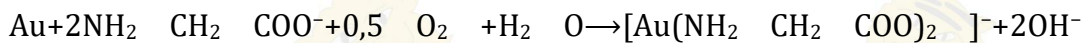
ABSTRACT

This study investigated the process of gold extraction from oxidized gold ore, leveraging the selective dissolution property of glycine for precious metals. Glycine, a non-toxic and simple amino acid, is of significant interest for its potential use in gold extraction. The study utilized glycine solutions at concentrations of 1-3 M, with reaction times ranging from 4 to 60 hours. Throughout the process, the pH was maintained at 11-12, the reactor temperature was set to 60 °C, the stirring speed was 350 rpm, and the air flow was 1 L/min. The average particle size of the oxidized ore was 70.7 μm. The results of the study indicated that the highest gold recovery rate of 81.41% was achieved after 48 hours in a 3 M glycine solution. Silver solubility was moderate at 44.50%, while iron exhibited low solubility at 7.71%. Furthermore, it was determined that extending the reaction time and increasing the glycine concentration promoted greater gold extraction from the oxidized ore.

Introduction

Gold is a yellow metal characterized by high plasticity, malleability, corrosion resistance, and chemical stability. It typically occurs as native gold, electrum (an Au-Ag alloy), Au-Ag tellurides, maldonite, aurostibite, auricupride, or in association with sulfide minerals such as pyrite and arsenopyrite (Harris, 1990; Vogan, 2004). The characteristics of mineral ores significantly influence the extraction methods and their efficiency. Due to the depletion of free-milling ores, fine-grained ores containing coarse and refractory particles have become more prevalent, making hydrometallurgical methods crucial for their processing (Breuer and Jeffrey, 2003; Dehghanpoor et al., 2016). The physical and chemical properties of gold, such as its thermal conductivity, electrical conductivity, and chemical inertness (Carvill, 1993; Yan et al., 2015; Salehian et al., 2017; Kim et al., 2018), along with its mineralogical characteristics, determine its reactivity with various reagents. Gold does not dissolve in common acids, but it can be dissolved when oxidizing agents - such as nitric acid, oxygen, or manganese dioxide - are added to acids like hydrochloric acid. Historically, amalgamation and cementation methods using mercury and zinc powder were employed, but cyanide leaching remains the

predominant method (Yannopoulos, 1991). Discovered in the 19th century, cyanidation is still the most widely used technique, accounting for over 85% of global gold production (Chamber of Geological Engineers, 2022). While heap leaching with cyanide allows for large-volume processing, the use of cyanide poses serious environmental and biological risks (Clesceri et al., 1999; Hedjazi and Monhemius, 2018; Cao et al., 2020; Freitas and Horta, 2023). It is crucial to maintain a pH level above 10 to prevent the formation of toxic HCN gas, and the treatment of cyanide-containing waste requires expensive facilities. Public opposition and stringent regulatory requirements are also intensifying the search for alternative technologies. Recently, glycine (C₂H₅NO₂) has gained attention as a promising extraction agent due to its non-toxic and biodegradable properties. It has the ability to selectively dissolve precious metals and can form stable metal-glycinate complexes. Glycine forms complexes with Au, Ag, Cu, Pd, Cd, Zn, Pb, Co, and Ni (Altinkaya et al., 2020; Aylmore, 2016). In selective leaching with glycine, the glycine primarily exists in the anionic form of glycinate, and its reaction is expressed by the following equation (Altinkaya et al., 2020):



The glycine leaching process is carried out in the presence of oxygen or other oxidizers, which provides the advantages of this reagent, including its recyclability, allowing for an increase in the economic efficiency of the process (Oraby and Eksteen, 2015). A number of studies have demonstrated the potential to extract 80-90% of gold from various ore types using a glycine-based method (Oraby and Eksteen, 2015; Oraby et al., 2019; Oraby et al., 2020; Altinkaya et al.). These studies also highlight the influence of parameters such as glycine concentration, pH, ore particle size, and the type of oxidizer. For example, Orabi and Eksteen (2015) demonstrated that gold and silver can be effectively dissolved in peroxide solutions at a pH of 11 using glycine. Oraby et al. (2020) achieved an 85.1% efficiency in gold extraction using permanganate as an oxidizing agent. Altinkaya et al. (2020) achieved a 90% recovery rate through a method optimized under laboratory conditions. In recent years, a number of studies have explored in greater depth the potential of glycine-based selective leaching for various gold compositions. Li et al. (2023) analyzed amino acid-based selective leaching systems and discussed the role of glycine. In recent years, a number of studies have deepened the possibilities of glycine-based leaching for various gold content. They noted that glycine could be used for the effective and selective leaching of precious metals under mild alkaline conditions. Field studies were also conducted, which showed, for example, that selective leaching at a pH of 12 using only glycine in Witwatersrand-type tailings significantly improved gold extraction efficiency. Overall, these studies demonstrate that scientific interest in glycine leaching is not waning. However, its effectiveness can vary considerably depending on the ore type, pretreatment methods, and operating conditions, which necessitates further research. Despite these promising results, the application of selective glycine leaching to various ore types remains limited. The primary reason for this is the lack of sufficient data to fully understand the selectivity, kinetics, and scalability of glycine. This study investigated the reaction characteristics of a standard oxide gold ore using alkaline glycine solutions prepared from non-analytical grade glycine. The research examined the effects of glycine concentration and reaction time on gold extraction, as well as on silver solubility. Other process parameters - pH, temperature, solid-to-liquid ratio, agitation speed, and airflow - were held constant

based on previously determined optimal conditions. The findings of this study, combined with previous results, confirm the potential of glycine as a sustainable and environmentally safe alternative to cyanidation, demonstrating its application possibilities in comparison with existing literature.

Materials and methods

A standard oxidized gold ore was used in all experiments. To determine the gold and silver content, gold and silver were separated from the ore's slag at a high temperature, and their exact amounts were determined using atomic absorption spectrometry (AAS). Following this assay, a small metallic bead containing concentrated gold and silver was formed during the cupellation stage and prepared for laboratory quantification. The general chemical composition of the oxidized ore is presented in Table 1. While the AAS method was used for the active gold (Au) and silver (Ag) content, the chemical composition of the sample for other elements was determined using X-ray fluorescence, a rapid and non-destructive analysis method.

Table 1.

Chemical composition of the gold-bearing oxide ore sample (by mass)

Au, g/t	Ag, g/t	Si, %	Fe, %	As, %	S, %	P, %
12.00	3.55	31.55	2.51	0.45	0.32	0.08

The method of separating gold and silver from ore slag at high temperatures and determining their exact quantity is a very ancient technique, with its first use dating back to approximately the 4th millennium BC. As shown in Figure 3, it includes the following main stages:

1. Ore samples are mixed with lead oxide, a reducing agent, and fluxing agents.
2. The mixture is melted at a high temperature, causing the precious metals to collect in the lead phase.
3. The precious metals are separated from the slag as a metallic product from the lead phase, and their composition is determined by chemical analysis or weighing.

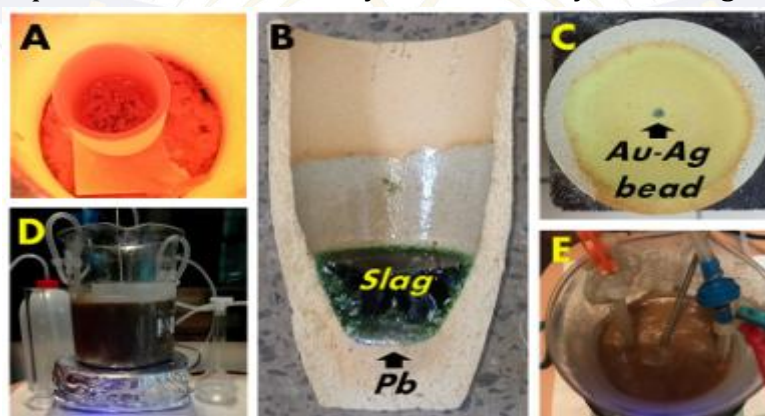


Figure 1. Photographs from the experiments: (a) the smelting process; (b) the resulting precious metal-bearing lead (Pb) and slag phases; (c) the resulting gold (Au) and silver (Ag) bead; (d) the solution in the beaker during the selective dissolution process; (e) the selective dissolution experimental setup.

The ore's X-ray diffractogram was obtained using an X-ray diffraction instrument at 40 kV/15 mA with Cu K α radiation. Figure 2 shows that the ore primarily consists of the SiO₂ (PC: 01-083-2465) phase, with minor amounts of the following phases also present: Mg₂Si₂O₆ (PC:

01-086-0432), $\text{Mg}_2\text{Al}_4\text{Si}_5\text{O}_{18}$ (RC: 00-013-0294), and Fe_2O_3 (RC: 00-039-0238). The average particle size of the ore was calculated to be $70.7 \mu\text{m}$, as determined by a Malvern Mastersizer 3000 Aero S laser analyzer. The particle size distribution of the ore is presented in Figure 3.

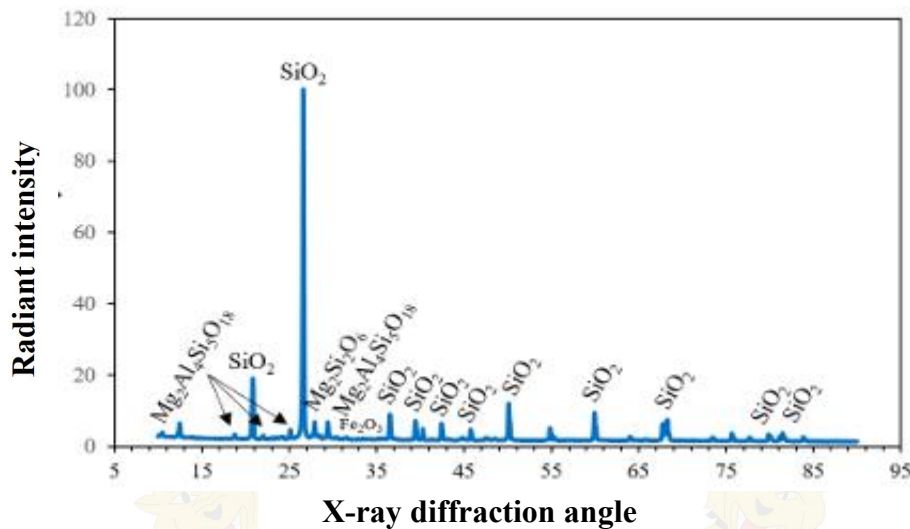


Figure 2. X-ray diffraction analysis (diffractogram) of the oxidized gold ore.

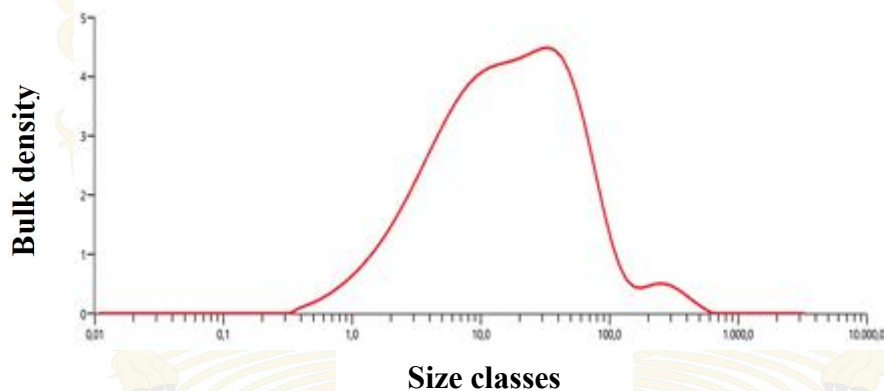


Figure 3. Particle size distribution of the oxidized gold ore.

In the leaching experiments, 97% pure glycine was used as the leaching reagent. NaOH was added to the leaching solutions to determine their pH values.

Method

To evaluate the effect of glycine concentration (1, 2, and 3 M) on leaching efficiency, experiments were conducted with leaching times extended from 4 to 60 hours. In each experiment, a 20 g ore sample was leached at a solid-to-liquid ratio of 1:10. A mixture of glycine and distilled water was used as the leaching medium. All experiments were carried out with constant agitation on a magnetic stirrer at a speed of 350 rpm. In accordance with the reaction mechanism, dry air was continuously supplied to the solutions at a flow rate of 1 L/min to provide oxygen. Concurrently, the pH of the solution was consistently maintained in the 11-12 range to ensure the maximum selective dissolution of gold in the glycine medium. To control and adjust the pH, a 2 M NaOH solution was gradually added to the glycine solution. All alkalization experiments were conducted at a temperature of 60°C . To prevent evaporation of the solution during the experiment, the reaction vessels were covered with paraffin film. Each alkalization experiment was performed separately in a single complete batch, meaning no intermediate samples were taken during the process. This approach served

to increase the reliability of the experimental results. After the alkalization process was complete, all solutions were filtered, and the gold, silver, and iron content in the resulting metal-bearing solutions was determined using atomic absorption spectrometry (AAS). The alkalization experiments are presented in Figure 4, and photographs from selected dissolution experiments are shown separately in Figure 1.

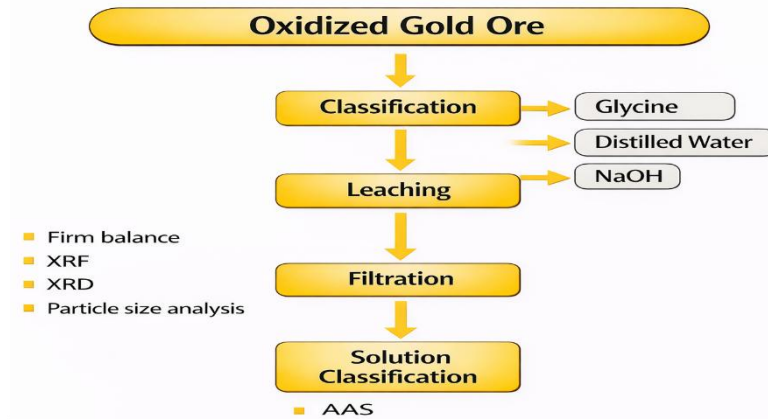


Figure 4. Block diagram of the experimental research.

Results and discussion

As clearly demonstrated in Figure 5, as well as in Tables 2 and 3, the dissolution rate of gold in a glycine solution increases with higher molarity and longer reaction times. A comparison of the results obtained at various concentrations and time intervals showed that the highest degree of gold dissolution was observed in a 3 M glycine solution. At this concentration, the solubility of gold reached a maximum value after 48 hours, achieving an equilibrium state. Under these conditions, the majority of the 9.77 g/t of gold present in the initial ore passed into the solution, resulting in a selective leaching rate of 81.41%. It is noteworthy that this result is the highest показатель among all the selective leaching experiments conducted. When the reaction time was extended to 60 hours, the solubility of gold decreased slightly to 9.62 g/t, or 80.17%. Under the same conditions, the solubility of silver was relatively low, determined to be 1.58 g/t or 44.50%.

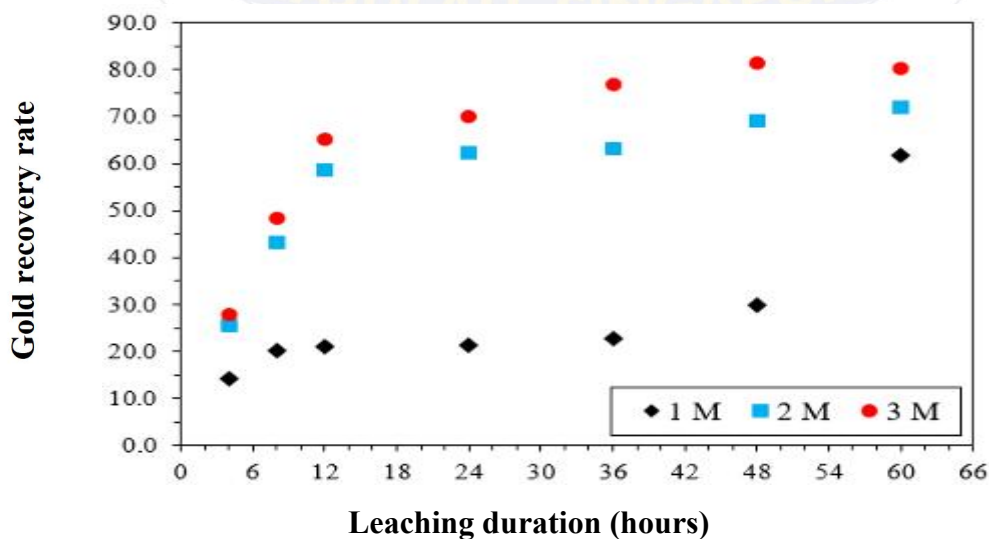


Figure 5. The effect of molarity and reaction time on the selective dissolution (recovery) rate of gold (Au) in a glycine solution.

Table 2.

A comparative analysis of the solubility levels of gold (Au), silver (Ag), and iron (Fe) in relation to initial ore composition, depending on the increase in molarity values and reaction duration.

Time	Au, g/t ore			Ag, g/t ore			Fe, g/t ore		
	1 M	2 M	3 M	1 M	2 M	3 M	1 M	2 M	3 M
4	1.72	3.06	3.35	0.44	0.51	0.55	1.95	2.09	2.04
8	2.43	5.19	5.79	0.72	0.82	0.96	1.91	2.07	2.01
12	2.51	7.02	7.80	1.01	1.15	1.30	1.87	2.05	1.97
24	2.57	7.46	8.40	1.08	1.26	1.41	1.84	2.03	1.95
36	2.72	7.58	9.21	1.03	1.22	1.51	1.89	2.00	1.94
48	3.57	8.29	9.77	1.16	1.36	1.58	1.94	1.98	1.93
60	7.42	8.62	9.62	1.20	1.39	1.63	1.97	2.07	1.93

Table 3.

Recovery rates of Au, Ag, and Fe with increasing molar values and reaction time

Time	Au, mass fraction, %			Ag, mass fraction, %			Fe, mass fraction, %		
	1 M	2 M	3 M	1 M	2 M	3 M	1 M	2 M	3 M
4	14.33	25.50	27.92	12.39	14.37	15.49	7.79	8.33	8.15
8	20.25	43.25	48.25	20.28	23.10	27.04	7.63	8.27	8.03
12	20.92	58.50	65.00	28.45	32.39	36.62	7.46	8.18	7.87
24	21.42	62.17	70.00	30.42	35.49	39.72	7.35	8.08	7.80
36	22.67	63.17	76.75	29.01	34.37	42.54	7.56	7.98	7.74
48	29.75	69.08	81.41	32.68	38.31	44.50	7.75	7.92	7.71
60	61.83	71.83	80.17	33.8	39.15	45.91	7.87	8.25	7.70

It was observed that the solubility of the silver element increased with the rise in the molarity of the glycine solution and the reaction time (Figure 6, Tables 2 and 3). It was noted that after 12 hours of leaching, the silver solubility indicators stabilized; specifically, more metal began to dissolve in the solution, but it quickly reached a corresponding value and then exhibited slow growth. The highest recovery rate was observed in a 3 Molar glycine solution during a 60-hour experiment. Under these conditions, the solubility of silver was 1.63 g/t, which corresponds to 45.91%. This result indicated that glycine concentration and reaction time have a direct impact on the efficiency of silver dissolution, which is important for determining the optimal conditions for the selective separation of gold and silver.

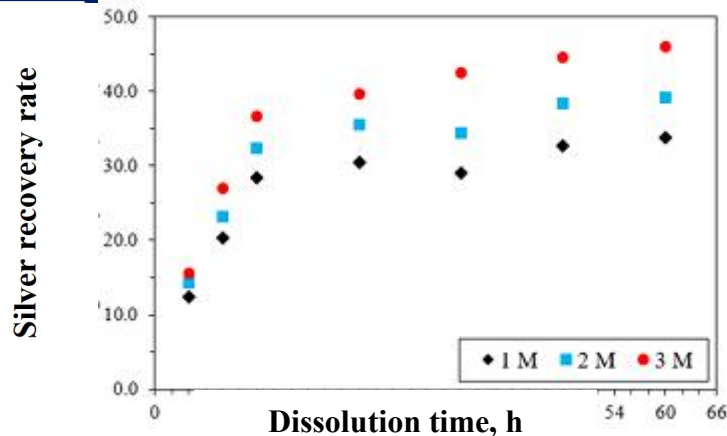


Figure 6. The recovery rate of silver (Ag) as a function of molarity and reaction time.

The primary objective in processing raw ore samples is the effective extraction of precious metals. However, it is also crucial that other base metals in the ore, such as iron, are not lost - that is, leached out - during this process, as they serve as important supplementary elements for the ore's chemical composition and subsequent processing stages. In this regard, the selectivity of glycine was investigated, particularly for iron (see Figure 7, Tables 2 and 3). The research results showed that an increase in molarity and reaction time did not significantly affect the solubility of iron; in other words, the iron was largely retained in the ore, and the amount leached was considerably low. In specific numbers: The lowest solubility was observed after 24 hours in a 1 M glycine solution, at 1.845 g/t, which corresponds to 7.35% of the total iron content in the ore. Conversely, the highest solubility was recorded at 2.091 g/t (8.33%) during a 4-hour reaction time in a 2 M glycine solution. In the 3 M solution, iron solubility was slightly lower, measuring 1.937 g/t (7.71%) in a 48-hour experiment. This same experiment also achieved the highest gold recovery. These results indicate that glycine primarily serves to effectively extract gold from the ore, while iron and other important metals remain almost unleached. This indicates that glycine has a high selectivity and can be reliably used in the process of separating precious metals.

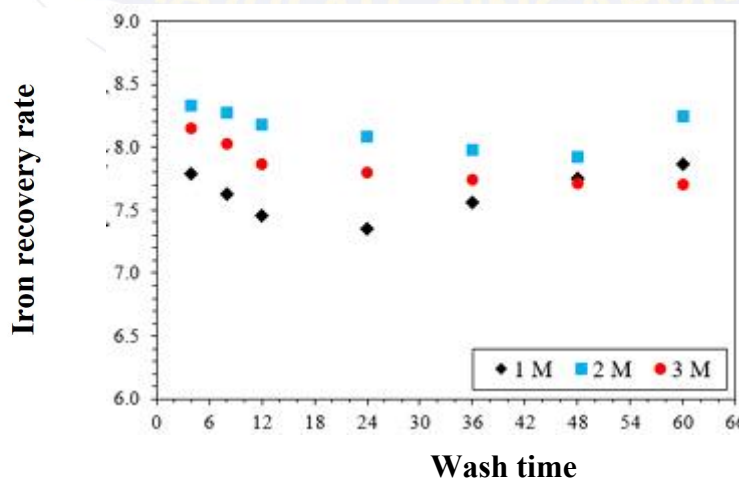


Figure 7. The effect of molarity and reaction time on the reduction degree of iron (Fe)

Conclusion

Cyanide leaching is widely used for gold extraction due to its simplicity and low cost, but it carries significant environmental risks. Recently, glycine has been studied as a

biodegradable and selective alternative. It can dissolve gold in alkaline conditions without requiring significant modifications to existing processing systems, meaning a hydrometallurgical plant does not need to be retrofitted when replacing the cyanide reagent with glycine. This study investigated the leaching characteristics of a standard oxide gold ore using glycine. The effect of glycine concentration and leaching time was systematically analyzed, while other parameters (pH, temperature, stirring speed, solid/liquid ratio, and air flow) were maintained at previously reported optimal conditions. The highest gold extraction of 81.41% was achieved with 3 M glycine and a 48-hour leaching period. Under these conditions, the solubilities of silver and iron were 44.50% and 7.71%, respectively, demonstrating the selective effect of glycine on gold over base metals. Silver, however, was moderately extracted, reflecting glycine's partial affinity for it. These results indicate that glycine is a promising reagent for selectively leaching gold from oxide ores. Further research is recommended to evaluate the efficiency and selectivity of glycine leaching in ores containing other precious metals such as platinum, palladium, and rhodium. In the stages following selective leaching, conventional methods - such as adsorption with activated carbon, extraction, or electrochemical precipitation - can also be applied in glycine systems. Future research should focus on the systematic evaluation and optimization of these stages.

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