MOBILITY OF PORES IN ICES IN THE SOLAR SYSTEM R. Smoluchowski and M.A. Marie, The University of Texas, Austin, Texas 78712

There is no reason to suppose that ices in the solar system whether on satellites, in cometary nuclei, in interplanetary grains or on the ring particles of Saturn have no pores. The low temperatures at which most of these ices were presumably formed, and the not much higher temperatures encountered later, imply a low mobility of adsorbed molecules and a tendency to form defects. Of comparable importance are impurities and admixtures of other ices with different equilibrium vapor pressures. This argument applies to crystalline as well as to amorphous ices. Inasmuch as porosity can have an important influence on heat transport (1) and on the rate of evaporation of solids, it is of interest to understand the behavior of pores under various conditions.

As long as the ambient temperature is so low that the vapor pressure in the pores is negligible, no significant changes in the pore configuration are expected. At higher, but uniform, temperatures, the pores will gradually tend to become equiaxial because the equilibrium vapor pressure above convex, or low concave curvature, walls of the pores, is higher than above areas with high concave curvature. In the first approximation, it is therefore permissible to assume that the pores do not have highly convoluted shapes. If there is a considerable thermal gradient, however, the vapor pressure in the pore corresponds to the temperature on the hotter end of the pore and is higher than that corresponding to the colder end. As a result, a gradual mass transfer from the hot to the cold end will occur and the pore will drift up the thermal gradient. During this drift, the pore may change its shape but this effect will be here ignored.

The drift effect depends on the size of the pore and both in the Knudsen and in the viscous flow region the larger temperature difference across a larger pore will produce a higher drift velocity. As a result, the larger pores will absorb smaller pores which they encounter on their way and thus accelerate their own motion. The net result is an increase of porosity and thus a decrease of density of the material near the hot end and a corresponding densification near the cold end. The equations governing these effects have been evaluated on a computer for pores in water-ice and in CO_2-ice. The velocity of a pore in a given temperature gradient in the viscous region in H_2O ice at 220^oK is comparable to that in CO_2-ice at 150^oK. In the Knudsen region the respective temperatures are 180° and 140^oK. In the particular application to cometary nuclei, the main effect occurs in the CO_2-ices rather than in water ices because in the latter the vapor pressure in the pores is rather low even in the proximity of perihelia. The periodic variation of the sign of the temperature gradient in cometary nuclei leads to a partly reversible motion of the pores but their growth is not reversible so that they eventually reach an equilibrium size and the smaller pores are largely eliminated. An interesting side result of the phenomena here discussed is the gradual, though very slow, transformation of porous crystalline water ice into porous amorphous water ice at temperatures below 150^oK. This effect may have and influence on the behavior of old comets (2).

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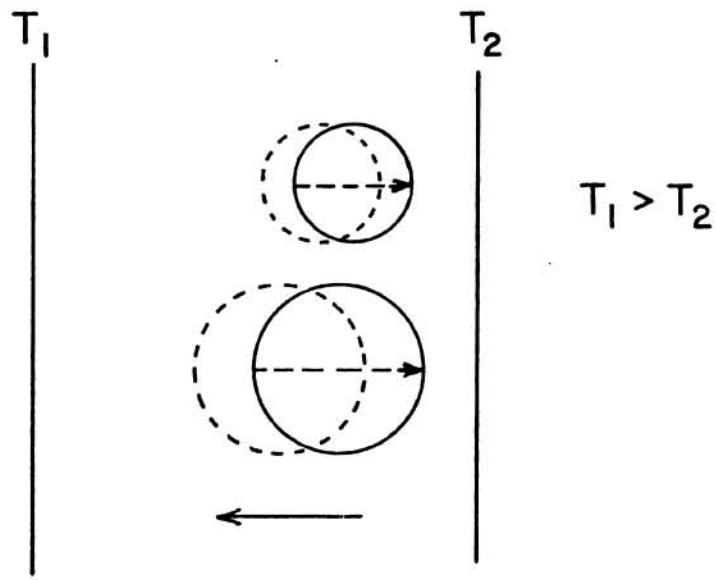

Motion of pores. Dashed arrow - mass transfer
Full arrow - direction of motion

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