Density of minerals VII: The effect of OH\(^-\) in oxysalts

Previous pages of this series have considered controls on the density of oxysalt minerals (e.g., carbonates, sulfates, chromates, etc.). Those controls have included mass of the inter-radical cation (e.g., Ca\(^{2+}\) in CaSO\(_4\)), mass of the intra-radical cation (e.g., S\(^{6+}\) in CaSO\(_4\)), and inclusion of structural water (e.g., the H\(_2\)O in CaSO\(_4\cdot\)H\(_2\)O). This page looks at the role of OH\(^-\), as found for example in malachite (Cu\(_2\)CO\(_3\)(OH)\(_2\)).

The plot below shows density of oxysalts of particular cations, with density plotted against the ratio of OH\(^-\) groups to anion groups (for example, that ratio is 2.0 for malachite). A generalizable pattern emerges: density increases with OH\(^-\)::anion ratio to a maximum at a value of that ratio of 1 to 2 and then decreases, with the ultimate limit of that decrease defined by the density of hydroxide minerals, where the OH\(^-\)::anion ratio goes to infinity. One apparent exception to this generalization is the Zn carbonates, but one might instead use this plot to hypothesize that Zn\(_3\)(CO\(_3\))\(_2\)(OH)\(_2\), with a OH\(^-\)::anion ratio of 1.0, would have a density of about 4.4 gm/cm\(^3\).

The increase in density from OH\(^-\)-less minerals to minerals with OH\(^-\)::anion ratios of 1 to 3 can be rationalized in terms of the charge contribution made by OH\(^-\) groups. Two OH\(^-\)s contribute the same charge as a CO\(_3\)^{2-} group, but in about two-thirds the volume, so incorporation of OH\(^-\)s rather than anionic radical groups would allow an increase in density. That remains valid so long as the positive loci of charge on the OH\(^-\)s are located away from cations. With increasing OH\(^-\)::anion ratio, the latter issue inevitably arises, leading the observed decrease in density at large values of the OH\(^-\)::anion ratio and ultimately exemplified by the hydroxide minerals at the right side of the diagram.