RADIOLYSIS PROCESSES ON EUROPA

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The galilean satellites of Jupiter are immersed in an intense plasma so their surfaces are bombarded by energetic ions and electrons that strongly influences their chemical composition. Implantation of sulfur ions, which originate from Io, provides an exogenic source of chemically active surface material for the outer satellites and the high-energy radiation can produce new chemical species through radiolysis. Radiolysis is shown to occur on Europa's icy surface by the observation of surficial hydrogen peroxide (Science 283, 2062, 1999). Europa's surface also contains a hydrated compound that we suggested is hydrated sulfuric acid, radiolytically produced from sulfur-bearing surface material. The initial source of sulfur is masked by subsequent radiolytic reactions, but the candidates include ion implantion and endogenic metal sulfates and sulfur dioxide (Science 286, 97, 1999). Sulfuric acid, sulfur, and SO_2 are part of a radiolytic sulfur cycle, in equilibrium with continuous production and destruction. We measured the rate of sulfate production by radiolysis of frozen aqueous sulfur solutions and find that the observed amount of sulfuric acid can be produced in a few thousand years. Destruction of hydrated sulfuric acid is less efficient so much of the sulfur exists in the acid form. The distributions of hydrated sulfuric acid and SO_2 both show a trailing side enhancement, suggesting that sulfur ion implantation, coupled with electron radiolysis, is a major source of sulfate and SO_2. The observed amount of sulfur (in the form of hydrated sulfuric acid) can be accumulated by ion implantation in just 30,000 years, so some process is removing sulfur from the surface. Sputtering is one possible mechanism, but burial by micrometeoritic gardening is likely a faster method (Cooper et al., Icarus, in press, 2000). We computed, for different rates of asynchronous rotation, the surface densities of implanted sulfur subject to burial by gardening. The computed densities agree with the observed amounts to within a factor of three and, given the large uncertainties in the gardening rate, are consistent with ion implantation.