Thermodynamics Exercises

Chemolithoautotrophic growth of Thioploca sp. with reduced sulfur compounds and employing nitrate as electron acceptor

We are investigating the growth thermodynamics of autotrophic biomass formation by the colorless sulfur bacterium Thioploca sp.in an environment characterized by the following boundary conditions: (concentrations are given in [mol/l])
$[HS^-]$ 10^{-3}; $[NO_3^-]$ stored in vacuoles $250*10^{-3}$; $[NH_4^+]$ 10^{-3}; $[SO_4^{2-}]$ $27*10^{-3}$; $[HCO_3^-]$ 10^{-2}; $5 < pH < 9$;

1. Define the stoichiometrically balanced equations for lithoautotrophic biomass (= $<C_4H_7O_3>$) formation at 5^oC
a) for incomplete hydrogensulfide oxidation to sulfur and
b) for complete oxidation of intracellularly stored sulfur to sulfate.
2. Define the stoichiometrically balanced anaerobic dissimilation equations which couple nitrate ammonification of the reduced sulfur compounds to the assimilations described under 1.
3. How would a temperature increase affect growth energetics ?

Syntrophobacter wolinii in association with hydrogenotrophs

Syntrophobacter wolinii oxidizes propionate to acetate and releases electrons in the form of hydrogen gas. In order to make its dissimilation reaction exergonic, it needs to be coupled to H_2-scavenging bacteria, e.g. hydrogenotrophic sulfidogens, methanogens or acetogens.

Find optimal H_2-coupling concentrations and define the threshold concentrations at which the pulling reactions become endergonic and the one below which hydrogenic propionate oxidation becomes exergonic.

Assume that the syntrophic association takes place under the following boundary conditions (concentrations are given in [mol/l]):
[Propionate] 10^{-3}; [Acetate] 10^{-3}; [Hydrogencarbonate] 10^{-4}; pH 8; [Sulfate] 10^{-3}; [Hydrogensulfide] 10^{-3}; [Methane] 10^{-3}.

Thermochemical energy yield from substrate oxidation with different oxidants

We will compare complete oxidation of ethanol with SO_4^{2-} ,SO_3^{2-} ,$S_2O_3^{2-}$,S^o, HCO_3^-, H^+, O_2, NO_3^- in a chemostat with the following operating conditions: (concentrations are given in [mol/l]): [Ethanol] 10^{-4}; $[HCO_3^-]$, $5*10^{-3}$; [oxidant] $0.5*10^{-3}$; [reduced oxidant] $\leq 0.3*10^{-3}$; $6 \leq pH \leq 10$. How can assimilation be balanced energetically by dissimilation ?

Microbially mediated formation of hydroxyapatite in sediments

Sediments of lakes containing calcium and carbonate-rich waters tend to accumulate calcite cristals produced during active algal photosynthesis in the photic zone. Surfaces of these cristals can act as nucleation centers for the formation of apatite. The necessary phosphate stems from microbial mineralization of organic detritus. In anoxic sediments phosphate can be permanently removed from the biochemical cycle if it is incorporated into highly insoluble phosphate minerals.

Steady state conditions observed in the interstitial water of an anoxic eutrophic sediment are:
$[HPO_4^{2-}]$ 10^{-4} mol/l; $[HCO_3^-]$ $5*10^{-3}$ mol/l; pH 7.5.

Will these conditions promote the formation of hydroxyapatite from calcite according to the reaction

$$\mathbf{10\,CaCO_{3(s)} + 2H^+ + 6\,HPO_4^{2-} + 2\,H_2O \rightarrow Ca_{10}(PO_4)_6(OH)_{2(s)} + 10\,HCO_3^-}$$

As a first approximation the thermodynamic evaluation may be based on standard conditions of temperature (T=25°C) and ionic strength (I=0).

How will microbially induced changes in the environmental pH alter hydroyapatite formation ?