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Chemistry in the near-surface atmosphere at Ganymede

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Abstract

Theoretical predictions of the composition and chemical evolution of near-surface atmospheres of the icy satellites in the Jovian and Kronian systems are of great importance for assessing the biological potential of these satellites. Depending on the satellite mass the formation of the rarefied exosphere with the relatively dense near-surface layer is possible as, for example, in the case of the relatively heavy Galilean satellites Europa and Ganymede in the Jovian system [1-3]. Ganymede is of special interest, because observations indicate that Ganymede has a significant O_2 near-surface atmosphere, probably subsurface ocean, and is the only satellite with its own magnetosphere. Processes of formation of the rarefied gaseous envelope of Ganymede and chemical exchange between atmosphere and icy surface will be considered. The water vapour is usually the dominant parent species in such gaseous envelope because of the ejection from the satellite icy surface due to the thermal outgassing, non-thermal photolysis and radiolysis and other active processes at work on the surface. The photochemistry of water vapour in the near-surface atmospheric layer [4] and the radiolysis of icy regolith [5] result in the supplement of the atmosphere by an admixture of H_2, O_2, OH and O. Returning molecules have species-dependent behaviour on contact with icy surface of the satellite and non-thermal energy distributions for the chemical radicals. The H_2 and O_2 molecules stick with very low efficiency and are immediately desorbed thermally, but returning H_2O, OH, H and O stick to the grains in the icy regolith with unit efficiency. The suprathermal radicals OH, H, and O entering the regolith can drive the surface chemistry.
The numerical kinetic model to investigate on the molecular level the chemistry of the atmosphere-surface interface of the rarefied H_2O-dominant gaseous envelope at Ganymede was developed. Such numerical model simulates the gas-phase and diffusive surface chemistry using the efficient algorithms [1,4,6] of the kinetic Monte Carlo approach. The photochemistry in such neutral gaseous envelopes [1-3] and the radiolytic chemistry in the icy regolith [5] are initiated by the solar UV radiation and solar wind and/or magnetospheric plasma influence. Chemical complexity of the near-surface atmosphere of the icy satellite arises due to both primary processes of dissociation and ionization by solar UV radiation and magnetospheric electrons and induced ion-molecular chemistry, and by chemical exchange between near-surface atmospheric layer and the satellite icy surface due to the thermal and non-thermal desorption processes. Therefore, the standard astrochemical KIDA network was used to follow the main chemical pathways of photochemistry in the near-surface atmosphere and of diffusive chemistry in the icy regolith.
Developed model was used to investigate the chemical diversity and complexity in the atmosphere – icy surface interface at Ganymede. This atmosphere is found to be a very tenuous and surface-bounded gaseous envelope with O_2 molecules being the main constituent [1-3]. Modelling of the chemistry of atmosphere-icy surface interface, and, especially, ionization chemistry [4], allows us to quantify neutral and ion densities near and exchange fluxes across the atmosphere-surface interface. Because ion composition measurements are far more sensitive, so that even trace species could be measured in the pick-up ion populations downstream from Ganymede. Results of calculations were compared with the measurements received by the Galileo spacecraft and can be used to support the future missions to the Jovian system. Moreover, theoretical predictions of the composition and chemical evolution of Ganymede's near-surface environment are of great importance for assessing the biological potential of this satellite.

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