ON THE RATE OF FLOW OF VARIOUS GASES THROUGH A POROUS WALL.[1]

By Jitsusaburo SAMESHIMA.

Received October 27, 1925. Published January 28, 1926.

The velocity of effusion of various gases through a perforated thin plate is expressed by the well known equation $t=k\sqrt{M}$, where t is the time of effusion of the definite volume of gas whose molecular weight is M, and k is a constant. This formula was derived by Schmidt[2] and then verified by Graham,[3] Ramsay and Collie[4] and Donnan.[5] If we use, however, a porous wall such as an unglazed earthenware of compact quality, the above equation can no more be applied as is to be seen from the following experiment.

The apparatus used is shown in Fig. 1. A is a small circular disc of compact unglazed earthenware, the diameter of which is 0.6 cm. and the thickness is 0.15 cm. The disc is attached to an end of a glass tube with sealing wax. The glass tube is connected to a vacuum pump and the pressure is always kept lower than 0.1 mm. The disc is kept at 25° by circulating the water of a thermostat as shown in the figure. The bulb B has a capacity of about 70 c.c. and marked at its upper and lower necks $-C$ and $D-$ with lines. A platinum wire attached at the point E on the side-tube serves as the indicator of the constancy of the gas pressure. The gas is put into the vessel B and then the cock F is opened. Now the gas escapes through A and the mercury head goes up. The time which the mercury head requires to pass from D to C is observed. The pressure indicated on the scale H is kept constant during an experiment by raising gradually the mercury reservoir G. The temperature is always kept at 25.°00.

(1) Read before the Chemical Society of Japan, April 4, 1925.

(2) Schmidt, *Gilb. Ann.*, 66 (1820), 39.

(3) Graham, *Phil. Trans.*, 55 (1846), 573.

(4) Ramsay and Collie, *Proc. Roy. Soc.*, 60 (1897), 206.

(5) Donnan, *Phil. Mag.*, [5] 49 (1900), 423.

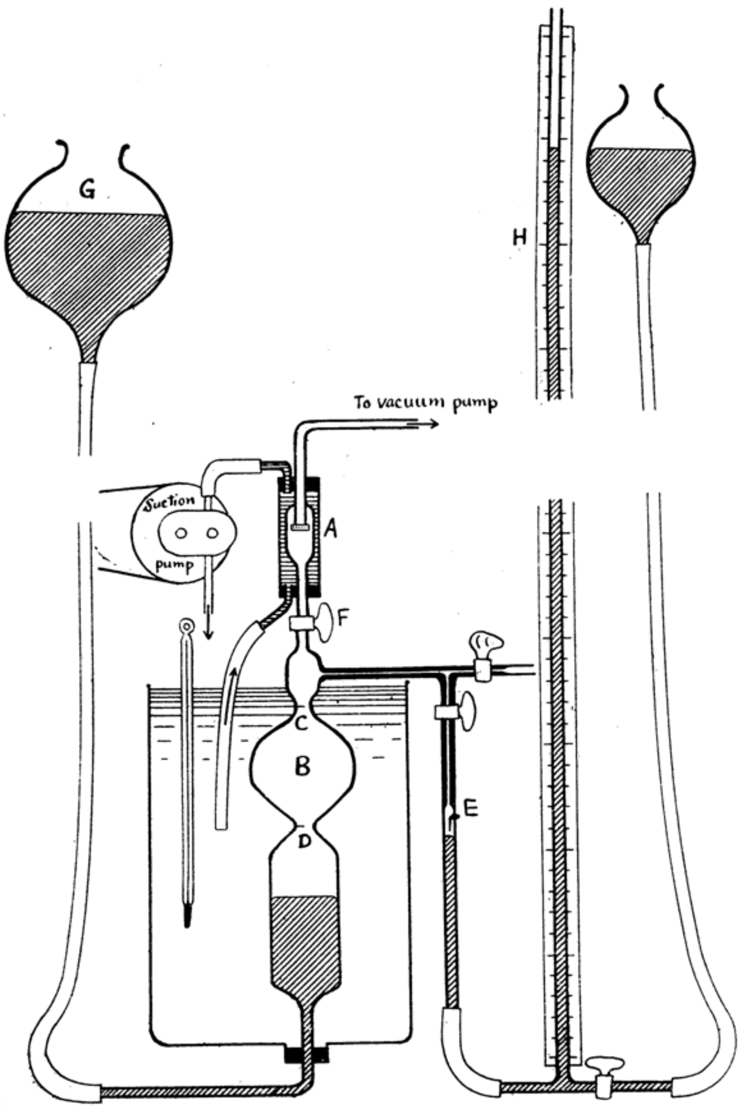

Fig. 1.

The gases examined were methane, ammonia, acetylene, ethylene, air, oxygen and carbon dioxide. All gases except air and oxygen were purified by washing with appropriate reagents and then fractionated by using the liquid air. Oxygen was made from potassium permanganate and passed through the tubes of calcium chloride, potassium hydroxide and phosphorus pentoxide. The results are shown in the following table. Moreover, the time of flow through a perforated platinum plate under one atmospheric pressure has been measured, and the results are also shown in the same table.

Gas.	Time of effusion through an unglazed earthenware, in seconds.				Time of effusion through a perforated Pt. plate.	Mol. weight of gas.
	1.0 atm.	1.5 atm.	2.0 atm.	2.5 atm.		
Methane	962	785	664	573	176.2	16.037
Ammonia	944	762	637	548	178.4	17.032
Acetylene	1048	830	685	583	216.0	26.026
Ethylene	1080	849	700	599	225.7	28.042
Air	1414	1169	1003	878	230.9	28.96
Oxygen	1521	1268	1090	956	243.4	32.000
Carbon dioxide	1457	1162	968	829	279.4	44.005

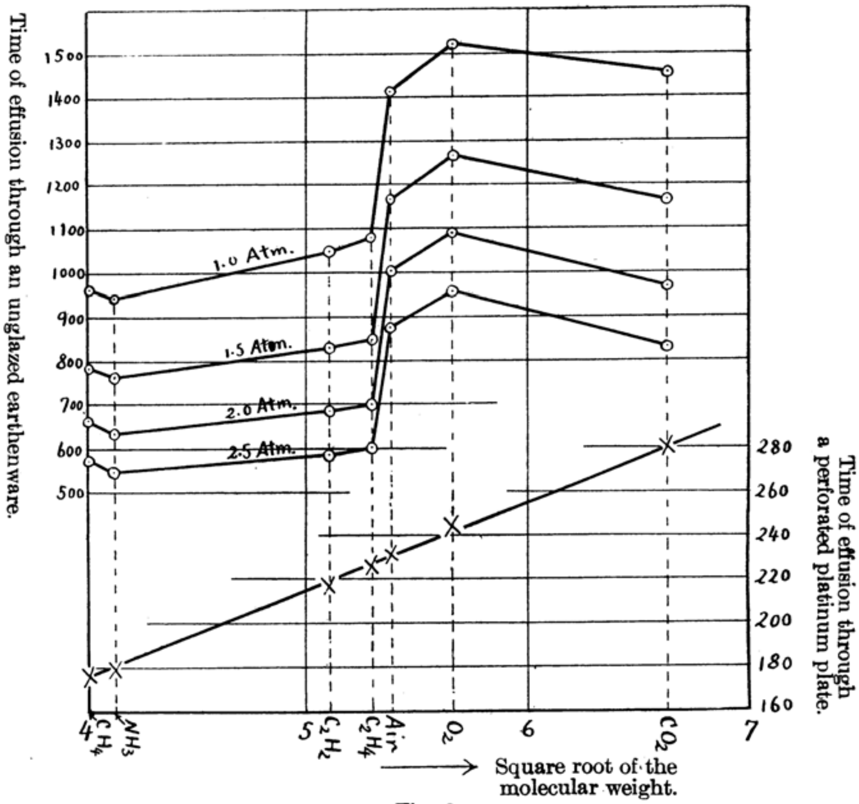

Fig. 2.

In Fig. 2 the square root of the molecular weight of gas is taken as abscissa and the time of effusion as ordinate. The circlets show the times of effusion through an earthenware under the pressures of 1.0, 1.5, 2.0 and 2.5

atmospheres, and the values corresponding to the same pressure are connected by straight lines. The results are far from expressed by the equation $t=k\sqrt{M}$. The crosses show the time of effusion through a perforated platinum plate. They lie nearly on a straight line, which means that they can be expressed by the above equation.

The time of effusion through an unglazed earthenware t will be expressed by the following equation,

$$t=k\eta^{n}M^{\frac{1-n}{2}}$$

where η is the viscosity coefficient of the gas, M is the molecular weight and k and n ($n<1$) are two constants independent of the kind of gas but depend on the nature of the porous wall and the pressure of gas. If the wall be very thin then n approaches to zero and the equation takes the usual form $t=k\sqrt{\mathrm{M}}$, while if the wall be very thick (or a long capillary tube) then n tends to one and the equation becomes $t=k\eta$.

In the present experiment I have calculated the times of effusion from the above equation and the results are given in the following table. The values of the viscosity coefficients at 25° have been obtained by interpolations from the observed values of numerous authors at various temperatures.

Gas.	Viscosity coeff. at 25°.	Time of effusion calculated from the above equation.			
		1.0 atm. $k=24100$ $n=0.44$	1.5 atm. $k=50400$ $n=0.53$	2.0 atm. $k=79800$ $n=0.59$	2.5 atm. $k=104600$ $n=0.63$
Methane	1118×10^{-7}	957	779	657	566
Ammonia	1042 "	943	761	638	548
Acetylene	1030 "	1057	835	691	588
Ethylene	1015 "	1072	844	696	592
Air	1850 "	1409	1168	998	868
Oxygen	2080 "	1525	1273	1092	951
Carbon dioxide	1550 "	1465	1174	980	838

The differences between the observed (former table) and the calculated values (latter table) are within one percent excepting only a few cases.

Laboratory of Physical Chemistry,
Faculty of Science, Tokyo Imperial University.