Stability of nanoparticles in the presence of biological material and their toxicity

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Cerium is the most abundant lanthanide and generally the only one to undergo redox reactions at the Earth's surface. Because their unique electron transferring properties, Ce-minerals have been proposed as optimal material for nanotechnological applications.

Yet, to date, little mechanistic information is available on the stability of Ce-bearing nanoparticles in the presence of biological material and their toxicity.

Here, we study molecular interactions between small-sized CeO_2 and biomolecules(e.g., DNA, RNA, proteins) using carbon and cerium spectroscopy. As determined by aggregation kinetics by Dynamic Light Scattering (DSL) and UV, the aggregation behavior of nanoCeO$_2$ is susceptible to pH variations imposed by the presence of biological moieties. The aggregation kinetics of aggregation is of zero-order with respect to solid concentration. Results show progressive transformation of biological material (as % carbon) with decreasing CeO_2 particle diameter (13 < d < 84 Å), which substantiates an intimate relation between CeO_2 unit cell expansion and reactivity towards organics susceptible to undergo redox transformations. As evidenced by C and Ce spectroscopy, organic polymers that form because of oxidation are distributed next to the mineral surface and its occurrence is coupled to Ce reduction-oxidation. Analyses by nephelometry of acidophiles and fungi cultures incubated with nanoCeO$_2$ at pH 2 show variations in the population density and growth rate values, which reveal bonding site specificity and in agreement with non-enzymatic results.

Experimental determination of equilibrium solubility quotients of the natural colemanite in NaCl solutions up to 2.0 m

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Colemanite ($CaB_3O_4(OH)_3$:H_2O) is an important evaporate borate mineral. Experimental studies on the solubility constants of colemanite in a wide range of ionic stengths are few. In this study, we experimentally determined the equilibrium solubility quotients of the natural colemanite from the Kestelek, Turkey, in NaCl solutions ranging from 0.1 m to 2.0 m at 20 °C. The solubility constant of the natural colemanite at infinite dilution at 20 °C from this study regarding the following reaction,

$$CaB_3O_4(OH)_3{:}H_2O + 4H_2O = Ca^{2+} + 3B(OH)_4^- + H^+$$
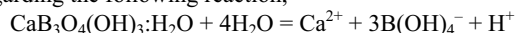
is -17.5 ± 0.1 (2σ) based on the Specific Interaction Theory (SIT) model for extrapolation to infinite dilution according to the weighted linear regression. The derived Δε is 0.027. By using ε(Ca^{2+}, Cl^-) and ε(H^+, Cl^-) from Xiong (2006), the ε(Na^+, $B(OH)_4^-$) derived from this study is -0.09 ± 0.02. This value is in excellent agreement with the literature value of -0.07 ± 0.05 evaluated by Ciavatta (1980).

The above solubility constant is significantly different from the one calculated regarding the above reaction from the Gibbs free energy of formation of colemanite predicted by Li et al. (2000) in combination with the auxiliary data from Wagman et al. (1983), which is -13.41 in logarithmic unit at 25 °C, or -13.57 at 20 °C according to the enthalpy of the reaction to extrapolate to that temperature. This means that colemanite is more stable than previously predicted.

References

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