Investigation of effect of sulfate ion on xanthate consumption in galena flotation based on thermodynamic diagrams

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Abstract
Flotation is a common process in sulfide ore beneficiation. Due to the restrictions and lack of access to high-quality water sources for industrial purposes, recycled water plays an important role in the flotation processes. Due to the existence of various organic and inorganic substances in the process, water influences the flotation performance. In this work, the effect of accumulation of sulfate ion in processed water on galena flotation was investigated. Flotation experiments using processed water without sulfate ion led to a concentrate containing 40.7% of lead and a maximum recovery of 58.9%. The presence of higher sulfate ion levels (2000 M) in processed water caused a significant decrease in the grade and recovery of the lead concentrate. With 2000 mg/L of sulfate ion, the grade and recovery of lead decreased from 40.7 to 24.3% and from 58.9 to 32.1 %, respectively. Thermodynamic calculations showed that when the sulfate ion concentration was increased from 300 to 2000 ppm, it was more likely that lead sulfate (solid) was formed. With increase in the xanthate ion concentration from 10^{-6} to 10^{-4} M, $PbSO_4(s)$ could be substituted by $PbX_{2\ (s)}$. On the basis of the results obtained, it was concluded that in order to reduce the negative effects of sulfate ion accumulation in water and increase the efficiency of the galena flotation process, higher dosages of xanthates should be added to the system.

Keywords: *Galena Flotation, Xanthate, Sulfate Ion, Water Quality.*

1. Introduction

Since the beginning of the 21st century, the efficiency in mining industry has experienced a fall, raising the environmental concerns and issues. To state this clearer, due to the reduction of high-grade ores in the mines, the implementation of advanced and sophisticated mining devices and techniques has become more and more demanding. The fact of the matter is that the quest for gaining the most from low-grade ores is quite challenging, and this requires intensive research works [1]. In the context of the present work, which focuses on mineral processing, especially in wet processes, water plays a significant role. In this line, a procedure known as "Froth flotation", which is a wet process, is carried out to concentrate minerals. In this aqueous process, some additives including collectors, depressants, adjustments, and modifiers are used for selectively separating different minerals. The surface of most minerals gets wet in contact with water. To prevent having a completely moisturized surface, collectors are used to produce a hydrophobic surface for the minerals in order to facilitate their attachment to the air bubbles [2].

In the froth flotation base-metal sulfide minerals, xanthates are the most common collectors. Activators are used to accelerate the collector ability, while depressants are used to inhibit the flotation of some minerals to improve the selectivity of a flotation process. In this process, desirable minerals attach to air bubbles due to specific surface chemical/physical properties (natural or modified) before transferring to the

froth phase, which eventually gets cleared out of the flotation cells. Note that in the context of pulp chemical, the quality of water plays an important role.

Today, the quality of water is extremely important, especially in mining industries. Due to the lack of water availability and in order to decrease the demand of fresh water, mining industries take water recycling very serious. This causes a decrease in the discharge of wastewater to the tailings dam, which benefits the environment [3]. In the processing units, water recycling from the liquid-solid separation stage is named as the recycled water or processed water.

Different sources of processed water can be used in mining sections as recycled water including the collected water from tailings dam, classification ponds, etc. [4]. Different element, ion, and residual additives such as SO_4^{2-}, Cl^-, F^-, Mg^{2+}, Ca^{2+}, Na^+, K^+, sulfide, thiosalts, base metals, collectors, frothers, activators, depressants, colloidal materials, and natural organic material are present in the tailings [4, 5].

To be used routinely in the flotation process, the collected processed water should be added to fresh water. However, depending on the source of collected water, the processed water may contain various organic and inorganic substances that will influence the flotation performance. Such contaminants can be introduced to the processed water from reagents, oxidation, and dissolution of ores [5].

Researches have shown that water quality may affect the performance of sulfide ore flotation, particularly on galena. The physico-chemical factors such as water hardness, ion strength, residual reagent, and metallic ions have effects on the flotation selectivity of sulfide minerals, froth stability, inadvertent activation of non-sulfide gangue, and variation in slurry pH and pulp potential [4, 6-9]. It is well-known that the galena flotation can be hindered by the presence of dissolved ions in the processed water. Calcium and sulfate are the two very common ions in the processed water from flotation of sulfide minerals. They are mainly originated from reagents such as lime (pH adjustment) and sulfate compositions (depressants), which, respectively, maintain and control the pH and the mineral surface properties [10, 11].

Recently, the electro-chemical behavior of galena and mechanism of xanthate absorbance on galena surface in the presence of calcium and sulfate ions have been studied [12, 13]. It has been stated that in the presence of calcium, during the pre-conditioning of galena, the adsorption of xanthate on the mineral decreases. This mechanism is probably due to the chemisorption of the Ca^{2+} ions on the active sites of the mineral surface (SO_4^{2-}, CO_3^{2-} and OH^-), which hinders the ion exchange collector-sulfate, collector-carbonate, and collector-hydroxyl, which causes a decrease in the hydrophobicity of the galena and a decrease in its flotation recovery. The presence of sulfate also adversely affects the collector adsorption. A primary candidate for this is due to the layer of lead sulfate, which is non-uniformly formed in the vicinity of the galena surface. The reason that this mechanism acts as a barrier for isolating the surface is the presence of lead-sulfate, which weakens the chemisorption mechanism [13].

It is well-understood that the presence of anions and cations in processed water increases the consumption of collectors. An investigation on the effects of synthetic waters on synthetic minerals has indicated that the adsorption of calcium onto the pentlandite and pyrrhotite surfaces increases the mineral hydrophilicity, which, therefore, requires more xanthate to induce hydrophobicity of the minerals [4, 14]. The excessive and unreacted amounts of xanthates can be present in the plant effluents, which may pollute the environment upon release [15, 16].

The aim of this work was to evaluate the influence of sulfate ion concentration present in processed water on galena flotation. Based on the sulfate ion concentration, the cause of change in grade and recovery of galena and more consumption of collector has been analyzed by thermodynamics calculations.

2. Materials and methods
2.1. Ore characterization
In this work, a set of low-grade Pb-Zn ore samples was obtained from Tapeh-Sorkh Mine located 20 Km east of Isfahan in central Iran. The mineralogical study indicated that the samples contained mainly galena, sphalerite, calcite, dolomite, quartz, and muscovite. Table 1 shows the chemical composition of mineral samples analyzed by XRF. As it can be seen in Table 1, the input grade of lead and zinc in the Bama processing plant are 0.69% and 2.30%, respectively.

2.2. Water samples
In order to evaluate the effect of sulfate ion on the galena flotation performance, some flotation tests were carried out under various concentration

levels of sulfate ion. To determine the maximum content of this ion in processed water, wastewater samples were taken directly from several points of the Bama flotation plant. The wastewater was settled for some time in order to remove the precipitated solids before sending the upper liquor to laboratory for sulfate analysis. Figure 1 shows water cycle in the Bama flotation plant, while Table 2 presents the concentration of sulfate ion in the samples.

On the basis of the results obtained, the maximum content of sulfate ion in galena rougher flotation test was considered to be 2000 ppm. Flotation studies on the samples were done using the one-factor-at-a-time approach, as an experimental design method. Thus some synthetic waters with different concentrations of sulfate ion were prepared. The Na_2SO_4 analytical grade was used as a source of SO_4^{2-} Ions.

Table 1. Chemical composition of mineral samples.

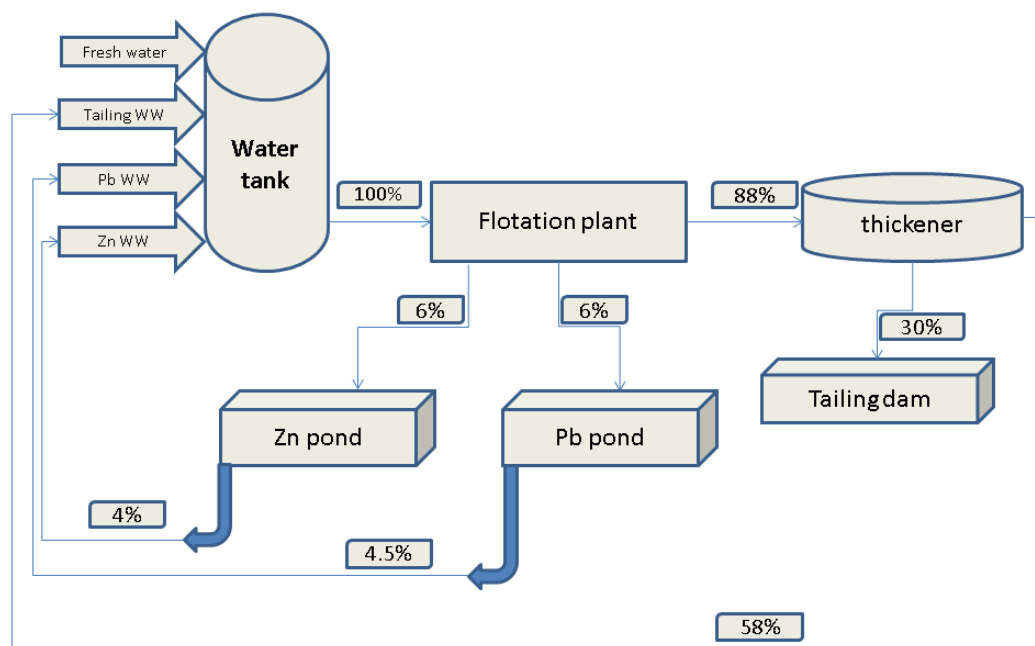| Compounds	Amount%	Compounds	Amount%
Na_2O	0.297	MnO_2	1.066
MgO	11.644	Fe_2O_3	5.201
Al_2O_3	4.607	Zn	2.302
SiO_2	16.812	Sr	0.043
P_2O_5	0.028	Zr	0.011
SO_3	2.591	Ba	1.173
K_2O	0.925	Pb	0.688
CaO	23.573	L.O.I	28.84
TiO_2	0.199		

Figure 1. Water cycle in Bama flotation plant (numbers shown in squares represent percentage of recycled water for each unit).

Table 2. Water samples analysis.

Type of water sample	pH	Eh (V-SHE)	TDS (ppm)	Sulfate ion (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	Pb (ppb)	Zn (ppb)
Fresh water	7.93	0.362	266	560	234	130	901	190	470
Process water	8.07	0.436	315	1193	285	130	791	260	390
Tailing WW	8.07	0.459	378	1601	157	200	797	150	90
Pb WW	8.24	0.324	308	938	280	142	733	380	560
Zn WW	8.03	0.237	322	942	215	139	770	360	880

2.3. Flotation experiments

In order to prepare the flotation feed, the mineral samples were crushed to below 4 mm by a roll crusher. In each test, 1 kg of crushed ore was wet ground with 600 mL of synthetic water with 62.5 wt% in a roll mill for 15 min-30 sec until the d80 of the flotation feed got under 75 microns. Flotation was conducted in a 2.5 L Denver laboratory flotation machine at a rotating speed of 800 rpm.

The sequences of reagent additions were pH regulator, depressants, collectors, and frother. The pH of pulp was regulated at 8, while the H_2SO_4 and NaOH solutions were used as the pH regulators. The dosages of depressants were 400 g/t $ZnsO_4$ and 40 g/t NaCN in order to depress sphalerite and pyrite. The dosages of the collector and frother were 50 g/t potassium ethyl xanthate and 30 g/t pin oil, respectively; these reagents were of industrial grade. The conditioning times for pH regulator, depressants, collectors, and frother were 3 min, 8 min, 2 min, and 1 min, respectively. Flotation was started by opening the air intake valve. It should be pointed out that the sequence of reagent addition was selected based on the Bama flotation plant operation.

The froth was collected into the concentrate pans in 5-s intervals for 1 minute. After flotation, the concentrates and the tailings were put in an oven at 105 °C for 60 min before analyzing the concentrate to determine the grade of Pb.
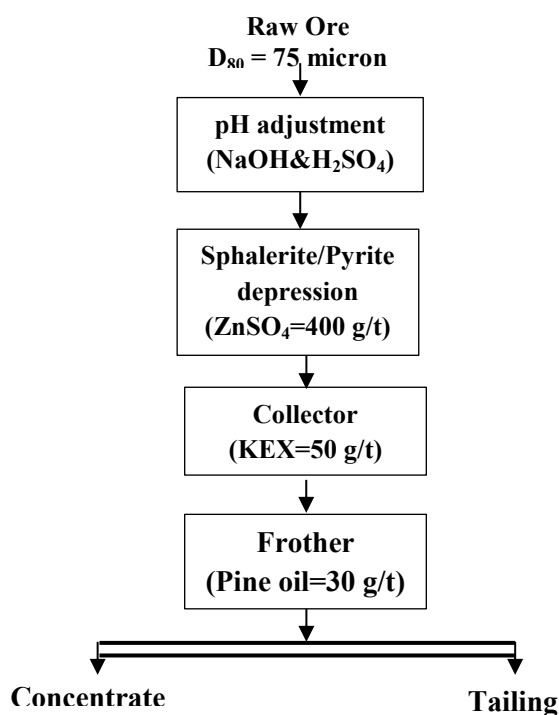
Raw Ore
D_{80} = 75 micron

↓

pH adjustment
(NaOH&H_2SO_4)

↓

Sphalerite/Pyrite depression
($ZnsO_4$=400 g/t)

↓

Collector
(KEX=50 g/t)

↓

Frother
(Pine oil=30 g/t)

↓

Concentrate   **Tailing**

Figure 2. Procedure of rougher galena flotation tests.

2.4. Elaboration of thermodynamic diagrams

The thermodynamic diagrams for the $Pb-SO_4^{2-}-X-H_2O$ (Pb-sulfate-xanthate-water) systems were constructed using the Spana© Software with a careful collection of the most reliable thermodynamic information for the species involved in the reactions. The equilibrium data contained in the database of the Spana© suite software [17] was complemented with thermodynamic data for different pb, X, and SO_4^{2-} species reported by several articles [18-21]. The stability constants of the new species were calculated based on the Gibbs free energies of formation, and added to the software database. Table 3 presents the thermodynamic data used in this work.

Table 3. Log K and E_h^0 for Pb, X, SO_4^{2-} species used in construction of thermodynamic diagrams.

Chemical reactions	$Log\ K_{298k}^0$	E_h^0	Reference
$Pb^{2+} + H_2O = PbOH^+ + H^+$	-7.71		
$Pb^{2+} + 2H_2O = Pb(OH)_{2\ (aq)} + 2H^+$	-17.12		
$Pb^{2+} + 3H_2O = Pb(OH)_3^- + 3H^+$	-28.06		
$2Pb^{2+} + H_2O = Pb_2OH^{3+} + H^+$	-6.36		
$3Pb^{2+} + 4H_2O = Pb_3(OH)_4^{2+} + 4H^+$	-23.88		
$4Pb^{2+} + 4H_2O = Pb_4(OH)_4^{4+} + 4H^+$	-20.88		
$6Pb^{2+} + 8H_2O = Pb_6(OH)_8^{4+} + 8H^+$	-43.61		Software Spana@ [17]
$Pb^{4+} + 2e = Pb^{2+}$	57.25	1.694	
$PbSO_4^0 = Pb^{2+} + SO_4^{2-}$	-2.69		
$SO_4^{2-} + 8H^+ + 8e = S^{2-} + 4H_2O$	14.692	0.150	
$SO_4^{2-} + 9H^+ + 8e = HS^- + 4H_2O$	33.692	0.252	
$SO_4^{2-} + 10H^+ + 8e = H_2S_{(aq)} + 4H_2O$	40.681	0.303	
$SO_4^{2-} + H^+ = HSO_4^-$	1.982		
$X^- + H^+ = HX$	1.64		[17,19]
$O_2 + 4H^+ + 4e = 2H_2O$	85.989	1.229	
$SO_4^{2-} + 10H^+ + 8e = H_2S_{(g)} + 4H_2O$	41.696	0.311	
$PbO_{(Cr)} + 2H^+ = Pb^{2+} + H_2O$	12.7		
$PbO_{(S)} + 2H^+ = Pb^{2+} + H_2O$	12.9		
$PbO_{2\ (s)} + 4H^+ + 2e = Pb^{2+} + 2H_2O$	48.98	1.450	
$Pb_2O_{3\ (s)} + 6H^+ + 2e = 2Pb^{2+} + 3H_2O$	61.01	1.806	
$Pb_3O_{4\ (s)} + 8H^+ + 2e = 3Pb^{2+} + 4H_2O$	71.0	2.094	Software Spana@ [17]
$Pb^{2+} + 2e = Pb_{(s)}$	-4.26	-0.126	
$Pb(OH)_{2\ (s)} + 2H^+ = Pb^{2+} + 2H_2O$	13.6		
$S_{(s)} + 2e = S^{2-}$	-14.692	-0.473	
$SO_4^{2-} + 8H^+ + 6e = S_{(Cr)} + 4H_2O$	35.837		
$PbSO_{4\ (s)} = Pb^{2+} + SO_4^{2-}$	-7.79		
$PbS_{(s)} = Pb^{2+} + S^{2-}$	-29.017		
$SO_4^{2-} + 8H^+ + 8e + Pb^{2+} = PbS_{(s)} + 4H_2O$	48.816		
$X_2 + 2e = 2X^-$	-4.90	-0.060	[17,19]
$PbX_{2\ (s)} = Pb^{2+} + 2X^-$	-16.7		[17,19]

3. Results and discussion

The results of this research work are provided in two sections. The first section is related to the effect of sulfate ion concentration in solution on the recovery and grade of galena in flotation, while the second section represents a thermodynamic analysis aimed at explaining the phenomena observed in the first section.

3.1. Effect of sulfate ion on galena flotation performance

Effects of different sulfate ion concentrations on galena flotation were examined. Figure 3 shows the influence of sulfate ion on the grade and recovery of galena during the rougher flotation.
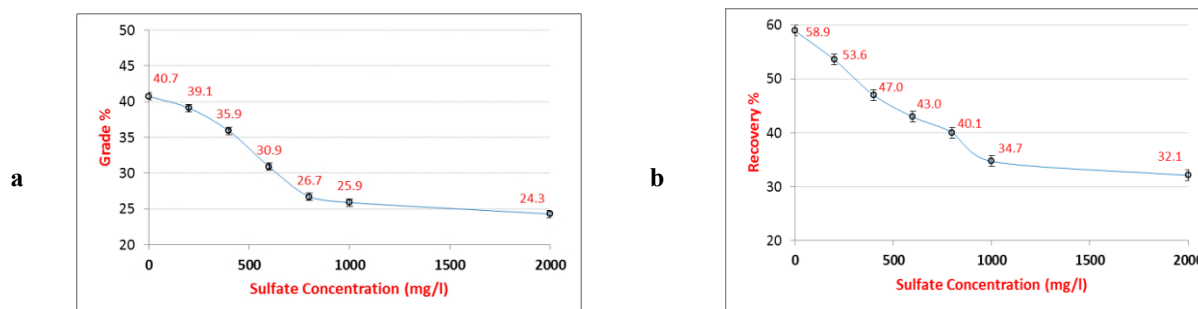
Figure 3. Effect of different sulfate ion concentrations in processed water on (a) grade and (b) recovery of galena within rougher flotation.

It could readily be seen in panels (a) and (b) of Figure 3 that a sulfate ion increase in the solution ends with a decrease in the grade and recovery of the lead concentrate. As the sulfate ion concentration in processed water is raised from 0 to 2000 mg/L, the grade and recovery of lead in the concentrate decrease from 40.7 to 24.3 and 58.9 to 32.1, respectively. The extent of grade and recovery variations in the sulfate ion concentration range of 0-1000 mg/L were 15 and 24%, respectively, while in the sulfate ion concentration range of 1000-2000 mg/L, the variations reached 2% and 3% for the grade and recovery, respectively. Therefore, an increase in the sulfate ion concentration up to a certain level causes a decrease in the grade and recovery; whereas, beyond this level, no considerable effect exists.

In order to investigate the reasons for the grade and recovery drops in galena concentrate, thermodynamic studies on the Pb-SO_4^{2-}-X-H_2O system was performed.

3.2. Thermodynamic studies in Pb-SO_4^{2-}-X-H_2O system

By analyzing several processed water samples taken from different Pb-Zn ore-processing plants (e.g. Bama plant), the range of sulfate and xanthate ions were determined (see Table 4). To assess the effect of sulfate and xanthate concentration variation on speciation, the Pb-SO_4^{2-}-X-H_2O system was considered.

Figure 4 outlines the predominance area of species for 1000 mg/L sulfate and 2×10^{-5} mole/L Pb ion condition along with 10^{-6}, 10^{-5}, and 10^{-4} mole/L xanthate ion. It is noteworthy that regarding the working range in the galena flotation and xanthate ion stability at pH > 6, the predominance area diagram is drawn for pH > 6.

In the pH range of 6-8, the predominant species are $PbSO_4^0$, $PbSO_4(s)$, and $PbX_{2\,(s)}$ (Figure 5). In a fixed concentration of Pb and sulfate ions, as the xanthate ion concentration is increased from 10^{-6} to 10^{-4} mole/L, the predominance area of $PbSO_4(s)$ species is substituted by $PbX_{2\,(s)}$. The latter means that at higher activities of xanthate ion, the formation of lead xanthate (solid) is more favorable, while at lower activities, it is more likely that lead sulfate (solid) is formed. In other words, in a real flotation system, the negative impact of sulfate and formation of lead sulfate complex may be compensated by adding more xanthate to the system.

Figure 5 shows the effect of different sulfate ion concentrations in processed water (300-2000 mg/L) on stability of species in the Pb-SO_4^{2-}-X-H_2O system. Concentrations of the xanthate and lead ions were constant and equal to 10^{-5} and 2×10^{-5} mole/L, respectively.

Effects of sulfate ion addition on the area of predominance for each species are depicted in Figures 5a-e. It should be noticed that by adding sulfate ion, the area for solid lead xanthate shrinks. This is while the solid lead sulfate expands. This substantially confirms that at a certain concentration of xanthate ions, an increase in the sulfate ion activity leads to an increase in the solid lead sulfate in the equilibrium system.

The trend stated in the present work can also be explained more clearly using the speciation diagrams in the case of Pb-SO_4^{2-}-X-H_2O (Figures 6a-6g). For sketching the diagram, 100-2000 mg/L sulfate ion was added to a fixed concentration of xanthate and Pb ions. This enables an explanation for the variation of the species.

Table 4. Ion content in solution under study.

Xanthate	**mg/L**	12	1.2	0.12	0.012			
	mole/L	10^{-4}	10^{-5}	10^{-6}	10^{-7}			
Sulfate	**mg/L**	1920	960	480	384	288	192	96
	mole/L	2×10^{-2}	1×10^{-2}	5×10^{-3}	4×10^{-3}	3×10^{-3}	2×10^{-3}	1×10^{-3}

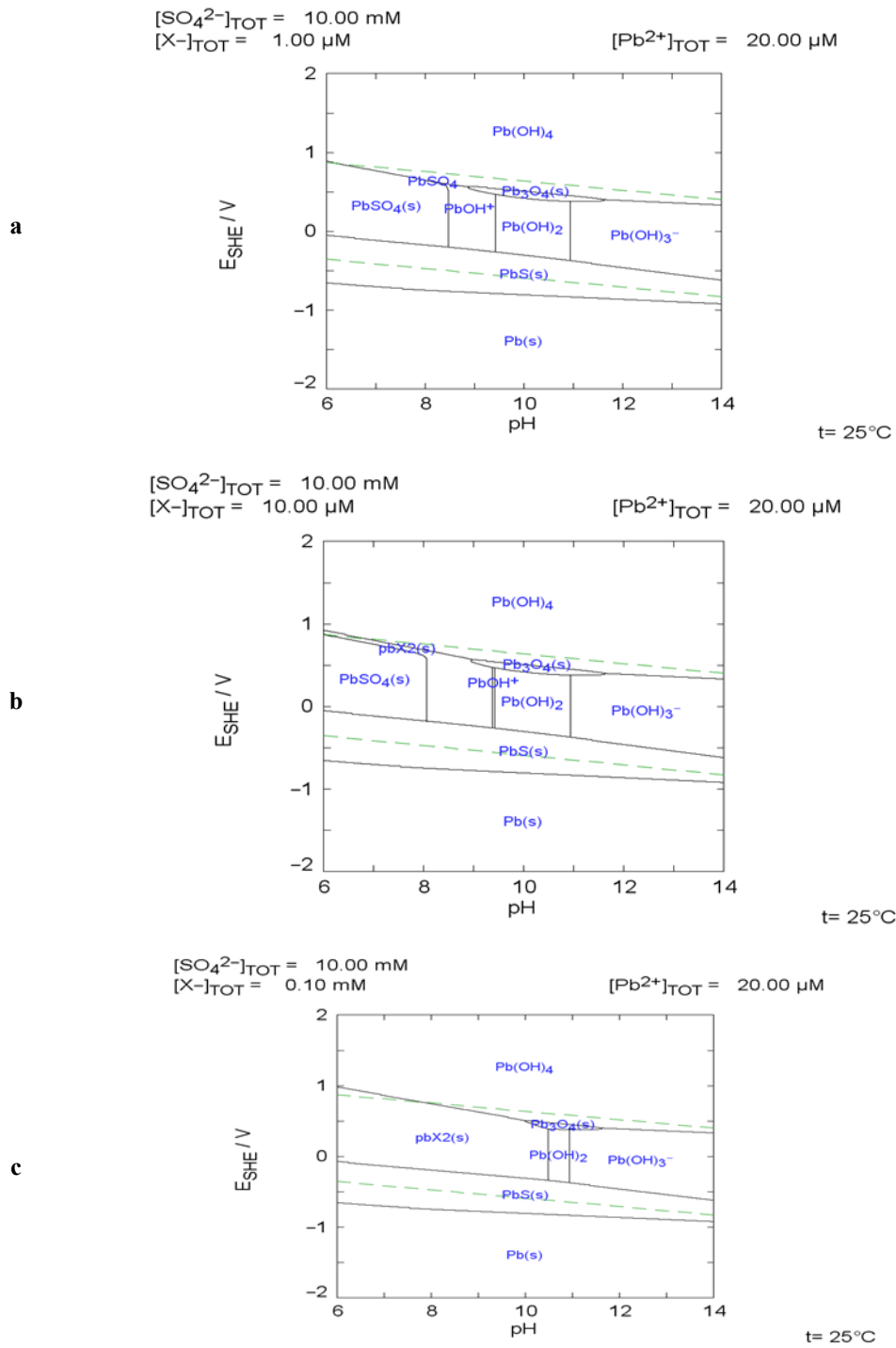**Figure 4. Pourbaix diagram for Pb-SO4-X-H2O system. Conditions for diagram construction are:**
$$SO_4{}^{-2} = 1000 \text{ ppm} , Pb^{+2} = 2 \times 10^{-5} \text{ M}.$$
$$\text{a: } X = 10^{-6} \text{ M} - \text{b: } X = 10^{-5} M - \text{c: } X = 10^{-4} M$$
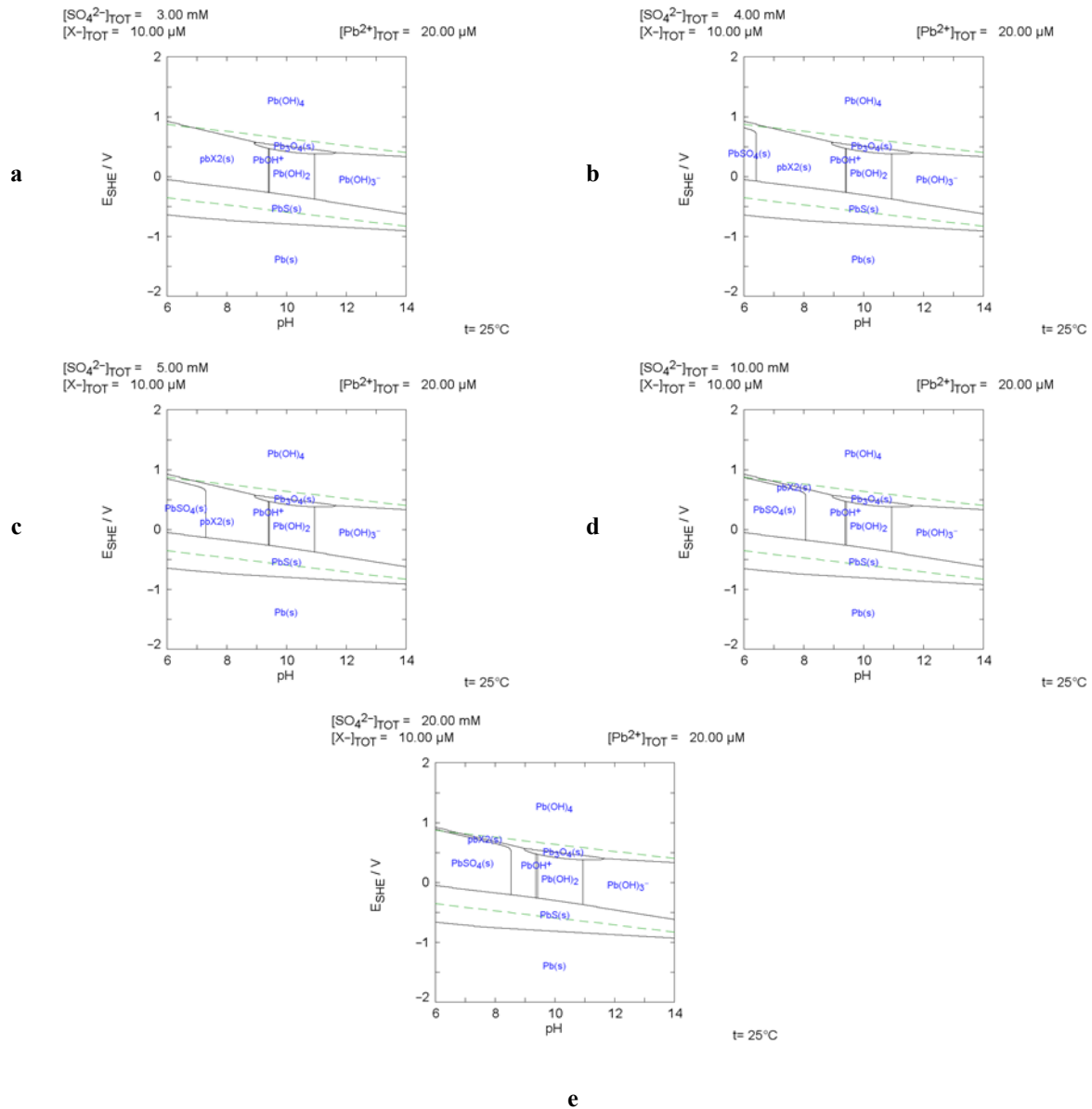
Figure 5. Pourbaix diagram for Pb-SO4-X-H2O systems. Conditions for diagram construction are:
$$: X = 10^{-5} \, M, Pb^{+2} = 2 \times 10^{-5} \, M.$$
$$a: SO_4^{-2} = 300 \, ppm - b: SO_4^{-2} = 400 \, ppm - c: SO_4^{-2} = 500 \, ppm - d: SO_4^{-2}$$
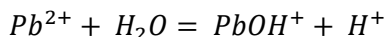$$= 1000 \, ppm - e: SO_4^{-2} = 2000 \, ppm$$

g
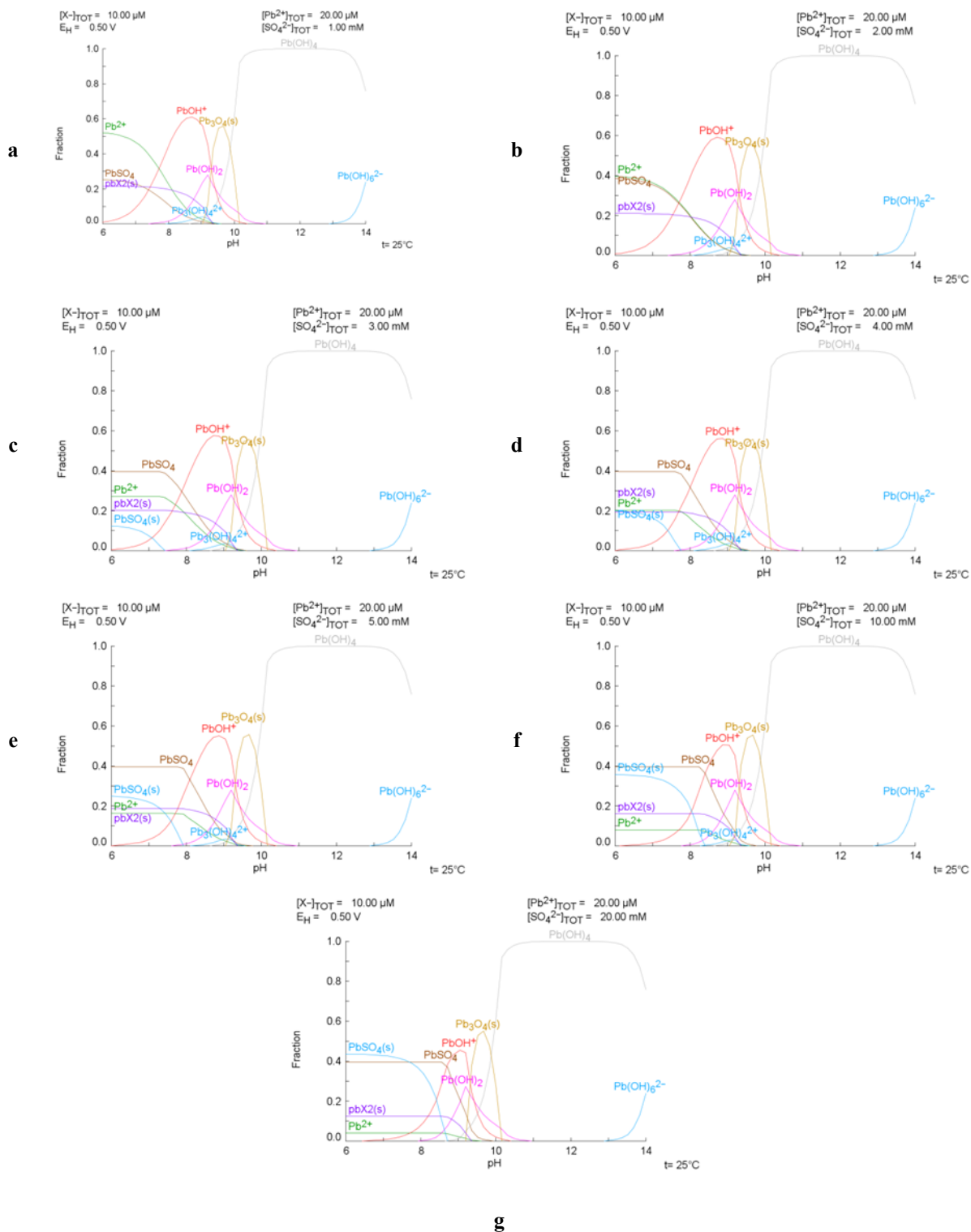
Figure 6. Distribution of Pb species at different pH values for Pb-SO4-X-H2O systems. Conditions for diagram construction are:

$$X = 10^{-5} \text{ M}, Pb^{+2} = 2 \times 10^{-5} \text{ M} \quad Eh = 0.5 \text{ V at } 25\,^{0}\text{C}.$$

a: $SO_4^{-2} = 100$ ppm − b: $SO_4^{-2} = 200$ ppm − c: $SO_4^{-2} = 300$ ppm − d: $SO_4^{-2} = 400$ ppm − e: $SO_4^{-2} = 500$ ppm − f: $SO_4^{-2} = 1000$ ppm − g: $SO_4^{-2} = 2000$ ppm

The chemical reactions responsible for the formation of the species within the pH range of 6-8 are as follow:

$$Pb^{2+} + H_2O = PbOH^+ + H^+$$
$$PbSO_4^0 = Pb^{2+} + SO_4^{2-}$$
$$PbSO_{4\,(s)} = Pb^{2+} + SO_4^{2-}$$
$$PbX_{2\,(s)} = Pb^{2+} + 2X^-$$
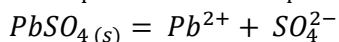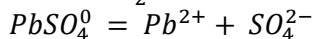
At pH 6 and a sulfate concentration of 100 mg/L, approximately 20% of the existing lead ions are in the form of $PbX_{2\,(s)}$; whereas, a slightly higher percentage of the total lead forms the $PbSO_4^0$ species (Figure 6a). As pH is increased to 8, both species are decreased and most of the lead would be in the form of $PbOH^+$. The latter trend is also observed at other sulfate concentrations as pH changes (Figures 6b-g). Raising pH acts as a depressant for galena as lead hydroxides (plumbite) are formed, preventing xanthate from adsorption onto galena [19]. As the sulfate ion concentration is increased to 200 ppm, $PbX_{2\,(s)}$ remains constant, while $PbSO_4^0$ contribution reaches nearly 40% (Figure 6b).

As sulfate ion concentration reaches 300 mg/L, the $PbSO_{4\,(s)}$ species appear in the speciation diagram (Figure 6c) so that by increasing the sulfate content from 300 to 2000 mg/L in solution, contribution of the corresponding species is enhanced from 12% to 42%, while the share of the other species ($PbX_{2\,(s)}$ and $PbSO_4^0$) remains constant.

Figure 7 shows the effect of xanthate ion on the stability of species in the form of the speciation diagrams. For developing these diagrams, the sulfate and lead ion concentrations are considered to be 1000 mg/L and 2×10^{-5} mole/L, respectively.
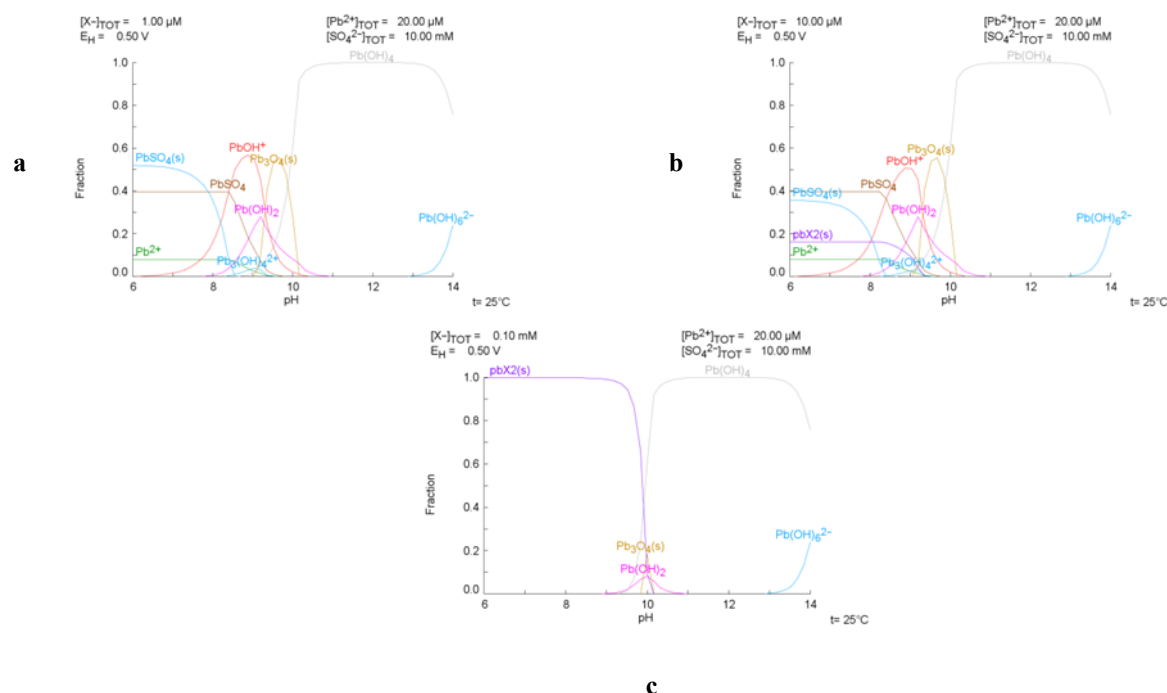
Figure 7. Distribution of Pb species at different pH values for Pb-SO$_4$-X-H$_2$O systems. Conditions for diagram construction are: $SO_4^{-2} = 1000$ ppm, $Pb^{+2} = 2 \times 10^{-5}$ M   Eh = 0.5 V at 25 ^{0}C
a: $X = 10^{-6}$ M − b: $X = 10^{-5}$ M − c: $X = 10^{-4}$ M − d

According to Figure 7a, at a xanthate ion concentration of 10⁻⁶ M, the $PbSO_{4\,(s)}$ and $PbSO_4^0$ species, respectively, constitute over 50% and 40% of the total lead ion in the pH range 6-8. Note that no sign of solid lead xanthate is observed in this diagram. As xanthate ion concentration reaches 10⁻⁵ M, the $PbSO_{4\,(s)}$ contribution decreases to lower than 40%, while about 18% of the lead is in the form of $PbX_{2\,(s)}$ (Figure 7b). A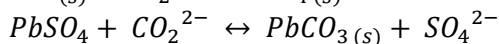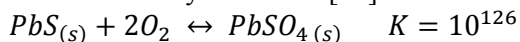t a 10⁻⁴ M xanthate concentration, within the desired pH range, 100% of the lead ions is in the form of solid lead xanthate with no sign of any other species (Figure 7c).

To explain the above-mentioned phenomena, it is noteworthy that during the galena flotation process, based on the conditions governing the process, there would be two possibilities for xanthate occurrence over galena surface: either as an chemically adsorbed mono-layer (causing hydrophobicity of the surface) or in the form of a

massive multi-layer precipitate of lead xanthate on the surface.

According to the existing theories, the following reactions take place.

The surface sulfide is oxidized to sulfate, where regarding the available CO_2 in air, a part of sulfate is substituted by carbonate [21].

$$PbS_{(s)} + 2O_2 \leftrightarrow PbSO_{4\,(s)} \qquad K = 10^{126}$$
$$PbSO_4 + CO_2{}^{2-} \leftrightarrow PbCO_{3\,(s)} + SO_4{}^{2-}$$

At a common pH applied in the flotation process (pH 8-9), lead xanthates are more stable than their carbonates, sulfates, and thiosulfates, and lead xanthate is formed through exchanges with lead salts [22].
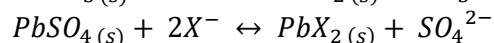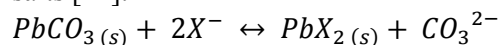
$$PbCO_{3\,(s)} + 2X^- \leftrightarrow PbX_{2\,(s)} + CO_3{}^{2-}$$
$$PbSO_{4\,(s)} + 2X^- \leftrightarrow PbX_{2\,(s)} + SO_4{}^{2-}$$

Figure 8 demonstrates the corresponding stages schematically.
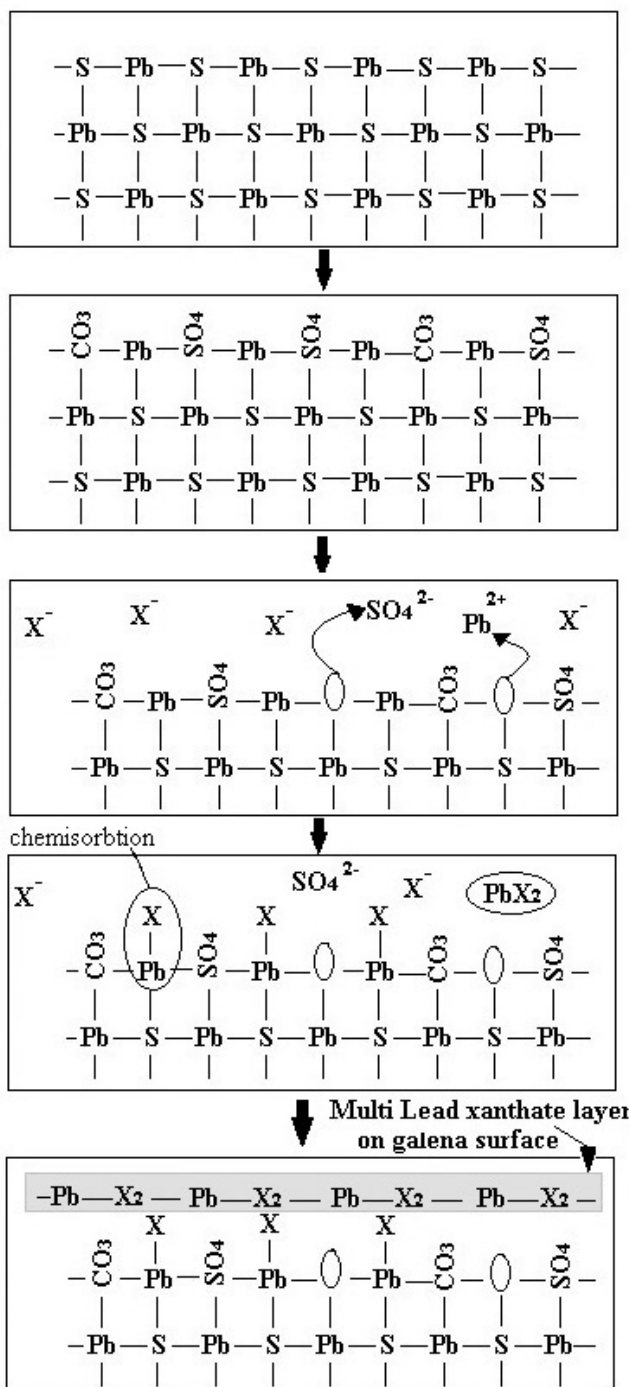

Figure 8. Schematic representation for mechanism of xanthate absorbance on galena surface [13].

At high sulfate ion concentrations, a competition takes place for the formation of either lead xanthate or lead sulfate. Formation of a lead sulfate layer will hinder xanthate adsorption on the surface and development of the multi-layer lead xanthate, which ends in lower hydrophobicity of galena in such conditions; this, in turn, reduces the grade and recovery of flotation. There is a sort of inverse relationship between grade and recovery in all the concentration processes [23]. In the present case, the concentration process of galena mineral is hindered by the adsorption of sulfate ions on its surface. This is the main reason for the decrease in both the grade and recovery. In other words, no concentration occurs for a part of galena that adsorbs sulfate ions. Figure 9 shows the different stages of lead sulfate formation over the galena surface.
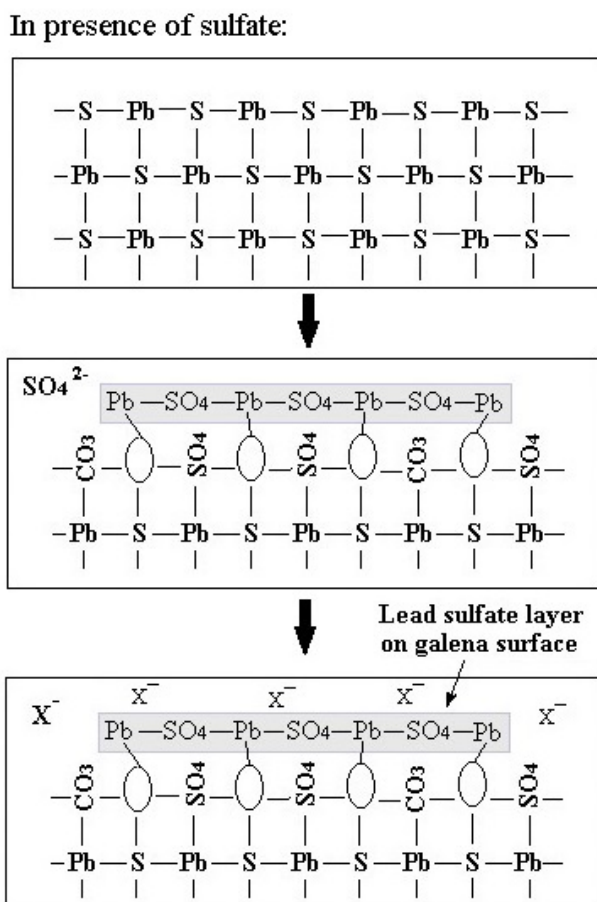

Figure 9. Schematic representation of mechanism proposed for generation of a lead sulfate layer on surface of galena due to presence of sulfate [13].

As a solution to this problem, a practical method is to increase the xanthate activity in the solution. Application of high xanthate concentrations leads to a higher xanthate contamination in the wastewaters. High concentrations of xanthates and its by-products (produced by its degrading) such as carbon disulfide (CS_2) may cause severe impacts on the environment. Therefore, it is highly recommended that in such cases, if sulfate ions enter the processed water from different sources, its concentration possibly increases. A reasonable method is taken into account for sulfate removal from water.

4. Conclusions

The effects of sulfate ion accumulation in the processed water on the xanthate consumption and grade–recovery of the lead concentrate were investigated. The results obtained from flotation of the Bama ore sample were interpreted based on the thermodynamic calculations. The results showed that the accumulation of sulfate ion in the solution led to the formation of lead sulfate on the galena surface. This phenomenon reduced the chemical adsorption of xanthate on the galena surface since it acted as a barrier disabling the contact between xanthate and the galena surface. The mentioned adsorption prevention mechanism

reduced the grade and recovery of galena in the flotation process.

Although the flotation performance could be optimized by a higher xanthate consumption, the increase in xanthate together with its by-products like CS_2 are not the best things for the environment. In such cases, it is advisable to implement sophisticated techniques in order to reduce the sulfate ion concentration in the solution in addition to optimize the additive agents. This prevents the accumulation of sulfate in the pulp, and leads to an increase in the adsorption of xanthate on the galena surface.

Acknowledgments

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بررسی تأثیر یون سولفات در آب فرآیندی بر مصرف گزنتات در فلوتاسیون گالن بر اساس دیاگرام‌های ترمودینامیکی

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چکیده:

فرآیند فلوتاسیون یکی از فرآیندهای متداول برای تغلیظ مواد معدنی است. اساس این فرآیند جدایش مواد معدنی با استفاده از خاصیت آبرانی و آبدوستی سطح کانی‌ها و مرتبط با شیمی پالپ (مخلوط جامد و آب) است. به علت کمبود آب، واحدهای فرآوری مجبور به استفاده از آب برگشتی هستند. استفاده از مواد شیمیایی مختلف در فرآیند موجب تجمع انواع ترکیبات حل شده و یون‌ها در آب فرآیندی می‌شود که شیمی آب را تغییر می‌دهد. این تغییر در عملکرد فلوتاسیون تأثیرگذار است. در این پژوهش، اثر تجمع یون سولفات در آب فرآیندی رافر گالن از کانه سرب و روی بررسی شد. با انجام آزمایش‌های فلوتاسیون رافر گالن با آب فرآیندی بدون یون سولفات، کنسانتره با عیار ۴۰/۷ درصد سرب حاصل شد. با استفاده از آب فرآیندی، بیشترین بازیابی سرب برابر با ۵۸/۹ درصد حاصل شد. حضور یون سولفات در آب فرآیندی، سبب کاهش قابل‌توجه عیار و بازیابی سرب در کنسانتره شد به نحوی که در حضور ۲۰۰ میلی‌گرم در لیتر یون سولفات، عیار از ۴۰/۷ درصد به ۲۴/۳ درصد و بازیابی از ۵۸/۹ درصد به ۳۲/۱ درصد کاهش یافت. تفسیر نتایج به کمک داده‌های ترمودینامیکی نشان داد که یون سولفات از ۳۰۰ تا ۲۰۰۰ میلی‌گرم بر لیتر افزایش پیدا کرده است سولفات سرب تشکیل می‌شود. با افزایش غلظت گزنتات از 10^{-6} تا 10^{-4} مول باعث می‌شود گزنتات سرب جایگزین سولفات سرب شود. کاهش اثرات منفی ناشی از افزایش غلظت یون سولفات در آب فرآیندی و بالا بردن کارایی فرآیند فلوتاسیون گالن باید از مقدار بیشتری کلکتور گزنتات استفاده شود که این خود منجر به نگرانی‌های زیست‌محیطی در رابطه با غلظت این آلاینده در پساب خروجی از واحدهای فرآوری و افزایش محصولات جانبی تولیدی ناشی از تجزیه گزنتات به‌عنوان آلاینده مانند دی‌سولفید کربن در محیط می‌شود.

کلمات کلیدی: فلوتاسیون گالن، گزنتات، یون سولفات، کیفیت آب.