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Evidence of Surface Diffusion of Helium

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COMMUNICATION

Evidence of Surface Diffusion of Helium

The importance of the surface diffusion in gas separation by means of permeation through a microporous membrane was emphasized in recent publications (*1*,*2*). The significance of the surface flow of helium was stressed (2), but the experimental findings were not sufficiently pronounced to convince investigators in this particular area of study. In the present paper, positive experimental evidence of the surface diffusion of helium is given, and this fact supports the previously proposed general theory.

If the observed flow rate is assumed as the sum of gas-phase flow and surface flow in the study of gas permeation through a microporous medium, one should have a reasonable method to separate the surface flow from the total flow, which is observed experimentally. The conventional method which utilizes the helium flow to estimate the gas-phase flow is in principle incorrect. This fact was pointed out in previous publications (*1*,*2*), but the minimum point of the $Q\sqrt{MT}$ value for helium was not located with adequate accuracy in the temperature range covered by the previous studies. That is, the $Q\sqrt{MT}$ value for helium kept decreasing as temperature went down as far as the liquid-nitrogen temperature, 77.4°K, which up to now has been the lowest attainable temperature. Therefore, helium was the only gas which did not show pronounced surface flow at the lowest temperature employed. Consequently, it was obvious that a further lowering of temperature would be desirable to observe the minimum value of $Q\sqrt{MT}$ and the expected steep increase of surface flow, if the behavior of helium were the same as those of other gases.

This experimental difficulty was easily solved when the Bendix Corporation, Davenport, Iowa, offered their help, providing liquid hydrogen and giving essential assistance. Thus the flow apparatus at the University Laboratories was moved to Davenport and installed there in a liquid-hydrogen-handling facility.

The bath temperature of liquid hydrogen at atmospheric pressure is 20.4°K. Since this temperature is so low, a slight error in temperature would cause a large change in the calculation of the permeability. This possibility definitely exists in any experimental determination.

Easy handling of the diffusion cell at the cryogenic temperature was achieved by constructing the whole unit from Pyrex glass. Thus, not only leakproof sealing was achieved, but also the least thermal expansion of the material. No evidence of breakage or damage of the cell was observed during the experiments. The flow data at higher temperatures after the cryogenic experiments proved that the porous Vycor glass was not changed in any way.

The experimental value of the helium permeability at 20.4°K was found to be 7.032×10^{-5} std cc-cm/sec-cm^2-cm Hg. This gives the $Q\sqrt{MT}$ value of

$$6.355 \times 10^{-4} \left(\frac{\text{std cc-cm}}{\text{sec-cm}^2\text{-cm Hg}}\right)\left(\frac{\text{g-°K}}{\text{g mole}}\right)^{1/2}$$

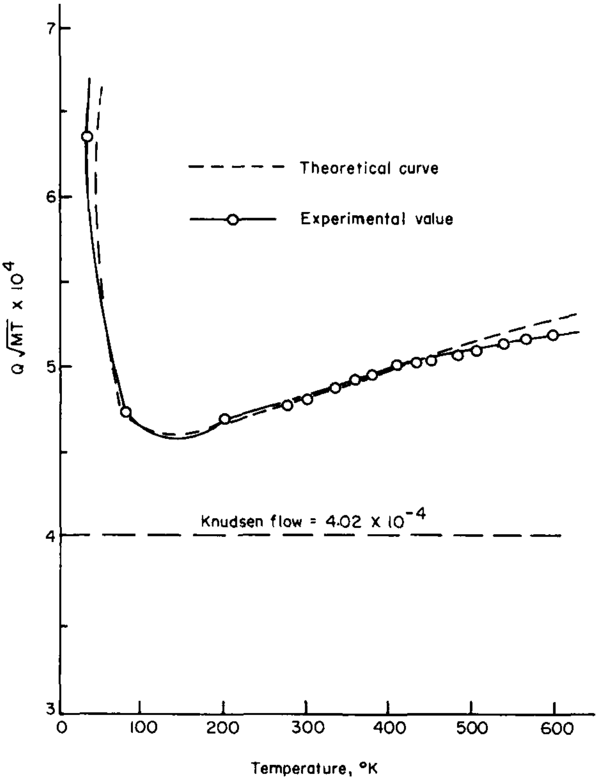

FIG. 1. Helium flow through porous Vycor glass.

Figure 1 shows the experimental values and predicted values of $Q\sqrt{MT}$ based on the flow data at higher temperatures. The minimum of $Q\sqrt{MT}$ occurred near 100°K. This compares with the previous prediction (*1*) of 127°K. But the significant fact is that the $Q\sqrt{MT}$ value, which is a measure of the deviation from the Knudsen equation, does show a minimum when it is plotted against temperature. The value of $Q\sqrt{MT}$ at 20.4°K is further positive evidence of the surface diffusion of helium.

As a conclusion of the present study, it is recommended that the *total helium permeability* should not be used in the estimation of the Knudsen flow. The true, gas-phase flow (Knudsen flow) can only be obtained by studying the temperature effect (*1,2*) (see Fig. 1).

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List of Symbols

Q permeability, $\frac{\text{std cc-cm}}{\text{sec-cm}^2\text{-cm Hg}}$
M molecular weight
T absolute temperature, °K

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