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## Abstract

## Full Text

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**E. A. Anfimova, V. A. Glembotskii, Corresponding Member of the Academy of Sciences of the USSR I. N. Plaksin, and A. S. Shcheveleva**

# The Influence of Structural Features and Surface Properties on the Recovery by Froth Flotation of Difficult-to-Float Lead Minerals

Of the considerable number of oxidized lead minerals occurring in nature and of industrial importance, some—cerussite $PbCO_3$, anglesite $PbSO_4$, wulfenite $PbMoO_4$, and, in part, vanadinite $Pb_5(VO_4)_3Cl$—are recovered comparatively readily by flotation.

However, present-day practice in mineral processing does not possess methods for any reasonably satisfactory recovery of such oxidized lead minerals of complex composition as pyromorphite $Pb_5(PO_4)_3Cl$, mimetite $Pb_5(AsO_4)_3Cl$, beudantite $PbFe_3(AsO_4)(SO_4)(OH)_6$, and plumbojarosite $PbFe_6(SO_4)_4(OH)_{12}$.

Systematic non-recovery of oxidized lead minerals at concentration plants leads to substantial losses of lead in the processing of oxidized lead ores and mixed ores.

The complex chemical composition and structure of the indicated minerals sharply distinguish them from minerals that are readily affected by the flotation reagents ordinarily used and are recovered on an industrial scale.

In this connection, we undertook an attempt to explain the unsatisfactory results of recovery of pyromorphite, mimetite, beudantite, and plumbojarosite on the basis of a study of their crystallochemical features and surface properties with respect to water and to a series of flotation reagents, so that, as a result of such a study, the most effective methods might be found for recovering the listed minerals.

**Table 1**

| Group | Mineral | Total lattice energy, kcal | Lattice energy, kcal, referred to unit valence of cations |
|---|---|---:|---:|
| I | Cerussite | 622.32 | 311.16 |
| I | Anglesite | 596.71 | 298.36 |
| I | Wulfenite | 571.10 | 285.55 |
| II | Vanadinite | 3290.80 | 329.08 |

| Group | Mineral | Total lattice energy, kcal | Lattice energy, kcal, referred to unit valence of cations |
|---|---|---:|---:|
| II | Mimetite | 3352.35 | 335.23 |
| II | Pyromorphite | 3329.30 | 332.93 |
| III | Beudantite | 5513.83 | 501.80 |
| III | Plumbojarosite | 10169.73 | 508.49 |

We first calculated the lattice energies of the lead minerals under study (according to Fersman)*. As can be seen from the data given in Table 1, the values of the lattice energy for cerussite, anglesite, and wulfenite (Group I) differ comparatively little from one another.

Group II of the minerals, which may include mimetite, pyromorphite, and vanadinite, is distinguished by high values of the lattice energy.

Beudantite, mimetite, plumbojarosite, and pyromorphite are characterized by the highest values of the crystal-lattice energy. The data already given

* The values of the crystal-lattice energy were referred by us to unit valence of the cations.

provide guidance in evaluating flotation properties with respect to the ability of all the listed minerals to interact with reagents.

Our investigations showed agreement between the flotation properties and the ability of these minerals to interact with reagents and the calculated values of the crystal-lattice energy. Thus, for example, it was established that the effectiveness of the action of sodium sulfide on oxidized lead minerals decreases in going from minerals of group I to minerals of groups II and III. Plumboyarosite is distinguished by the highest value of the crystal-lattice energy.

Corresponding to this feature of plumboyarosite is the fact that it is not at all amenable to the action of sodium sulfide, and sulfidization does not occur even at elevated temperature. Under similar conditions, cerussite and anglesite interact very actively with sodium sulfide.

The features of interaction with sodium sulfide and xanthate and, in accordance with this, the flotation ability for cerussite and all the other oxidized lead minerals investigated were established by us by applying the radioactive-isotope method, by measuring the attachment time of an air bubble on an electronic instrument designed by one of the authors (^1), and also, in almost all cases, by experiments in the direct flotation of minerals under various conditions. All these experiments established that the effectiveness of sulfidization of the lead minerals investigated and of the hydrophobization of their surface by the action of xanthates (both when the latter are used independently and in combination with preliminary sulfidization) decreases in almost all series of experiments in the following order: cerussite —anglesite —wulfenite —pyromorphite —mimetesite —bedantite —plumboyarosite, i.e., it changes practically in accordance with the increase in the value of the crystal-lattice energy.

This relationship between flotation ability and the ability to be sulfidized, on the one hand, and the value of the crystal-lattice energy, on the other, shows that as it increases, the bonding energy of the mineral surface with water dipoles and the strength of the hydrate layers covering the surface of mineral particles by collectors increase, counteracting the interaction of the mineral with flotation reagents. Substantial data for judging the adsorption and flotation activity of the minerals studied can be obtained on the basis of considering the crystallochemical and structural features of the latter. Thus, for example, the lattice of cerussite (^2) is distinguished mainly by a planar character and has parallel-directed bonds in the absence of three-dimensional configurations.

These features of the cerussite lattice create favorable conditions for replacement of lattice ions by other ions and for the introduction into it of ions of flotation reagents. All this is in good agreement with the adsorption and flotation features of cerussite. The presence of distinct cleavage along the planes (110) and (021) and very weak cleavage along the planes (010) and (012) indicates that, upon grinding of cerussite, a considerable number of lead ions are exposed, active with respect to interaction with flotation reagents. Anglesite (^2) is characterized by a denser packing of atoms, and it is distinguished to a greater extent by a three-dimensional rather than a planar configuration; this creates less favorable conditions for the action of flotation reagents (which is also observed in practice).

In the series of anions $\mathrm{CO}_3$^-, $\mathrm{SO}_4$^-and $\mathrm{MoO}_4$^-, the ionic radii increase from $\mathrm{CO}_3$^-to $\mathrm{MoO}_4$^-. It is known that, at one and the same charge, the polarizability of ions increases with increasing ionic radius; in this process the ions are, as it were, drawn together and brought closer, which leads to an increase in the strength of the crystal lattice and explains the decrease in interaction with flotation collectors in the series from cerussite to wulfenite (along with

with the other crystal-chemical features of these minerals considered above).

For the minerals of group II, a crystal-lattice structure of the apatite type is characteristic[^3]. In addition to the already mentioned high values of lattice energy, these minerals are characterized by close packing of atoms and a high coordination number (the coordination number of close bonds is equal to six); lead here is strongly bound to neighboring atoms; cleavage is weakly expressed.

All this explains the weak ability of the minerals of group II to interact with flotation reagents.

The crystal structure of plumboyarosite has been insufficiently studied; however, on the basis of data available in the literature, it should be noted that the structure of this mineral is characterized by the presence of very close, strong bonds, which, together with the exceptionally high values of the mineral's crystal-lattice energy, determines its pronounced inertness toward flotation collector reagents.

It has been established, as a result of experiments using radioactive isotopes and flotation tests, that the alkalinity of the pulp, apparently by influencing the degree of hydration of the surface, has a significant effect on the flotation properties of the minerals studied.

With changes in the alkalinity of the medium, the stability of attachment of the flotation reagent on the sulfidized surface of the minerals changes.

An alkaline medium is optimal for cerussite (pH 8.5–9.5) and wulfenite (pH 8.0–8.5). For anglesite, a slightly alkaline medium is preferable. A neutral medium is optimal for pyromorphite and vanadate. Mimetesite and bedantite float in a slightly acidic medium (pH 5.5–6.0). Thus, the alkalinity of the pulp in the flotation of sulfidized oxidized lead ores must be set depending on their mineralogical composition.

All the minerals indicated require different sulfidization conditions, and the duration of sulfidization increases in the transition from minerals of group I to minerals of group III. Plumboyarosite does not undergo sulfidization. Experiments, however, have established the possibility of flotation of plumboyarosite with the use of phosphotene*.

As new and effective flotation reagents for the flotation of difficult-to-concentrate oxidized lead ores, the following may be used: phosphotene, petroleum, avtól, and polygudron together with xanthates.

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* Phosphotene is a naphthene derivative of alkaline dithiophosphate.

*Note: Figure translations are in progress. See original paper for figures.*

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