Memoirs of the College of Science, University of Kyoto, Series A,
Vol. XXV, No. 2, Article 15, 1949.

The Exchange Efficiencies of the Translational and the Internal Energy of Gas Molecules on Solid Surfaces II. Measurement by Means of a Vibrating Hot Filament

By

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(Received February 20, 1948)

In the preceding paper a molecular beam method for measuring separately the exchange efficiencies of the translational (a_t) and the internal energy (a_i) of gas molecules was described.[1] The present report is concerned with another new method. Here we make use of a filament F in a Λ shape, fixed at both ends and capable of heating by an electric current in a glass tube A which can be evacuated to a high vacuum by a mercury diffusion pump. Trap T is cooled with liquid air. The pressure in A is measured by a Mcleod gauge. After baking out the apparatus, hydrogen in R is admitted into A through a capillary gas pipette P to a pressure about 10^{-2} mm Hg. The filament set in vibration by a light knock at the tube, is gradually damped by the internal friction of the filament and the friction with the surrounding gas. The period of half decrement τ is affected by the velocities of the on-coming as well as the departing molecules, irrespective of their internal energy. With the filament at a higher temperature than the gas, the larger value of a_t is directly related with the larger velocity of the departing molecules, so that a_t is a function of τ, which can be found as follows. The motion of the

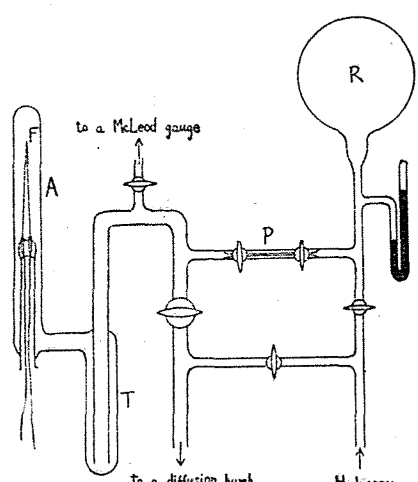

Fig. 1

1. N. Sasaki, K. Taku and K. Mitani: This Memoirs, A, **25** (1949), 70.

heated filament in a gas at a very low pressure may be given by the equation:

$$m_f \frac{d^2x}{dt^2} + r\frac{dx}{dt} + Kx = 0 \ , \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where m: the mass of the filament per unit length,

r, k: constants.

From (1) follows

$$r = \frac{2\ \ln 2}{\tau} m_f \ . \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

r can be regarded as a sum of r_1 and r_2. While r_1 related to the internal friction of the material of the filament can be determined experimentally, r_2 related to the friction with the surrounding gas can be calculated by the kinetic theory of gases. Thus with a filament of a circular cross-section, the following equation is obtained as a result of a rather lengthy calculation:

$$k_2 \frac{p\sqrt{M}}{T}\sqrt{T + a_t(T_1 - T)}\left\{1 + \frac{(1-a_t)T}{T + a_t(T_1 - T)}\cdot\frac{1}{3\pi}\right\}$$

$$= \frac{k_1}{\tau} - 1 - \frac{128}{3\pi^3}k_2\frac{p\sqrt{M}}{\sqrt{T}} \ , \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (3)$$

where T, T_1 : the absolute temperatures of the gas and the filament respectively,

p : the pressure of the gas,

M : the molecular weight of the gas,

k_1, k_2 : the constants characteristic of the apparatus to be determined experimentally by various methods.

If the temperature of the filament is equal to that of the gas, the above equation is reduced to the ordinary equation for a quartz fibre manometer deduced by A. Einstein[1]:

$$b = (p\sqrt{M} + a)\tau \ ,$$

where a and b are constants.

Equation (3) transformed into the following form:

$$a_t = \frac{T}{T_1 - \left(1 + \frac{2}{3\pi}\right)T}\left[\frac{T}{k_2^2 p^2 M}\left(\frac{k_1}{\tau} - 1 - 1.376k_2\frac{p\sqrt{M}}{\sqrt{T}}\right)^2\right.$$

$$\left. - \left(1 + \frac{2}{3\pi}\right)\left\{1 + \frac{(1-a_t)^2 T}{T + a_t(T_1 - T)}\frac{1}{3\pi(3\pi + 2)}\right\}\right]$$

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1. F. Haber and F. Kerschbaum: Z. Elektrochem., **20** (1914), 296.

can be used to calculate a_t by the method of successive approximation, since the last term in the brace is a small correction term.

As for the accommodation coefficient a_i for the internal energy, we measure the total heat loss from the filament heated *in situ* and calculate a_i by equation (3) in the preceding paper.[1]

The result obtained is $a_t = 0.48$ and $a_i = 0.10$, for a tungsten filament at 300° C and hydrogen at 23° C. In this case a_t surpasses a_i to a greater extent than in the preceding paper.

Details of the calculation and the apparatus will appear elsewhere before long.

The present investigation was carried out by the Education Ministry grant for natural science.

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1. *loc. cit.*