EPSC Abstracts,
Vol. 4, EPSC2009-156, 2009
European Planetary Science Congress,

Kuiper belt objects: Influence of radionuclides on the internal structure formation

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Abstract

The building material of the forming KBOs was exclusively a uniform matter of the protosolar nebula consisted of fine-dispersed dust and fine-fractionated condensate of H_2O. The main process of formation was accretion of small dust particles trapped by a dynamically changing gravitational field of the growing body. As a result, a spherically symmetric body was being created which material was a multicomponent disperse system consisting initially of H_2O amorphous ice with embedded in it dust particles, carriers of radionuclides**.** Short-living radionuclide ^{26}Al was the main source of heating at the body formation stage. Since different spherical body layers were being formed at different times, different was the age of ^{26}Al embedded in these layers and, therefore, its intensity as a heat source. This circumstance played a decisive role in the process of the celestial body thermal evolution making a possibility to create inside it areas filled with liquid water with suspended dust particles.

The structure and composition of the internal body matter are defined by H_2O phase changes: crystallization of amorphous ice, sublimation and melting of crystalline ice. In the process of thermal evolution the amorphous ice changes into the crystalline form with a rate of

$\lambda(T) = 1.05 \cdot 10^{13} \cdot \exp(-5370/T)\ s^{-1}$ [1].

From this it follows that at T<85 K the crystallization time is comparable with the body formation time, whereas at T>150 K the whole crystallization process lasts less than several hours. Thus, at T<85 K the body ice exists only in an amorphous form, and at T>150 K does only in a crystalline one; at 85<T<150 K both ice forms exist in a body volume unit.

The sublimation process of the icy component is in progress all the time but with different rate depending on the temperature, saturated vapour pressure over the icy or liquid water surface and the vapour pressure in the given volume which is determined by the Clausius–Clapeyron relation. If these two pressures are equal the sublimation process stops and the energy released in the volume goes only to the matter temperature increase up to the melting point. Crystalline ice melting goes with a rate proportional to the thermal energy release rate in the given volume. The ice can be melted partially or completely depending on the amount of the released energy. The rates of different kind phase transitions are calculated in our thermal model using the relations for thermal physical parameters obtained in [2-5].

Thus, thermodynamic processes running in the icy component and decreasing from the centre to the surface intensity of radiogenic thermal sources determine dynamically changing structure and composition of the celestial body different areas.

These changes have been caused by the icy component phase transitions dependent on the intensity of the radiogenic heat sources and the body formation time. The domains of these parameters have been found where in the process of the thermal evolution there can be areas filled with liquid water.

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