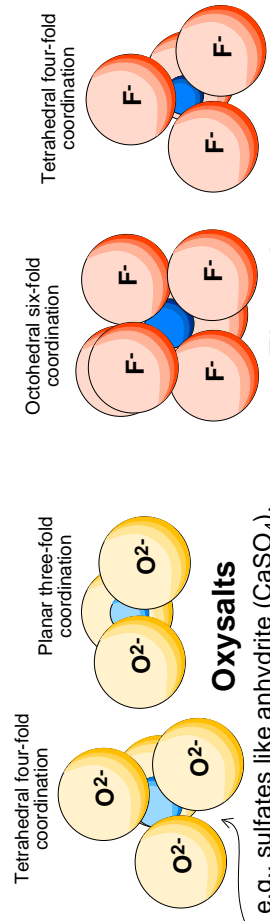


# Radical groups in minerals, and the oxysalts, sulfosalts, seleniosalts, telluriosalts, and fluosalts

Most mineralogy students learn about mineral groups like sulfates, carbonates, and nitrates as the principal examples of minerals in which radical groups (e.g.,  $\text{SO}_4^{2-}$ ,  $\text{CO}_3^{2-}$ ,  $\text{NO}_3^-$ ) bond with cations to form minerals. In such radical groups, three or four large anions ( $\text{O}^{2-}$ ) bond to a central cation of high ionic potential (e.g.,  $\text{S}^{6+}$ ,  $\text{C}^{4+}$ , or  $\text{N}^{5+}$ ).

The same happens in other, but less common, groups of minerals. For example,  $\text{S}^{2-}$  clusters around cations to form sulfosalts.  $\text{Se}^{2-}$ ,  $\text{Te}^{2-}$ , and  $\text{F}^-$  likewise cluster to make radical groups in seleniosalts, telluriosalts, and fluosalts. In this context, minerals in which  $\text{O}^{2-}$  forms radicals are "oxysalts".



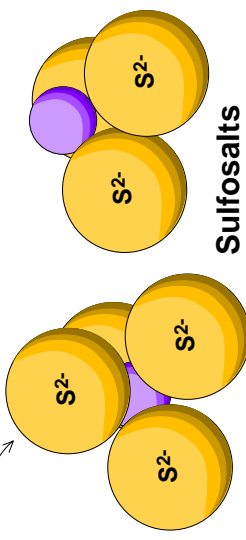
**Oxysalts**  
e.g., sulfates like anhydrite ( $\text{CaSO}_4$ ), silicates like forsterite ( $\text{Mg}_2\text{SiO}_4$ ), arsenates like chernovite ( $\text{YAsO}_4$ ), carbonates like calcite ( $\text{CaCO}_3$ ), etc.

**Fluosalts**  
e.g., fluosilicates like hieratite ( $\text{K}_2\text{SiF}_6$ ), fluoroborates like ferrucite ( $\text{NaBF}_4$ ), fluoaluminates like cryolite ( $\text{Na}_3\text{AlF}_6$ ) and non-mineral fluoberyllates like  $(\text{NH}_4)_2\text{BeF}_4$ .

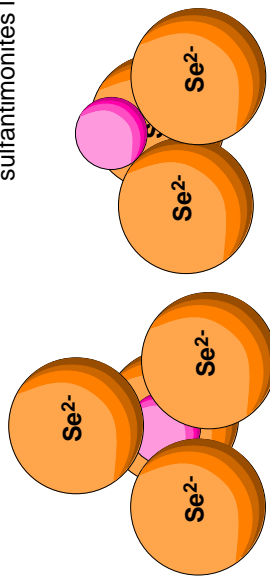
Note the very different guises of sulfur, as  $\text{S}^{6+}$  and  $\text{S}^{2-}$ .

**Intermediate to Soft Cations:**

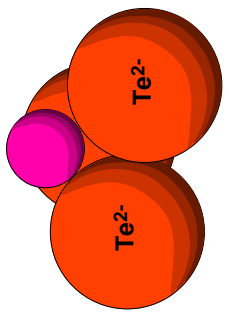
<b>Hard Cations:</b>	$\text{Be}^{2+}$	$\text{B}^{3+}$	$\text{C}^{4+}$	$\text{N}^{5+}$					
	$\text{Mg}^{2+}$	$\text{Al}^{3+}$	$\text{Si}^{4+}$	$\text{P}^{5+}$	$\text{S}^{6+}$				
	$\text{Ca}^{2+}$	$\text{Sc}^{3+}$	$\text{Ti}^{4+}$	$\text{V}^{5+}$	$\text{Cr}^{6+}$				
	$\text{Sr}^{2+}$	$\text{Y}^{3+}$	$\text{Zr}^{4+}$	$\text{Nb}^{5+}$	$\text{Mo}^{6+}$				
	$\text{Ba}^{2+}$	$\text{La}^{3+}$	$\text{Hf}^{4+}$	$\text{Ta}^{5+}$	$\text{W}^{6+}$				
						$\text{Ge}^{4+}$	$\text{As}^{5+}$	$\text{Se}^{6+}$	$\text{S}^{4+}$
						$\text{Sn}^{4+}$	$\text{As}^{3+}$	$\text{Se}^{4+}$	
						$\text{Sn}^{2+}$	$\text{Sb}^{5+}$	$\text{Te}^{6+}$	$\text{I}^{5+}$
						$\text{Pb}^{2+}$	$\text{Sb}^{3+}$	$\text{Te}^{4+}$	
							$\text{Bi}^{3+}$		



**Sulfosalts**  
e.g., sulfarsenates like fangite ( $\text{Ti}_3\text{AsS}_4$ ), sulfantimonites like pyrrargyrite ( $\text{Ag}_3\text{SbS}_3$ ), etc.



**Seleniosalts**  
e.g., selenioantimonates like permingerite ( $\text{Cu}_3\text{SbSe}_4$ ), and seleniobismuthites like bohdanowiczite ( $\text{AgBiSe}_2$ ).



**Telluriosalts**  
e.g., volynskite ( $\text{AgBiTe}_2$ )

$\text{O}^{2-}$	$\text{F}^-$
$\text{S}^{2-}$	$\text{Cl}^-$
$\text{Se}^{2-}$	$\text{Br}^-$
$\text{Te}^{2-}$	$\text{I}^-$

Harder ← → Softer

Anions of ionic potential that ... is too low to form radical groups

Colloquial usage includes seleniosalts and telluriosalts among sulfosalts, largely because there are few of the former relative to the latter, and all three groups are treated as distinct from the oxysalts.

This page is a very general treatment of issues addressed more thoroughly in Railsback, L.B., 2007, Patterns in the compositions of oxysalt and sulfosalts minerals, and the peculiar nature of quartz: *American Mineralogist*, v. 92, p. 356-369.