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Mechanism and kinetics of a mineral transformation under hydrothermal conditions: Calaverite to metallic gold

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Abstract

The transformation of calaverite to gold under hydrothermal conditions was studied experimentally by probing the effects of temperature (140 to 220 °C), pH (2–12), oxidant concentration, geometric specific surface area, and solid-weight to fluid-volume ratio on the sample textures and the reaction kinetics. Under all of the experimental conditions explored, calaverite transformed to various extents to metallic gold. The replacement is pseudomorphic, as gold preserves the external dimensions of calaverite. The resulting elemental gold is porous; consisting of filament-shaped aggregates with diameters ranging from 200 to 500 nm and lengths up to 25 μm. Gold crystals appear to be randomly oriented with respect to the twinned calaverite grains.

The transformation proceeds via a coupled calaverite dissolution–gold precipitation mechanism, with calaverite dissolution being rate-limiting relative to gold precipitation. Tellurium is lost to the bulk solution as Te(IV) complexes, and may further precipitate away from the dissolution site (e.g., autoclave walls) as TeO_2(s). In contrast, gold precipitates locally near the calaverite dissolution site. Such local gold precipitation is facilitated by fast heterogeneous nucleation onto the calaverite surface. The dissolution of calaverite and the overall reaction are oxidation reactions, and oxygen diffusion through the porous metallic gold layer probably plays an important role in sustaining the reaction.

A similar dissolution-reprecipitation process may be responsible for the formation of mustard gold during the weathering of gold-telluride ores. At 220 °C, solid-state replacement of calaverite by gold is slow (months), but calaverite grains ~100 μm in size are fully replaced in <24 h under hydrothermal conditions, providing a possible alternative to roasting as a pre-treatment of telluride-rich gold ores.

Keywords: Calaverite, gold, dissolution-reprecipitation, pseudomorphism, replacement