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# Persulfates

## Mining Applications



# Persulfates in Gold Mining – Cyanide Leaching and Remediation Processes

Gold mining commonly relies on cyanide leaching to extract gold from ores, as cyanide effectively dissolves gold, forming a stable gold-cyanide complex. However, the use of cyanide results in significant environmental and safety risks due to its high toxicity. Effective cyanide removal or destruction before the discharge of process water is therefore crucial to mitigate environmental hazards and comply with regulatory standards.

One promising method for cyanide degradation is the use of persulfates, such as sodium persulfate **NPS/SPS** ( $\text{Na}_2\text{S}_2\text{O}_8$ ) or ammonium persulfate **APS** ( $(\text{NH}_4)_2\text{S}_2\text{O}_8$ ) from **United Initiators**. Persulfates are strong oxidizing agents that facilitate the breakdown of cyanide ( $\text{CN}^-$ ) as well as cyanometalates ( $[\text{M}(\text{CN})_x]$ ) into less harmful compounds such as carbon dioxide and nitrogen.



# Persulfates in Gold Mining – Cyanide Leaching and Remediation Processes

## Mechanism of Cyanide Oxidation with Persulfates

Persulfates decompose in aqueous solutions to generate sulfate radicals ( $\text{SO}_4^{\bullet-}$ ), which are highly reactive and capable of oxidizing cyanide ( $\text{CN}^-$ ). The oxidation process generally follows these steps:

### 1. Activation of Persulfates

Persulfates can be thermally activated, catalytically activated (using transition metals such as iron), or UV-activated to generate sulfate radicals.

### 2. Oxidation of Cyanide

The sulfate radicals react with cyanide ( $\text{CN}^-$ ), converting it into cyanate ( $\text{NCO}^-$ ), which is significantly less toxic.

### 3. Further Degradation Steps

Cyanate undergoes hydrolysis to produce ammonium ( $\text{NH}_4^+$ ) and carbon dioxide ( $\text{CO}_2$ ), completing the detoxification process.

## Advantages of Persulfate-Based Cyanide Removal

- **High Oxidation Potential:** Persulfates exhibit a strong oxidizing capability, ensuring effective cyanide breakdown.
- **Reduced Toxic Byproducts:** Persulfates primarily convert cyanide into non-toxic or low-toxicity compounds. The degradation products of the persulfates are environmentally harmless salts such as sodium sulphate ( $\text{Na}_2\text{SO}_4$ ) in the case of using **NPS**.
- **Versatility:** Persulfates can be used in a wide range of pH conditions and can be activated by multiple methods, making them adaptable to different mining operations.
- **Environmental Compatibility:** Compared to other chemical treatments, persulfates have minimal environmental impact when properly managed. The solid products from **United Initiators** are bottled in containers that meet the highest international standards.

The use of **Persulfates from United Initiators** in actual cyanide wastewater is stable, reliable, simple, and efficient, and it is of great significance for the gold industry to tap the potential, increase efficiency, save energy, and reduce emissions.



# Persulfates in Cobalt / Nickel Mining – Hydrometallurgical Processes

The use of **Persulfates from United Initiators** in the hydrometallurgical processing of cobalt and nickel offers numerous advantages, including their strong oxidizing properties, adaptability, and environmental compatibility. Hydrometallurgical processes are commonly employed to recover these metals from ores, utilizing leaching and precipitation techniques. While challenges such as selective cobalt recovery and Co-Ni separation persist due to similar precipitation characteristics, combining persulfate-based oxidation with advanced separation techniques and optimized chemical conditions can overcome these obstacles. This approach enhances the efficiency and sustainability of metal recovery, making persulfates a valuable tool in modern hydrometallurgical processes.

## Advantages of Persulfates in the Process

### 1. Strong Oxidizing Capability for Selective Recovery

Persulfates, such as sodium persulfate **NPS/SPS** ( $\text{Na}_2\text{S}_2\text{O}_8$ ) are highly effective oxidizing agents that generate sulfate radicals ( $\text{SO}_4^{\bullet-}$ ) when activated. These radicals can oxidize cobalt to higher oxidation states (e.g. Co(III)), facilitating its selective removal from pregnant leach solutions (PLS). This strong oxidation potential enhances the efficiency of cobalt recovery even in the presence of competing ions like nickel and copper.

By precisely controlling the persulfate activation method (e.g. thermal or UV activation), cobalt oxidation can be prioritized over reactions with nickel or copper.

### 2. Reduced Toxic Byproducts

Persulfates decompose into environmentally harmless compounds, reducing the ecological impact of the process. The solid Persulfates from United Initiators are bottled in containers that meet the highest international standards

### 3. Versatility

Persulfates can operate effectively across a wide range of pH and temperature conditions, providing flexibility in adapting to different ore compositions and process requirements. Their versatility makes them a valuable tool for addressing the complex chemistry of mixed-metal leach solutions.

# Product Portfolio for Mining Applications

## NPS/SPS Sodium persulfate

- **Free of nitrogen**  
NPS from United Initiators does not contribute to an increase of the nitrogen load in the soil. In contrary to our competition, we are producing NPS directly from sodium sulfate and not by conversion of ammonia salts and can offer this nitrogen-free grade from both European and Chinese production.
- **High solubility (more than 500 g/l at 20 °C / 70 °F)**  
Enables convenient handling and preparation of aqueous solutions.
- **High oxidization potential, facile activation**
- **High purity (> 99 %)**
- **Standard packaging**  
25 kg / 55 lbs in PE bags  
1000 kg / 2200 lbs Big Bags  
1000 kg / 2200 lbs per pallet

Packaging qualification according to the highest international standards enables safe handling and storage.

## APS Ammonium persulfate

- **Higher solubility in water than NPS (more than 620 g/l at 20 °C / 70 °F)**  
Features the highest solubility of all available peroxodisulfates.
- **High oxidation potential, facile activation**
- **High purity (> 99 %)**  
Enables improved efficiency and safe handling due to the absence of impurities.
- **Standard packaging**  
25 kg / 55 lbs in PE bags  
1000 kg / 2200 lbs per pallet

Packaging qualification according to the highest international standards enables safe handling and storage. Big bags up to 500 kg with anticaking agent (silica) are available on request.





# Product Portfolio for Mining Applications

## Persulfates - Typical Analytical Data

	Unit	NPS/SPS	APS	Comment <sup>1</sup>
Active Oxygen	%	> 6.65 / 6.68	> 6.94 / 6.99	S/T
Purity	%	> 99.0 / 99.4	> 99.0 / 99.7	S/T
Sulfuric Acid	%	< 0.1 / 0.02	< 0.1 / 0.03	S/T
Moisture	%	< 0.03	< 0.03	T
Bulk Density	g/cm <sup>3</sup>	1.25	1.10	T
Insolubles	ppm	< 10	< 10	T
pH (1 % in water, 20 °C) <sup>2</sup>		4.7	4.4	T
pH (10 % in water, 20 °C) <sup>2</sup>		3.8	3.6	T
Copper (Cu)	ppm	< 0.1	< 0.1	T
Chloride (Cl)	ppm	< 3.0	< 3.0	T
Chromium (Cr)	ppm	< 0.1	< 1	T
Iron (Fe)	ppm	< 5 / < 1	< 5 / < 1	S/T
Manganese (Mn)	ppm	< 0.2	< 0.2	T
Zink (Zn)	ppm	< 2.5	< 2.5	T
Vandium (V)	ppm	< 0.2	< 0.2	T
Platinum (Pt)	ppm	< 0.2	< 0.2	T
Tin (Sn)	ppm	< 0.4	< 0.4	T
SADT (dry state)	°C	180	130	T
SADT (5 % moisture)	°C	approx. 60	≤ 45	T



<sup>1</sup> S = technically specified; T = typical value (European production)

<sup>2</sup> The initial pH value depends on the sulfuric acid content.

**United Initiators - Serving a Growing World out of Various Production Sites in Europe, India and China with Persulfates**





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