Olympias
Beneficiation

CRM: Arsenic

- Overview
- Uses of As-Cu
- Location
- VE
- Criticality of As & Cu
- VEs Map
- Disclaimer

CRM: Copper

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Overview

General Information

EldoradoGold is a Canadian mining company that has actively mining activities in different countries around the globe. Especially in Greece, the EldoradoGold department, franchised as HellasGold SA, focuses on mining activities at the Kassandra mining site in Chalkidiki. The Greek Multi-Metallic Ore deposit contains the following metals:

1) Critical Raw Materials such as Arsenic (As) and Copper (Cu)
2) Precious Metals such as Gold (Au) and Silver (Ag)
3) Base Metals such as Lead (Pb) and Zinc (Zn)

Specific Information

The Underground Multi-Metallic Sulfur Deposit Ore in Olympias Location (South-Western side of the Olympias mining site in Kassandra area) contains 8 ppm of Gold enclosed to the Arsenopyrite (FeAsS)
Due to the consecutive increase of supply risk in CRMs, the company purified Arsenic using aqua-acidic reagents and catalysts. Olympias underground mining site has a depth range of 0-210m.

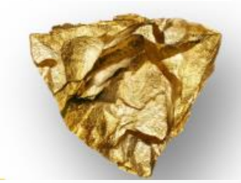
The 360 panoramas in the current VE refer to the industrial unit processing/purifying the multi-metallic ore after its grinding. The sink/flotation technique is implemented by adding chemical reagents to separate Arsenic (As) and Copper (Cu) from other metals, such as Silver (Ag), Gold (Au).

Images of Spontaneous Metals | Beneficiation Information | Flowchart | Purification Technique

Images of Spontaneous Metals

Arsenic (As) CRM
Arsenic occurs as a chemical compound of FeAsS known as Arsenopyrite

Copper (Cu) CRM
Copper occurs
as a chemical compound of $CuFeS_2$



Gold (Au)
Gold is well-known as a precious metal. In Olympias mine ore,
the gold is enclosed in the structure of Arsenopyrite.
Its concentration is approximately 8.23 g/t

Silver (Ag)
Silver is well-known as a precious metal. In Olympias mine ore,
its concentration is approximately 131.5 g/t

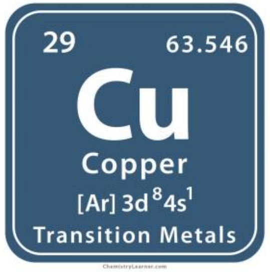
Lead (Pb)
Plumbum-Lead is well-known as a base metal. In Olympias' mine ore,
its concentration is approximately 4.16%

Zinc (Zn)
Zinc is well-known as a base metal. In Olympias mine ore,
its concentration is approximately 4.74%

CRMs – Arsenic (As), Copper (Cu)
Click to see Criticality Assessment of As & Cu

Supply Risk: Risk Grade of the material resources
Economic Importance: Grade of the material's price value to the market
Criticality: Grade of material's impact on the Market

CRM	Supply Risk SR	Economic Importance EI	Criticality CR
Arsenic (As)	1.9	2.9	5.51
Ranges for SR, EI, CR	0-5	0-9	0-45
Impact on SR, EI, CR (%) (Numerical Value of the CRM) ÷(Maximum Threshold)	$(SR)_{CRM}÷(SR)_{Max}$ 38%	$(EI)_{CRM}÷(EI)_{Max}$ 32%	$(CR)_{CRM}÷(CR)_{Max}$ 12.2%



CRM	Supply Risk SR	Economic Importance EI	Criticality CR
Copper (Cu)	0.1	4	0.4
Ranges for SR, EI, CR	0-5	0-9	0-45
Impact on SR, EI, CR (%) (Numerical Value of the CRM) ÷(Maximum Threshold)	$(SR)_{CRM}÷(SR)_{Max}$ 2%	$(EI)_{CRM}÷(EI)_{Max}$ 44.4%	$(CR)_{CRM}÷(CR)_{Max}$ 0.8%

Source: European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M. and Veeh, C., *Study on the critical raw materials for the EU 2023 – Final report*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2873/725585

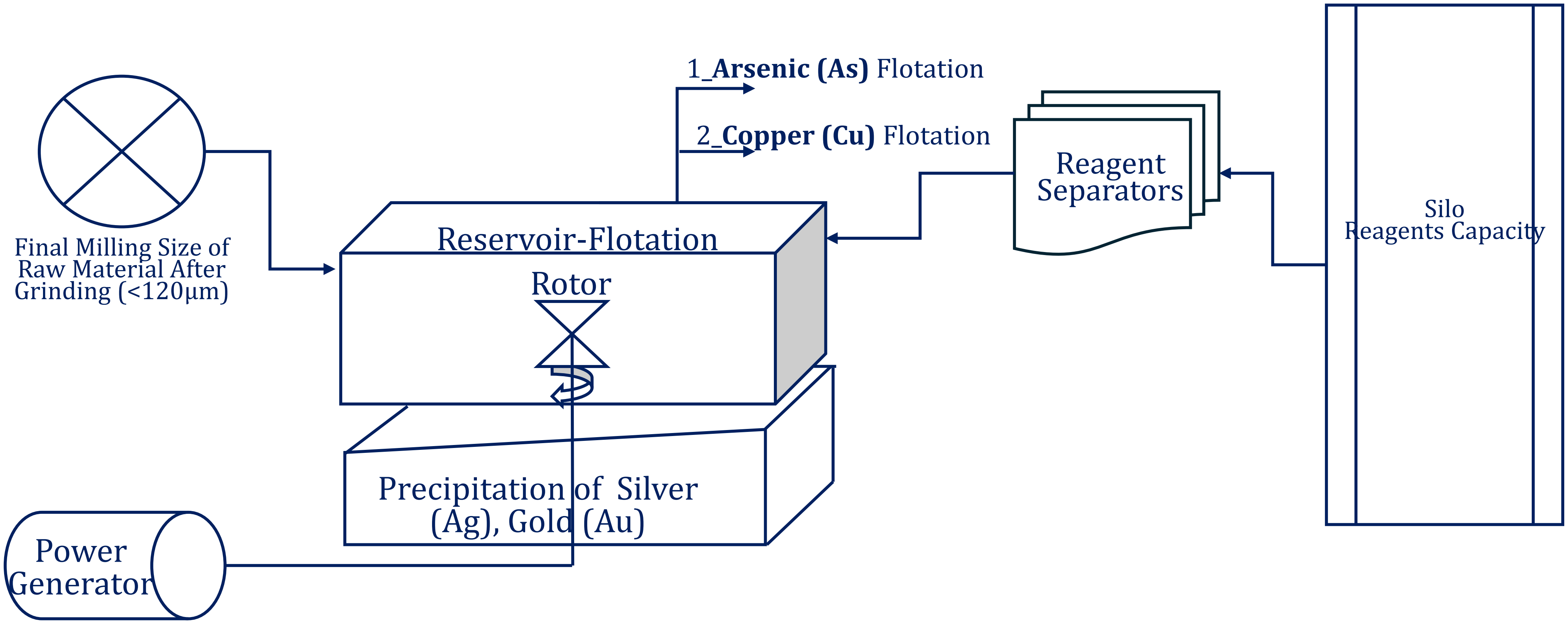
Criticality Matrix

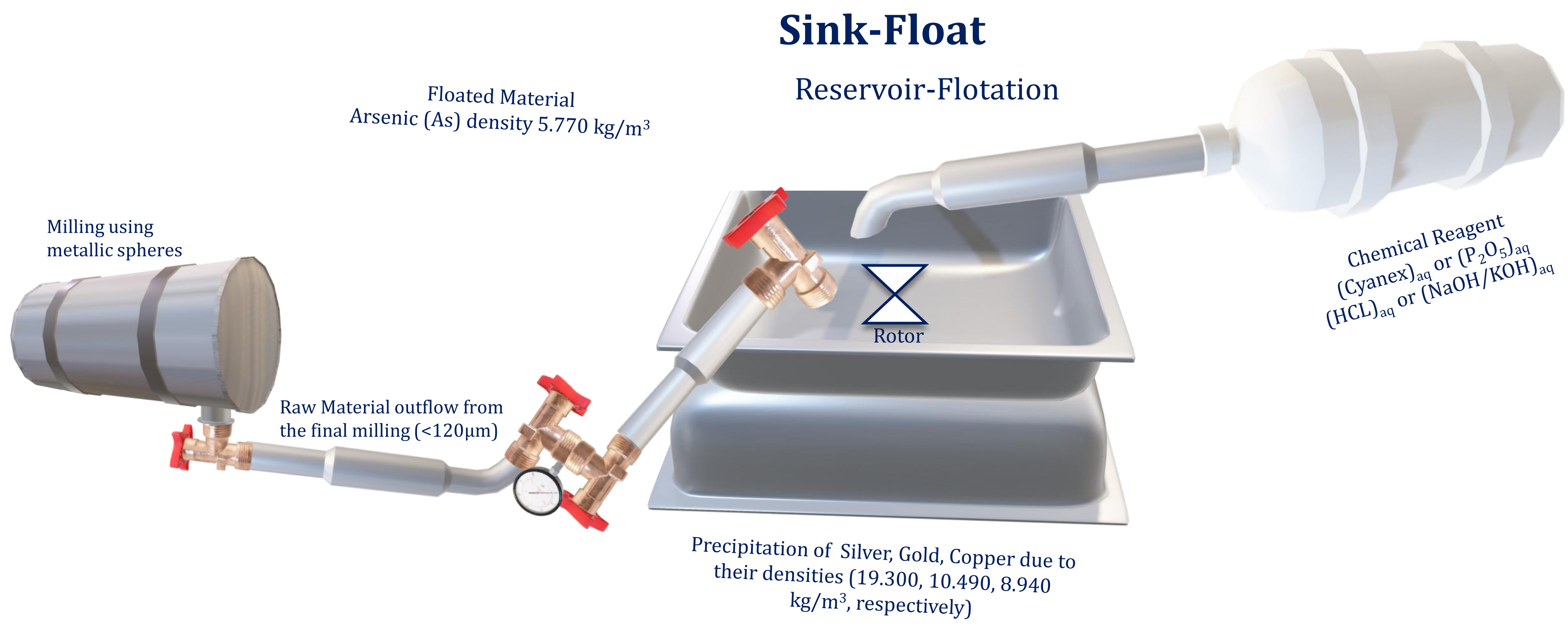
Criticality Matrix		Supply Risk (SR)				
		1	2	3	4	5
(CR)=(EI)*(SR)						
Economic Importance (EI)	1	**(Cu=0.4)**1	2	3	4	5 **(As=5.51)**
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5 **(As=5.51)**	10	15	20	25
	6	6	12	18	24	30
	7	7	14	21	28	35
	8	8	16	24	32	40
	9	9	18	27	36	45

- The **Criticality Matrix** displays a quantitative assessment of the Criticality grade for each examined raw material, based on the information contained in the European Study on CRMs, as shown below on this slide.
- The **Supply Risk (SR)** and **Economic Importance (EI)** refer to variable parameters that depends on the entire resources of raw materials and their configured price values according to their demand, respectively. i.e. the SR of a raw material could fluctuate within a period. Therefore, depending on the global resources data and industrial needs, the corresponding Study for CRMs could be updated, including the existing SR and EI indices for raw materials.
- The **Criticality (CR)** is configured by the multiplication of EI and SR grades. The CR index shows the criticality grade of each examined raw material.

Source: European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M. and Veeh, C., *Study on the critical raw materials for the EU 2023 – Final report*, Publications Office of the European Union, 2023, **https://data.europa.eu/doi/10.2873/725585**

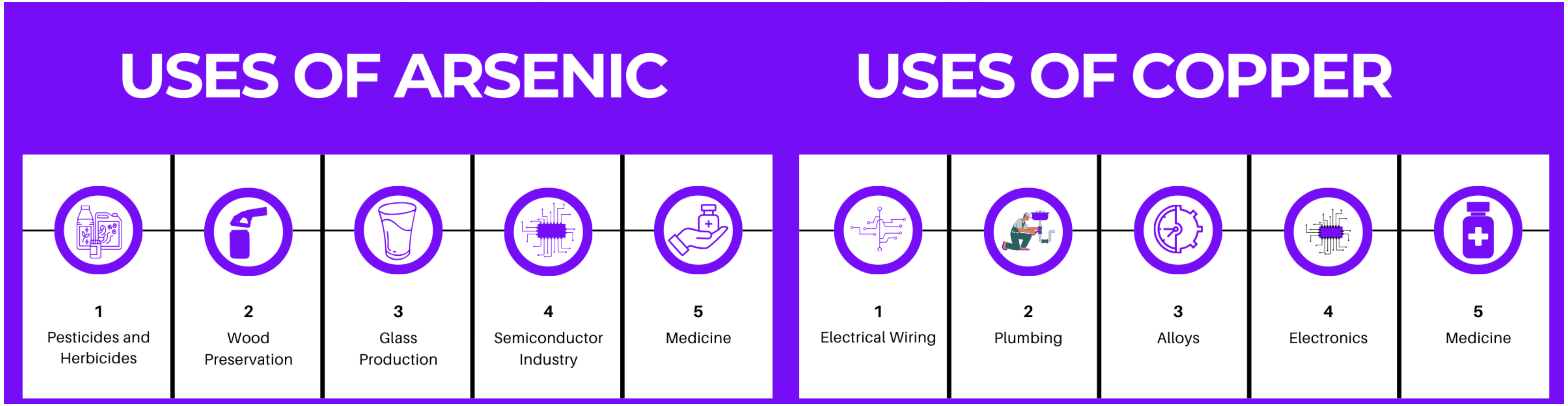
Beneficiation Flowchart





Sink-Float
Reservoir-Flotation
Floated Material
Arsenic (As) density 5.770 kg/m³
Milling using
metallic spheres
Chemical Reagent
(Cyanex)aq or (P2O5)aq
(HCL)aq or (NaOH/KOH)aq
Rotor
Raw Material outflow from
the final milling (<120μm)
Precipitation of Silver, Gold, Copper due to
their densities (19.300, 10.490, 8.940
kg/m³, respectively)

Spontaneous Metals
(As, Cu) and Industrial Applications



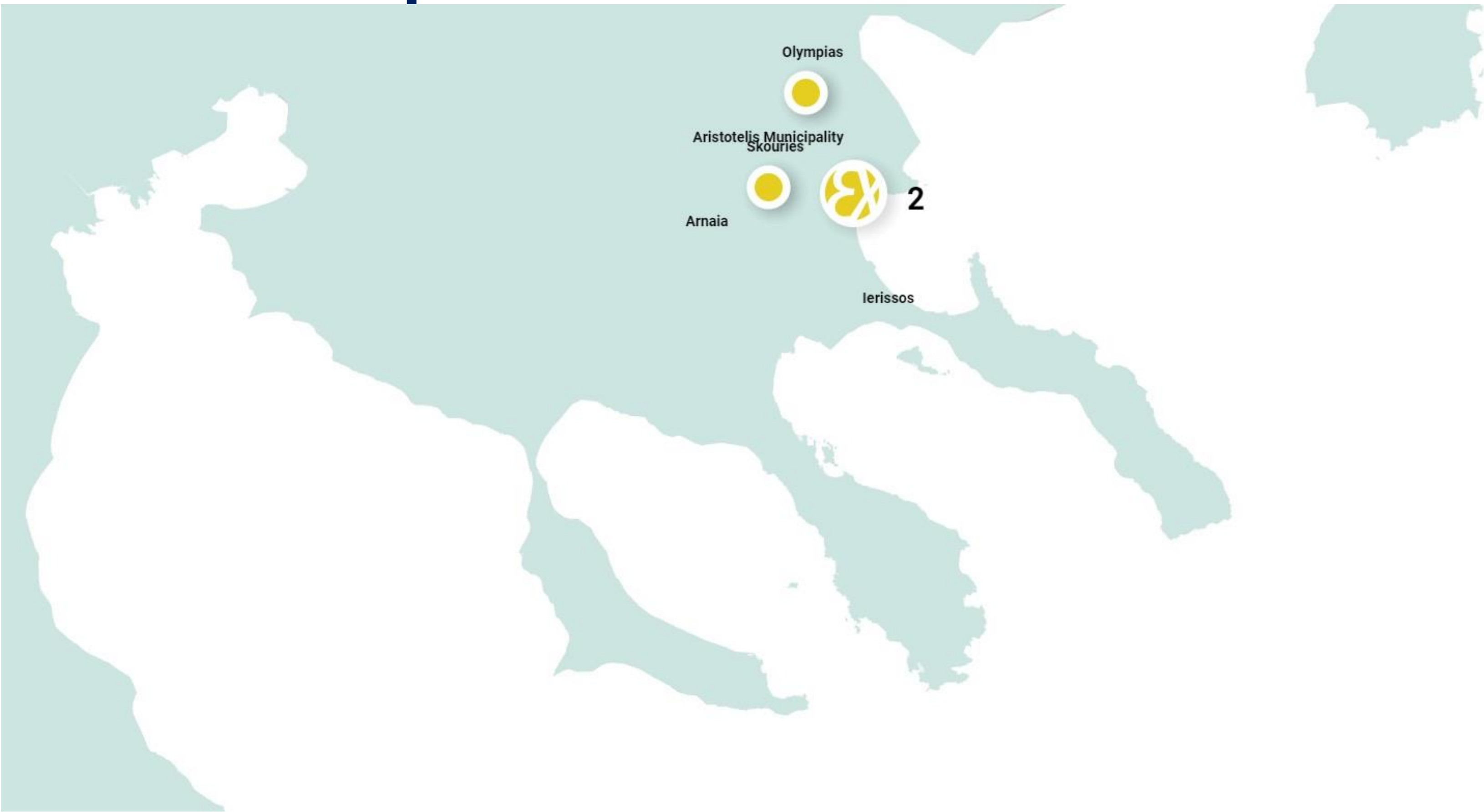
Arsenic (As)

Arsenic occurs as a chemical compound of FeAsS known as Arsenopyrite.

Copper (Cu) CRM

Copper occurs as a chemical compound of $CuFeS_2$ known as Chalcopyrite.

Map of the Virtual Excursion



<u>HellasGold SA_Olympias Mine Site</u>

Latitude_40º60’ 00’’ Longitude_23º74’ 91’’

Enrichment/Beneficiation

Processing Information Click

The beneficiation processing starts after the final milling of the grinded raw material (size <120 μm).
The entire processing of beneficiation is, firstly, based on the separation of metals from the ore.
In continuous, the beneficiation processing focuses on the separation of metals from each other.

First Stage of Beneficiation

To separate the metals by applying a combination of physical-chemical methods, the raw material flows to the thickeners. Each thickener is structured with a planetary rotor that stirs the pulp. This contributes positively to the physical separation of metals that are downstream (sink). To rapid the process, catalysts (Cyanex or P_2O_5-DEHPA) or hydroxide (KOH, NaOH) aqueous reagents are used. The addendum of chemical reagents enhances the quick separation of the metal mixture from the ore. The sunk material inflows to the thickeners of the second stage for further separation.

Second Stage of Beneficiation

The second stage of the beneficiation/purification focuses on the metal separation from each other. So, acidic reagents ($HCL_{(aq)}$, $H2SO4_{(aq)}$) are used in the second stage-thickeners to chemically de-bind the existing compounds. Catalysts inflow too. The planetary blender-rotor distributes the metallic elements, and due to their different densities, they are separated from each other. So, primarily the Arsenic floats (as shown in the right picture), and the sunk pulp inflows to the next thickener.
Continuously, the copper floats from the inflow pulp while the PGMs sink.
The same processing is consecutively revised to separate the sunk PGM metals from each other.

Chemical Engineering

Beneficiation Stages

[1st]_Multi-Metallic Sulfur Mining Ore+Sodium Hydroxide
[2nd]_Chemical Salt containing CRMs+Acid

[1]_CRM [As] $4FeAsS+24NaOH+25O_2 \rightarrow 4Na_3AsO_4+4Na_3SO_4+2Fe_2O_3+12H_2O$

[1]_CRM [Cu] $4CuFeS_2+16NaOH+15O_2 \rightarrow 4CuO+8Na_2SO_4+2Fe_2O+8H_2O$

[2.1]_CRM [As] $4Na_3AsO_4+12HCL \rightarrow 12NaCl+4H_2AsO_4+2H_2$

or using water-soluble ionic compound NaI to rapid the chemical reaction

[2.2]_CRM [As] $4Na_3AsO_4+8NaI+4H_2SO_4 \rightarrow 4Na_3AsO_3+4Na_2SO_4+4I_2+4H_2O$

As-Beneficiation
Stoichiometric
Analysis

[2.1]_CRM [Cu] $4CuO+8HCL \rightarrow 4CuCl_2+4H_2O$

or using H_2SO_4

[2.2]_CRM [Cu] $4CuO+4H_2SO_4 \rightarrow 4CuSO_4+4H_2O$

The produced chemical salts $Na_2AsO_{(3\text{-}4)}$ and $CuSO_4$ precipitate and are separated from the pulp.

Cu-Beneficiation
Stoichiometric
Analysis

As & Cu
Chemical Salts
Lewis Electron
Structure

Quantitative

FlowChart

Chemical Engineering-Stoichiometric Analysis for Beneficiation of Arsenic

Stage	Reactants			Products			
[1st]	$4FeAsS$	$24NaOH$	$25O_2$	$4Na_3AsO_4$	$4Na_3SO_4$	$2Fe_2O_3$	$12H_2O$
Mr	163	40	32	208	165	160	18
moles	4	24	25	4	4	2	12
m(gr)	652	960	800	832	660	320	216
m(kg)	0.652	0.96	0.8	0.832	0.66	0.32	0.216
Verification based on the Lavoisier's Law	Reactants Mass (Kg)		2.412	Products Mass (Kg) ≤ Reactants Mass (Kg)			2.028

Stage	Reactants		Products		
[2nd.Step 1]	$4Na_3AsO_4$	$12HCL$	$12NaCl$	$4H_2AsO_4$	$2H_2$
Mr	208	37	59	141	2
moles	4	12	12	4	2
m(gr)	832	444	708	564	4
m(kg)	0.832	0.444	0.708	0.564	0.004
Verification based on the Lavoisier's Law	Reactants Mass (Kg)	1.276	Products Mass (Kg) ≤ Reactants Mass (Kg)		1.276

Stage	Reactants			Products			
[2nd.Step 2]	$4Na_3AsO_4$	$8NaI$	$4H_2SO_4$	$4Na_3AsO_3$	$4Na_2SO_4$	$4I_2$	$4H_2O$
Mr	208	150	98	192	142	254	18
moles	4	8	4	4	4	4	4
m(gr)	832	1200	392	768	568	1016	72
m(kg)	0.832	1.2	0.392	0.768	0.568	1.016	0.072
Verification based on the Lavoisier's Law	Reactants Mass (Kg)		2.424	Products Mass (Kg) ≤ Reactants Mass (Kg)			2.424

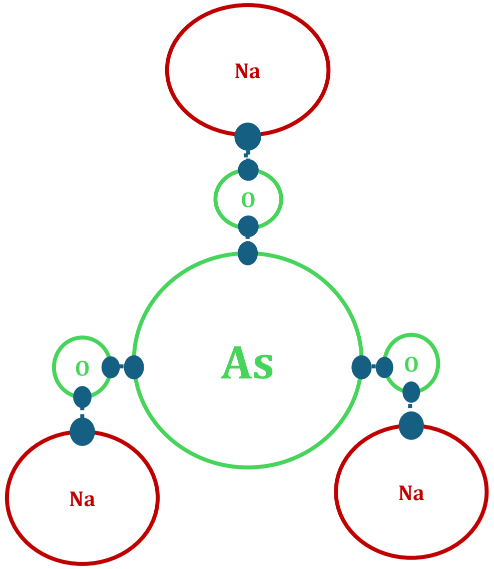
Chemical Engineering-Stoichiometric Analysis for Beneficiation of Copper

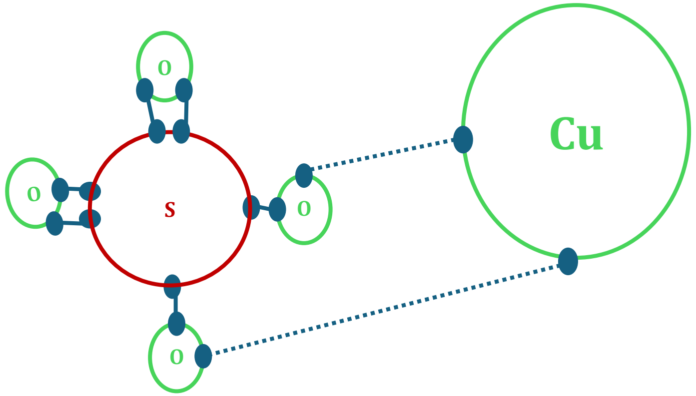
Stage	Reactants			Products			
[1st]	$4CuFeS_2$	$16NaOH$	$15O_2$	$4CuO$	$8Na_2SO_4$	$2Fe_2O$	$8H_2O$
Mr	184	40	32	80	142	128	18
moles	4	16	15	4	8	2	8
m(gr)	736	640	480	320	1136	256	144
m(kg)	0.736	0.64	0.48	0.32	1.136	0.256	0.144
Verification based on the Lavoisier's Law	Reactants Mass (Kg)		1.856	Products Mass (Kg) ≤ Reactants Mass (Kg)			1.856

Stage	Reactants		Products	
[2nd.Step 1]	$4CuO$	$8HCL$	$4CuCl_2$	$4H_2O$
Mr	80	37	136	18
moles	4	8	4	4
m(gr)	320	296	544	72
m(kg)	0.32	0.296	0.544	0.072
Verification based on the Lavoisier's Law	Reactants Mass (Kg)	0.616	Products Mass (Kg) ≤ Reactants Mass (Kg)	0.616

Stage	Reactants		Products	
[2nd.Step 2]	$4CuO$	$4H_2SO_4$	$4CuSO_4$	$4H_2O$
Mr	80	98	160	18
moles	4	4	4	4
m(gr)	320	392	640	72
m(kg)	0.32	0.392	0.64	0.072
Verification based on the Lavoisier's Law	Reactants Mass (Kg)	0.712	Products Mass (Kg) ≤ Reactants Mass (Kg)	0.712

Chemical Salts containing As & Cu





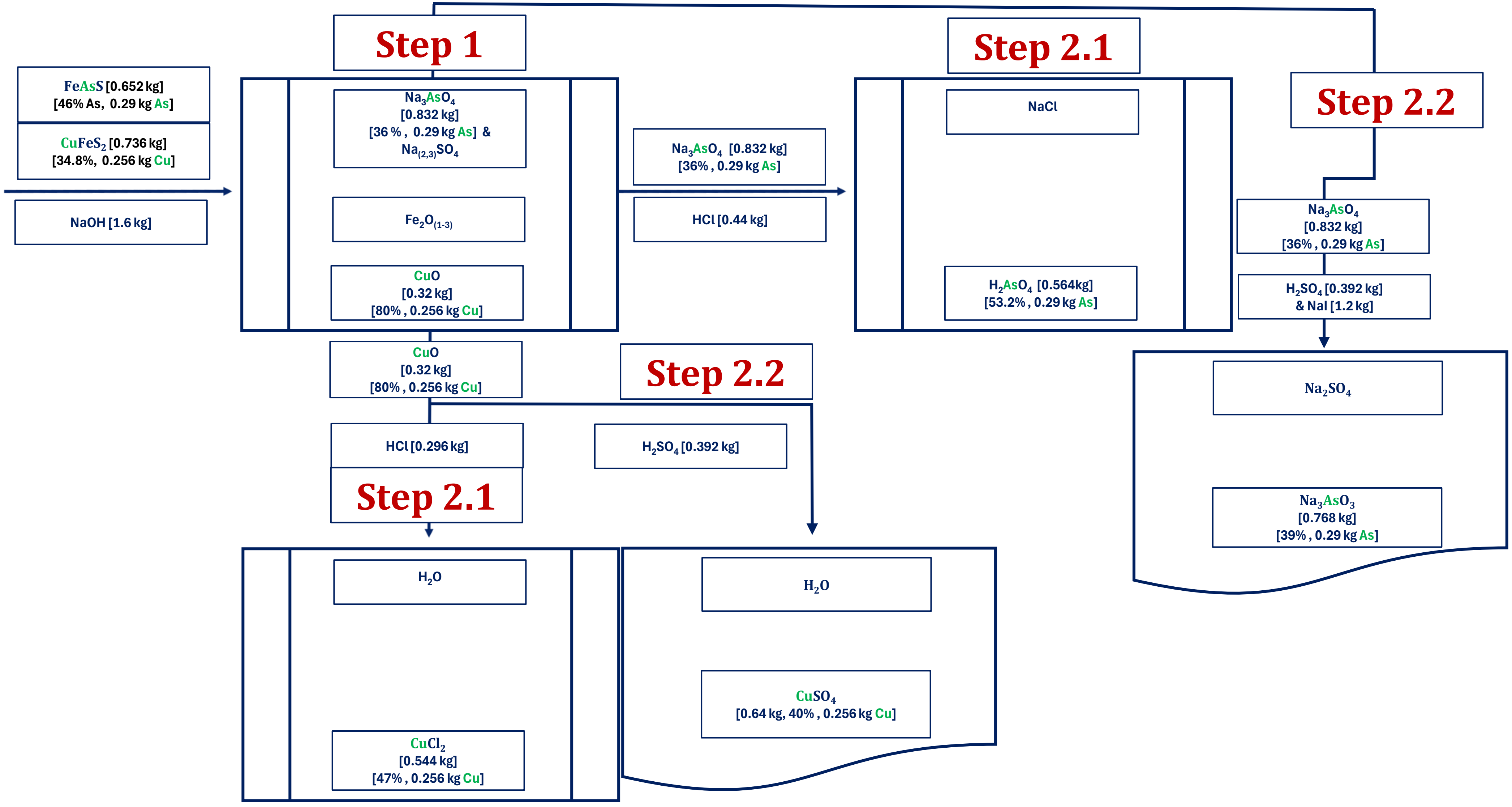
The valence electrons, symbolized in blue, are calculated from the Lewis Electron Structure for each chemical element. The valence electrons of each chemical element are used to bind with the corresponding valence electrons of the rest of the bound elements.

The first Lewis structure refers to the Sodium Arsenite, and the second one refers to the Sulfuric Copper. These two chemical salts, containing CRMs (As and Cu), are the primary chemical compounds produced during the beneficiation stage.

Lewis Electron Structure of all the displayed chemical elements is provided below:

[As]_$1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^{10}$, $4s^2$, $4p^3$ [3 valence electrons missing in the external electron shell]
[O]_$1s^2$, $2s^2$, $2p^4$ [2 valence electrons missing in the external electron shell]
[Na]_$1s^2$, $2s^2$, $2p^6$, $3s^1$ [1 valence electron missing in the external electron shell]
[S]_$1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^4$ [2 valence electrons missing in the external electron shell]
[Cu]_$1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^{10}$, $4s^1$ [1 valence electron missing in the external electron shell]
[Cu^{++}]_$1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^9$ [2 valence electrons missing in the external electron shell]

Beneficiation Processing on Industrial Scale



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