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The Chemistry of Pluto and its Satellites

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Pluto's bulk composition and the composition of the surface layers hold clues to the origin and evolution of a number of other Solar System bodies of comparable size in the region beyond Neptune. The July 14, 2015 flyby of the Pluto system with the New Horizons spacecraft afforded the opportunity to corroborate and greatly improve discoveries about the planet and its satellites derived Earth-based studies. It also revealed extraordinary details of the surface and atmosphere of Pluto, as well as the geology and composition of Charon and two smaller satellites. With a mean density of 1.86 g cm^{-2}, the bulk composition of Pluto is about two-thirds anhydrous solar composition rocky material and one-third volatiles (primarily H_2O in liquid and solid states) by mass, the surface is a veneer of ices dominated by N_2, with smaller amounts of CH_4 and CO, as well as limited exposures of H_2O ice (considered to be "bedrock"). N_2, CH_4, and CO occur as solid solutions at temperature-dependent mutual concentrations, each component being soluble in the others. Frozen C_2H_6 as a minor component has also been identified. Sublimation and recondensation of N_2, CH_4, and CO over seasonal (248 y) and Milankovich-type megaseasons (~3 My) result in the redistribution of these ices over time and with latitude control. Solid N_2 is found in glaciers originating in higher elevations and flowing at the present time into a basin structure larger than the State of Texas, forming a convecting lens of N_2 that overturns on a timescale of order 10 My. The varied colors of Pluto's landscape arise from the energetic processing of the surface ices in processes that break the simple molecules and reassemble complex organic structures consisting of groups of aromatic rings connected by aliphatic chains. When synthesized in the laboratory by UV or electron irradiation of a Pluto mix of ice, this material, called tholin, has colors closely similar to Pluto. The Pluto ice tholin analog contains carboxylic acids, urea, ketones, aldehydes, amines, and some nitriles. The largest satellite, Charon has density1.70 g cm^{-2} and it is about 3/5 anhydrous solar composition rock, with the remainder in H_2O ice. The surface H_2O ice is infused in some way with NH_3, probably as a hydrate, distributed nonuniformly, but to some degree related to geological structures. Pluto's atmosphere is N_2, CH_4, with CO, C_2-hydrocarbons, HCN, and other molecules in trace but detectable amounts. The atmosphere supports a complex haze structure with about 20 discrete layers, and suspected clouds. The haze is presumed to be made of aggregates of complex hydrocarbons (tholins) produced by photolysis of the atmospheric gases, and with similar composition to the ice tholins made on the planet's surface. Urea and a suite of carboxylic acids are of interest for prebiotic and biological chemistries.