Cometary delivery of water, noble gases and organics to earth

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Laboratory experiments on the trapping of gases by ice forming at low temperatures implicate comets as major carriers of the heavy noble gases Ar, Kr and Xe to the inner planets. Recent work on deuterium in Comets Halley, Hyakutake and Hale-Bopp provides good evidence that comets contain some unmodified interstellar material. However, if the sample of three comets analyzed so far is typical, the Earth's oceans cannot have been produced by comets alone. The highly fractionated neon in the Earth's atmosphere also indicates the importance of non-icy carriers of volatiles, as do the noble gas abundances in meteorites from Mars. The additional carrier is probably the rocky material comprising the bulk of the mass of these planets. Along with water and the noble gases, comets and carbonaceous chondrites delivered also the plethora of gases observed in these three comets as well as the heavy organic materials in the "CHON" particles observed in comet Halley and in carbonaceous chondrites. The accumulation of volatiles was interrupted frequently by giant impacts which eroded the atmosphere and some, if not all, of the water. Finally, around 3.8×10^9 years ago, when the bombardment diminished, a stable atmosphere and hydrosphere persisted on the earth. Merely 2×10^8 years elapsed until cellular organisms recognizable as fossils were formed on Earth.

Experimental determination of the standard thermodynamic properties of solid phases in the Au-Ag-S system

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Calculation of the standard thermodynamic properties of AuHS° and $Au(HS)_2^-$ is impeded by the absence of reliable thermodynamic data for the sulfides used in solubility experiments. Besides, these data are necessary to develop a thermodynamic model for Au bearing sulfide solid solutions in which gold is "invisible". The purpose of this study is to determine the standard thermodynamic properties of Au_2S, low AgAuS and Ag_3AuS_2 from solid-state electrochemical measurements and low temperature heat capacity determinations. New gold solubility measurements were performed to check the consistency of the thermodynamic properties of crystalline sulfides with those of aqueous species. The solid-state electrochemical cells

Pt, Ag $|Ag_4RbI_5|$ Ag_3AuS_2, Ag_2S, Au, Pt

and Pt, AgAuS, Au, S $|Ag_4RbI_5|$ AgAuS, Au_2S, Au, Pt

were used to determine the constants of the reactions

$Ag_{(cr)} + Ag_3AuS_{2(cr)} = 2Ag_2S_{(cr)} + Au_{(cr)}$

and $2Au_{(cr)} + S_{(cr)} = Au_2S_{(cr)}$.

Low temperature heat capacity of AgAuS was measured at 59-303K using an adiabatic calorimeter. Gold solubility was measured in sulfide solutions ($m(H_2S)$~0.1) at 22°C and pH from 2 to 6.5. The retrieved constants of the reactions

$Au_{(cr)} + H_2S^0_{(aq)} = AuHS^0 + 0.5\ H_{2(g)}$ (1)

$Au_{(cr)} + H_2S^0_{(aq)} + HS^- = Au(HS)_2^- + 0.5\ H_{2(g)}$ (2)

are $K_1=10^{-10.16\pm0.25}$ and $K_2=10^{-5.65\pm0.25}$. Combination of Au_2S solubility products ($Au_2S_{(cr)} + 3HS^- + H^+ = 2Au(HS)_2^-$ and $Au_2S_{(cr)} + HS^- + H^+ = 2AuHS^0_{(aq)}$) measured at 25°C by Renders and Seward (1989) with $\Delta_f G^0(Au_2S)$ determined in the present study yields $K_1=10^{-10.54\pm0.35}$ and $K_2=10^{-4.94\pm0.35}$. These values are in close agreement with those, listed above, deduced from gold solubility. Determinations of the other thermodynamic properties of Au_2S, AgAuS, and the heat capacity of Ag_3AuS_2 are in progress.

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