

## **Patterns in the compositions of oxysalt and sulfosalt minerals, and the paradoxical nature of quartz**

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### **ABSTRACT**

Compositions of oxysalt, sulfosalt, seleniosalt, telluriosalt, and fluosalt minerals all follow the same generalizable patterns with regard to hardness or softness of cations, and with regard to ionic potential. For example, the hard  $F^{1-}$  anion forms simple fluosalt minerals (fluoborates and fluosilicates) with hard cations. The relatively hard  $O^{2-}$  anion forms simple oxysalts (e.g., sulfates and arsenates) largely with hard to intermediate cations. On the other hand, the softer  $S^{2-}$  anion forms sulfosalt minerals almost entirely with intermediate to soft cations, and the still softer anions  $Se^{2-}$  and  $Te^{2-}$  form seleniosalt and telluriosalt minerals with an even more predominately soft suite of cations. Thus, across all these classes of minerals, harder anions generally form minerals with harder cations, and softer anions form minerals with softer cations.

The compositions of simple oxysalt minerals of one inter-radical cation vary greatly, but they do not include minerals in which both the inter-radical cation and intra-radical cation (e.g.,  $Ca^{2+}$  and  $S^{6+}$  in  $CaSO_4$ ) have high ionic potential. Their compositions thus reach, but do not exceed, a limit on a plot of the ionic potential of cations in these minerals. The same general relationship, wherein no simple minerals contain both inter-radical and intra-radical cations of high ionic potential, also exists among sulfosalts, seleniosalts, telluriosalts, and fluosalts. These limits of ionic potential of cations are greatest in oxysalts and progressively less in fluosalts, sulfosalts, seleniosalts, and telluriosalts. The limits thus decrease, both through the  $2-$  anions and across the hard anions, from more negative ionic potential of the anion to less so, seemingly because anions of less negative ionic potential have lesser capability to shield cations from each other and thereby preclude cation-cation repulsion.

Among the simple oxysalts of one inter-radical cation, three minerals near the oxysalt limit form less commonly, or with greater inhibition, than one might expect. For example, thermodynamic calculations indicate that magnesite should precipitate abundantly from seawater, but it does not instead, in low-temperature systems  $Mg^{2+}$  only forms simple carbonate minerals with a cation of lesser ionic potential ( $Ca^{2+}$ ). Similarly, the chemistry of Earth's crust suggests that  $(Al,Fe^{3+})_2(SO_4)_3$  would be a common mineral, but instead analogous hydrous minerals with additional cations of lesser ionic potential are common. Finally,  $SiO_2$  minerals crystallize at distinctly low temperatures in magmatic systems, and they either fail to nucleate or precipitate as a hydrous disordered mineral in many low-temperature systems. In all three cases, cation-cation repulsion seemingly inhibits formation of what might otherwise be more common or more readily forming minerals.

**Keywords:** Geochemistry, systematic mineralogy, sulfosalts, quartz, magnesite, alunite, millosvichite, cations