MEASUREMENT OF THERMAL CONDUCTIVITY OF GASES USING THERMAL DIFFUSION COLUMNS : AIR AND HELIUM

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This paper describes a method for determining the thermal conductivity of a gas by using a thermal diffusion column and uses it for finding the thermal conductivity of air and helium upto 140°C. The study widens the scope for finding the thermal conductivity of a gas at still higher temperatures.

The various methods used for the accurate measurement of thermal conductivity of gases can be classified into two broad groups (*a*) the steady state and (*b*) the dynamic state. From the discussion given by Saxena & Gandhi[1] it is clear that the unsteady state methods are more suitable than the steady state methods at high temperatures.

Blais & Mann[2] have suggested a promising steady state technique which could be conveniently used to measure thermal conductivity values for a wide temperature range. These authors exploited the familiar hot-wire type thermal diffusion columns and measured the thermal conductivity of helium and hydrogen in the temperature range 1200–2000° K. In the case of hydrogen, the thermal conductivity values have been reported by Gier & Schafer[3] over a small range of temperature 1173–1473°K and hence a comparison is possible between the above values and those obtained by Blais & Mann, whose values are systematically larger than Gier & Schafer values, the discrepancies being as big as 20% and 29% at the lowest and highest temperature respectively. An elaborate discussion of the results obtained by Blais & Mann in the light of theoretical investigations using exp–six and purely exponential potentials, is given by Saxena & Agarwal[4]. The authors concluded that the data were in error being systematically greater than the actual values. A further evidence to this trend is provided by the recent theories explaining thermal conduction in polyatomic gases. Two formulations, one by Mason & Manchic[5] and the other by Saxena, Saksena & Gambhir[6] are available. Both these theories take into account the internal—translational relaxation and can be regarded as fairly dependable. Blais & Mann values for hydrogen are significantly and systematically greater than the values predicted by these theories, the percentage deviations being 18·6, 25·0, 29·6 and 32·2 at temperatures 1200°, 1500°, 1800° and 2000°K respectively. A few suggestions like partial dissociation of hydrogen close to the hot wire, presence of convection and variation of accommodation coefficient have been put forward to account for this discrepancy but these again can not explain simultaneously the deviations for both hydrogen & helium.

Thus for the proper appreciation of the method and to establish this technique a planned set of experiments extending from the relatively low temperature region, where other reliable data are available, to the high temperatures as investigated by Blais & Mann, are necessary. An initial effort where the thermal conductivity values of air and helium are measured using this technique in the temperature range 300–415°K, is presented in this paper.

APPARATUS

The complete experimental set up consists of several independent units described below :

TABLE 1
CONSTANT OF THE COLUMNS

Length of the axial platinum wire (column 1)	91·56	cm.
Length of the axial platinum wire (column 2)	64·05	cm.
Radius of the wire	0·02463	cm.
Internal diameter of the column tube	0·8544	cm.
External diameter of the column tube	1·023	cm.
Resistance per unit length of the column wire at 0°C	0·005447	ohm/cm.
Constant A for the platinum wire	$38·25\times10^{7}$	$^{4}/°C$
Constant B for the platinum wire	-49×10	$^{8}/°C$
The additional resistance due to lead wires etc. for column 1	0·0166	ohm
The additional resistance due to lead wires etc. for column 2	0·045	ohm

Conductivity columns

They were similar in design to the familiar hot wire variety of thermal diffusion columns used for isotope separation. Two completely identical columns, except for length, were constructed from a special glass tube having a uniform bore (See Fig. 1, Table 1). Their uniformity and verticality was tested by watching the free fall of a machine-finished cylinder through them and confirmed by plumb line and vertically movable cathetometer. The glass columns were jacketed and a flow of water at a constant temperature was maintained through them to ensure a constant and uniform temperature of the cold wall. In order to evacuate or fill the columns with a gas a glass connection was fitted to them through the jackets. A closed limb mercury manometer was attached to the bottom end of the tube to measure gas pressure. The ends of the columns were closed by standard vacuum joints. A special design for these joints had to be evolved for 2 reasons: (*i*) the platinum wire of uniform cross section serving as a hot surface should stretch axially and remain taut when heated to different temperatures. This was achieved by attaching at the bottom end a proper weight which could move freely up and down. (*ii*)Since the wire is heated by passing an electrical current, this necessitates that the two ends of the wire should be brought out neatly. It should neither interfere withthe task of maintaining a high degree of vacuum in the columns nor add any appreciable resistance to the low resistance involved in the experiment. With these requirements as guiding features the joints were made as follows:

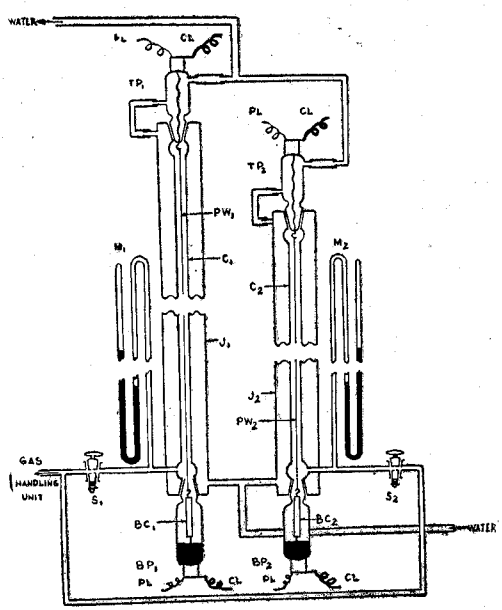

Fig. 1: Thermal conuedtivity columns.
C-Column tube; J-Jacket; M-Mercury mamometer; PW-Platinum wire; TP-Top piece; BP-Bottom piece; BC-Brass cylinder; S-Stop-cock; CL-Current lead; and PL-Potential lead.

Top joint—A tungsten hook was sealed to the narrow end of the standard joint to suspend the platinum wire. The other end of the hook was welded to a thick stranded copper wire the other end of which was soldered to a brass cap connected to the current and potential leads. This design maintained the hook at a constant temperature through the circulation of water which is an essential requirement for solving the heat flow equation for such a case.

Bottom joint—A tungsten rod was sealed to a glass tube joined to the broad end of the standard joint. The outside end of the rod was put in electrical communication with a brass cap carrying leads in a manner similar to the one at the top joint.

A small quantity of mercury was poured in the bottom piece which was then slided in at the bottom of the column. A hanging weight was attached to the platinum wire to keep it properly stretched. This weight carried at its bottom a thick copper wire which dipped into this pool of mercury and thus completed the electrical circuit. The relative dimensions of the brass weight, the connected rod and the mercury column were such that even when the platinum attained the highest temperature neither the copper wire hit the glass surface nor the brass weight touched the mercury surface.

Gas handling unit

The details of a gas handling unit designed to load the columns with a gas or evacuate them is shown in Fig. 2. All the stop-cocks were capable of maintaining high vacuum of the order of 10^{-6} cm. of mercury.

High vacuum unit

This was installed to evacuate the 'conductivity columns' as well as the 'gas handling unit'. It consisted of (*i*) two-stage rotary pump, and (*ii*) oil diffusion pump. The latter was fitted with a baffle valve and the entire set-up employed only metal lines, vacuum unions and needle valves etc. The connection from this unit was taken through a glass flask connected by a standard joint to the metal flange sitting right over the baffle valve. A parallel by-pass line to the diffusion pump was also provided to directly evacuate the systems

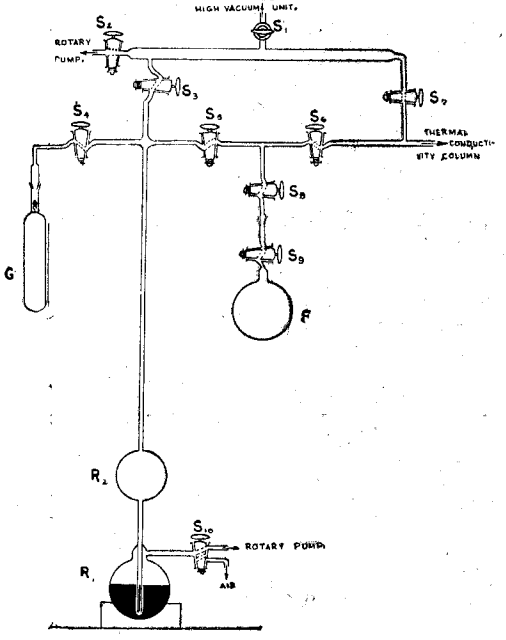

Fig. 2—Gas handling unit.
R-Reservoir; G-Gas cylinder; F-Flask; and S-Stop-cock.

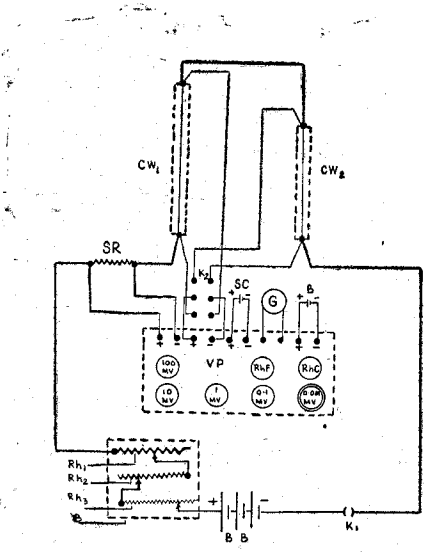

Fig. 3—Electrical circuit.
CW-Column wire; SR-Stannard resistance; Rh-Rheostat; OB-Oil bath; B-Battery; G-Galvanometer; SC-Standard cell; VP-Vernier potentiometer; and K-key.

when-ever necessary. To operate the mercury lift system of the gas handling unit a connection was directly brought from the rotary pump.

Electrical circuit

A potentiometric arrangement (Fig. 3) for measuring small resistances more accurately than a Wheatstone bridge was employed. A precision vernier potentiometer (accuracy–0·01 %; min reading–1 microvolt) was used in conjunction with a short period galvanometer (sensitivity–10^{-8} volt per mm.) and a standard resistance of 0·01 ohm (current carrying capacity–10 amp). The circuit was energised by four high capacity 6-volt batteries and the current controlled by three rheostats immersed in an oil bath at constant temperature. A potential divider arrangement was used whenever the voltages to be measured exceeded the maximum limit of the potentiometer.

Water bath

A thermostat (fitted with distributed heaters; efficient stirrers and a mercury ether regulator) in conjunction with an electromagnetic relay was used to provide water at constant temperature (fluctuation$\pm$ 0·2°C). This was circulated through the jackets by a motor in order to maintain the walls of the columns at a constant temperature.

THEORY

Let us assume that the ends of the axial hot wire are held at the same steady temperature as the walls of the column and this temperature be taken as an arbitrary zero. We further assume the wire to be at a uniform temperature throughout its length so that there is only radial heat flow from the wire surface and that the free convection effects which develop due to temperature non-uniformity are negligible. These assumptions do not strictly hold in an actual system but one can approximate his system to achieve them to a large extent. Under these ideal conditions the differential equation for the flow of heat is

$$\pi a^2 K \frac{d^2\theta}{dz^2} - 2\pi a h_c \theta - Q_r + \frac{I^2 \rho_o}{J}\left(1 + \alpha\theta\right) = 0 \qquad (1)$$

where

K—thermal conductivity of the material of the wire

a—radius of the wire

θ—excess of temperature of an element of the wire over the arbitrarily chosen zero

α—temperature coefficient of resistance of the wire

ρ_o—resistance per unit length of the wire at $\theta=0$

I—current in amperes flowing through the wire

J—mechanical equivalent of heat

h_c —loss of heat (by conduction through the gas) from the wire per unit area per unit temperature difference

Q_r —amount of heat radiated by a unit length of wire.

When the temperature of the wire is not sufficiently high, Q_r can be taken as proportional to θ and equal to $2\pi a h_r\ \theta$. Here h_r will represent the heat lost by radiation per unit area per unit temperature difference. When the column is highly evacuated $h_c = 0$ so that (1) becomes

$$\pi a^2 K \frac{d^2\theta}{dz^2} - Q_r + \frac{I'^2 \rho_0}{J}\left(1 + \alpha\theta\right) = 0 \qquad (2)$$

where I' denotes that value of the current which will maintain the element of the hot wire under consideration at the same temperature in vacuum as a current I flowing through it will in the presence of a gas.

(2) when subtracted from (1) yields

$$2\pi a h_c\ \theta = \frac{(I^2 - I'^2)\,\rho_0}{J}\ (1 + \alpha\theta) \qquad (3)$$

$$\equiv \omega_c$$

In writing (3) two assumptions are implicitly involved (*a*) the temperature distribution along the length of the wire remains practically unchanged with or without the gas and (*b*) the heat lost by radiation is independent of the nature of surroundings. The temperature gradient along the wire will, of course, change if the gas in the column is replaced by vacuum. If the column is sufficiently long so that the region where the temperature is markedly different from the temperature in the mid region is small, one can justify the first assumption. The second assumption holds under ordinary conditions of pressure where the gas in the column can be assumed transparent to heat radiations. For cylindrical symmetry and radial heat flow

$$2\pi a h_c\ \theta = -2\pi a \lambda\left(\frac{d\theta}{dr}\right)$$

$$= \frac{2\pi\lambda}{\log_e (b/a)}\ \theta \qquad (4)$$

where λ is thermal conductivity of the gas and b is the radius of the outer wall. Thus

$$\omega_c = \frac{2\pi\lambda}{\log_e (b/a)}\ \theta$$

or

$$\left(\frac{d\omega_c}{d\theta}\right)_{r=a} = \frac{2\pi\lambda}{\log_e (b/a)}$$

or

$$\lambda = \frac{\log_e (b/a)}{2\pi}\left(\frac{d\omega_c}{d\theta}\right)_{r=a} \qquad (5)$$

EXPERIMENTAL PROCEDURE

The determination of thermal conductivity λ involves an accurate knowledge of several constants of the apparatus as well as a set of measurements of the power conducted through the gas from the wire as a function of temperature. In the former category are included the

geometrical constants of the column and the electrical constants of the hot wire. The radius of the hot-wire and the diameter of the column tube were measured accurately at the National Physical Laboratory, New Delhi. A profile projector (least-count 2 microns) and a Universal Measuring Machine (least count 10 microns) were used to determine the diameter of wire and tube respectively. The length of the hot-wire was obtained by a cathetometer (least count 10 microns). The resistance of the hot wire at any temperature was determined by measuring the potential difference across it as well as against a standard resistance of known value put in series with it. As the same wire is used as a platinum resistance thermometer, it became imperative to determine the constants A and B occurring in the relation

$$R_t = R_0 (1 + At + Bt^2)$$

in order to obtain its temperature. Here R_t and R_0 are the resistances of the wire at $t°C$ and 0°C respectively. For this purpose resistance of a known length of wire was measured at three known temperatures viz. 30°, 60° and 90°C. These temperatures were kept constant and known to an accuracy of more than one-hundredth of a degree.

A set of experiments were then performed with the columns. These were first evacuated to a very high degree and a number of observations taken for the electrical power dissipated by the wire for different currents and hence different temperatures of the wire. If ω_r denoted power per unit length of the wire then it represents the energy radiated and conducted through the wire in the longitudinal direction. The column was then filled with the gas at the desired pressure and similar observations for power dissipated per unit length of the wire (ω) were taken. Obviously, ω includes ω_r and ω_c . Plots of ω_r and ω as a function of temperature of the wire were then used to determine ω_c at various temperatures. A graph was then drawn between w_c and the temperature of the wire and its slope determined at various temperatures. Knowing $\left(\frac{d\ \omega_c}{d\theta}\right)_{r=a}$, λ could be readily evaluated from (5) as other constants were known.

CORRECTIONS

In developing the theory it was assumed that the wire was perfectly axial and at a uniform temperature throughout its length. Further the convection as well as the temperature jump effect at the wire were supposed to be small so that they could be neglected. The "wall effect" had also to be given full consideration. The effect of all these factors on the gas thermal conductivity is investigated and discussed. It may, however, be pointed out that the boundary conditions of assuming the two ends of the hot wire at the same temperature as the cold wall are fairly valid because the design of the column took care of this requirement.

The temperature distribution along the length of the wire under such conditions was discussed by Gregory & Archer[8]. Their treatment can be applied here if it is assumed that the wire temperature is not very high which implies that the heat radiated is approximately proportional to θ, the temperature difference below the hot and the cold walls. Further $\beta l >> 1$, where β is given by the relation

$$\beta^2 = \frac{1}{\pi a^2 K}\left[2\pi a h - \frac{I^2 \rho_0 \alpha}{J}\right] \qquad (6)$$

with $h = h_c + h_r$

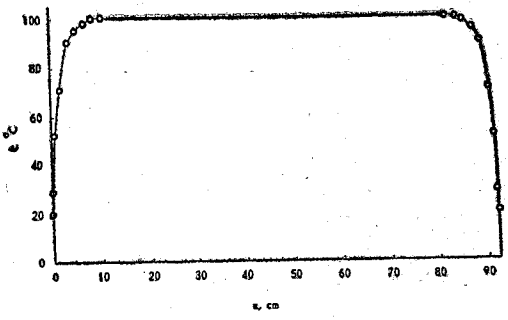

Fig. 4: Plot of the temperature of the axial hot wire, $t°C$, as a function of distance, x cm, measured from one of its ends.

The excess temperature θ at any distance x measured from one of the ends is then given by

$$\theta = \theta_{max} \left[1 - e^{-\beta x}\right] \qquad (7)$$

where θ_{max} is the maximum excess temperature which exists in the mid-region of the wire.

The temperature distribution for the wire was calculated from (7) assuming that θ_{max} is 80°C and the temperature of the cold wall is 20°C. The results are graphically represented in Fig. 4 which shows that the temperature of the wire is uniform for most of its length and falls sharply to the temperature of the cold wall at the two ends. A correction for the non-uniformity of the temperature at the ends was made by assuming a linear variation of temperature at the end portions. This correction was only 0·6 per cent for air and negligible for helium.

(7) is also valid for column 2 and, therefore, the temperature distribution for column 2 will also be similar to that for column 1. As a result if these two columns be connected in series and differential measurements performed for the power conducted through the gas, it will be still more rigorous to assume the constancy of the temperature of the wire whose length is now equal to the difference in the length of the two hot wires. Actual measurements of this type were performed with completely satisfactory results. This in fact is an experimental confirmation of the theoretical view point. Thus the assumption that the hot-wire remains at a uniform fixed temperature is valid to a satisfactory degree in the present investigation.

Calculation from (5) helps in eliminating the uncertainty arising out of the non-radial heat flow conditions. This is so because λ is related to $\left(\frac{d\omega_c}{d\theta}\right)_{r=a}$, which is ratio of the difference in power conducted for two nearly equal temperatures to the difference in the temperatures of the wire. The determination of $\left(\frac{d\omega_c}{d\theta}\right)_{r=a}$ makes it practically a differential method whereby the non-radial flow effects get eliminated to a large extent.

In order to know exactly the power conducted it is necessary to eliminate the power convected and the power radiated. The theoretical understanding of the energy consumed in convection is rather limited. Bosworth[9] has shown that it is a function of the product of the Grashof & Prandtl numbers. Ulsamer[10] while studying quantitatively the convection losses in a gas contained between two concentric cylinders found that the convection losses will be within 1 per cent provided the product of Grashof & Prandtl numbers does not exceed 2000. If these calculations are any guide the columns should be convection free under the conditions in which they are operated. Further Ulsamer's investigations predict convection losses to be pressure dependent. This provides an experimental check for the presence of convection in the columns. The experiments were consequently performed

for both the gases to determine the power consumed as a function of pressure in the range 2 to 60 cm. of mercury. These measurements revealed that the convection losses are absent above 9 cm. of mercury in as much as the power conducted is independent of pressure.

The 'temperature jump effect,' which results because of the failure of the gas molecules to get accommodated to the wire temperature, is also important in such measurements and has been discussed in detail by Present[11] and many other workers. Its exhibition in our experiments is again by the pressure dependence of the power required to maintain the hot wire at a particular temperature when the cold wall temperature is fixed. The experiments therefore, confirm the absence of this effect for pressures above 9 cm. of mercury.

The 'wall effect' is due to the low thermal conductivity of the material of the wall of the column which causes a temperature gradient across it. The thermal conductivity so determined will correspond to the composite cylinders of gas and glass. This physical picture helps to calculate the correct thermal conductivity of the gas under investigation. The correction in the case of air was 0·2 % at 150°C while for helium it rose to 1% at 115°C. The correction monotonically increased with temperature. The measurements reported in this paper were corrected for 'wall effect'.

It is very important that the wire be axial in the glass column. This will also make the heat flow non-radial. The calculations, as already pointed out accommodate slight variations from the desired radial heat flow and small deviations of the hot wire from the axis will not alter λ values very much. Our experience has however been that with proper design and careful installation it is possible to achieve a degree of centering which will lead to enough accurate results. Indeed it is possible under certain conditions to calibrate the apparatus by working on a known system.

The ordinary air used in these measurements was dried by passing through (*a*) tube packed with calcium chloride and (*b*) concentrated sulphuric acid. Air was used as an experimental gas for two reasons (*i*) a large amount of the test gas was needed to study the behaviour and working of the apparatus (*ii*) the values of λ for this sample of air in the overlapping temperature range were available in our laboratory (λ was obtained by exploiting an established technique viz., the thick wire variant of the hot wire method). Helium was another gas for which this procedure was applicable and it was possible to theoretically interpret and understand its behaviour. Therefore, spectroscopically pure helium supplied by British Oxygen Co., England was used for this study.

RESULTS

Observations were taken on column 1 by filling it with air at various pressures and measuring the power W consumed to heat the axial wire at a certain temperature. The column was then highly evacuated and again the power W' required to maintain it at a particular temperture t was determined. The plots of W and W' against t are shown in Fig. 5 along with the difference plot which gives the power conducted through the gas as a function of temperature. Similar measurements made for helium are shown in Fig. 6. A number of points at 5°C interval were read from the W_c curve for both the gases and

then, by using the Stirling's method of numerical differentiation, the values of the factor $\left(\frac{d\omega_c}{d\theta}\right)_{r=a}$ were determined in the relevant temperature range with a gap of 20°C. Thermal conductivity was calculated with the help of (5). The values of λ were then corrected for the 'end conduction' and the 'wall effect'. The corrected values are listed in Table 2.

Measurements for helium were taken on column 2 also; power conducted per unit length was found to be the same as in column 1. A similar result was obtained when the two columns were run simultaneously in series and a differential arrangement adopted to determine the power conducted per unit length. Thus the three sets of points shown concordantly in Fig. 6 are indentical. It is important to note from both these plots that W and W_c are usually not much different or the heat lost by radiation as well as by end conduction is invariably small. Further from these plots the absence of convection and temperature jump effects is evident.

DISCUSSION

The experimental results of thermal conductivity of air and helium as a function of temperature are recorded in Table 2. The measurements are estimated to be within 1% on the basis of the reproducibility, smoothness and uncertainties involved in the numerical treatment of the data. It is relevant to quote here that the hot wire exhibited the constancy in resistance within 0·02% (0·1 milliohm) and the current remained constant within 0·03%. Uncertainty in the determination of the quantity $\left(\frac{d\omega_c}{d\theta}\right)_{r=a}$ is more pronounced at lower temperatures. It is hard to precisely pin-point the accuracy of the measurements. These values and those available in literature agree within 3 %. Measurements on helium and air obtained by using the established hot-wire technique agree with our values within 1·5%. In the case of helium the value at 100°C exactly coincides with the value reported by Kannuluik & Carman[12]. The agreement with the other data is also by all means satisfactory and we feel that from our present experience these values must not involve an uncertainty more than about 2%.

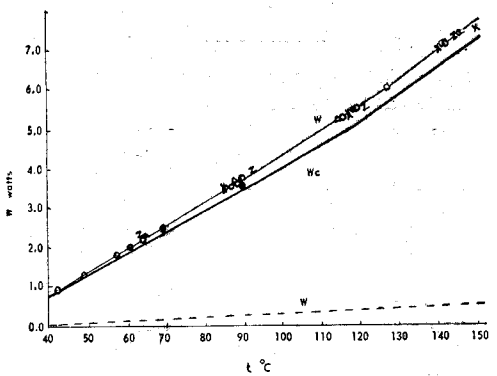

Fig. 5 : Plots of power dissipated as a function of temperature. The various experimental points refer to the values of pressure of air (cm of mercury) as : × —2. 3; Z —9. 3; θ —12. 6; ∞ —15. 7; ▽—31. 8; [] —45. 8; O —60. 4.

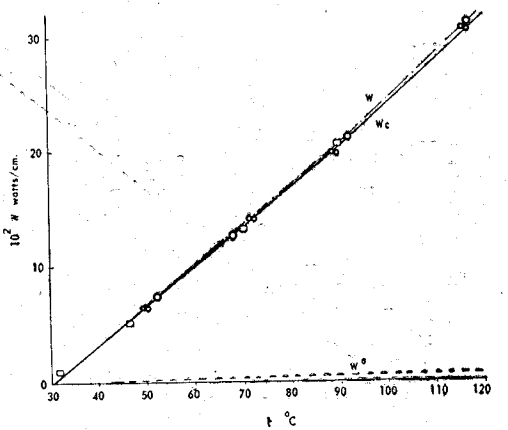

Fig. 6 : Plots of power dissipated per unit length of column wire as a function of temperature. The experimental points refer to the valnes of pressure of helium (cm of mercury) as: O —15. 5; [] —30. 7; ∞ —46.8.

In Fig. 7 our measurements on air as a function of temperature are shown along with the values by Gambhir *et al*,[13] Taylor & Johnston[14] and Gier & Schafer[3]. In all other measurements hot wire cell is used. The maximum departure of 5% between the various measurements is at the lowest temperature. This reduces systematically with rise in temperature till it is about 2% at 90°C. 100°C is the highest temperature at which a comparison is possible. At this temperature our value agrees with that of Gier & Schafer[3] within 1%. It is observed from Fig. 7 that on air there is a very good agreement between the two sets of measurements reported from this laboratory. The measurements of Taylor & Johnston[14] though quite smooth amongst themselves exhibit a sharp difference in the slope of λ *vs* T as compared to the one suggested by our work. The reason for this cannot be pin-pointed as we have no idea regarding the relative compositions of air used in these investigations.

In order to compare these results with the predictions of theory air must be regarded as a mixture of gases. We have treated air as a binary mixture of nitrogen (76·00%) and oxygen (24·00%). Hirschfelder[15] was the first to derive an expression for the thermal conductivity of mixtures involving ployatomic gases. His theory was tested and even simplified for practical use by Mason & Saxena[16]. Recently Hirschfelder's theory has been improved partially by Saxena, *et al*[17] by taking into account translational-internal energy exchange. In view of the uncertainty in the composition of air we only compare the experimental results with the values calculated according to the Hirschfelder's expression and the approximate formula of Mason & Saxena. However, it is important to note here that an earlier calculation[17] revealed that the formula of Saxena *et al* leads to a value of λ_{mix} [nitrogen (39·02%) and oxygen (60·98%)] at 319°C which is only 3·8% different from that obtained on the basis of Hirschfelder's expression. Computed values of λ_{mix} according to the two approaches are shown in Fig. 7. The continuous curve is for Hirschfelder's expression using the Lennard-Jones (12-6) potential and the usual two parameters as.:

$$\epsilon_{N_2}/k = 91{\cdot}5°\text{K},\ \sigma_{N_2} = 3{\cdot}658\text{A};\ \epsilon_{O_2}/k = 113{\cdot}0°\text{K},$$

$$\sigma_{O_2} = 3{\cdot}433\text{A};\ \text{and}\ \epsilon_{N_2-O_2}/k = 101{\cdot}7°\text{K},$$

$$\sigma_{N_2-O_2} = 3{\cdot}559\text{A}.$$

The dashed curve is on the theory of Mason & Saxena.

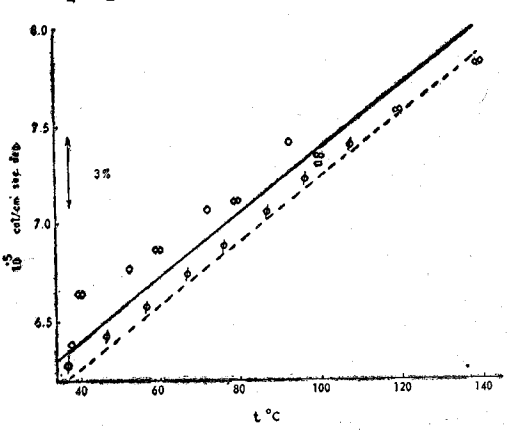

Fig. 7 : Comparison of the calculated and various experimental thermal conductivity values of air as a function of temperature. Experimental points : ∞ Present work; O Gambhir, Gandhi, & Saxena; ϕ Taylor and Johnston; [] Gier and Schafer.

TABLE 2

EXPERIMENTAL VALUES OF THERMAL CONDUCTIVITY λ IN CAL./CM SEC. DEG.

t°C	$10^5\lambda$ Air	$10^5\lambda$ Helium
40	6·64	36·58
60	6·87	38·27
80	7·11	39·96
100	7·35	41·65
115	—	43·09
120	7·58	
140	7·82	

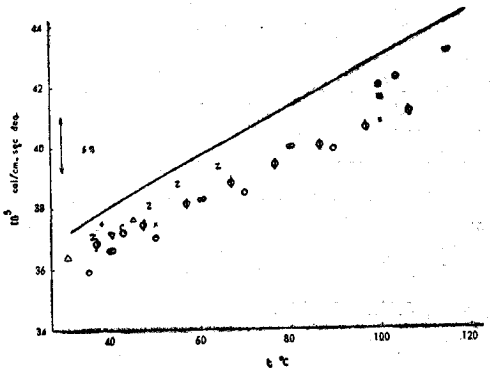

Fig. 8.— Comparison of the calculated and various experimental thermal conductivity values of helium as a function of temperature. Experimeutal points : ∞ present work; O Gambhir, Gandhi & Saxena; △ Srivastava & Barua; + Saxena, θ Cheung, Bromley & Wilke; □ Kannuluik & Carman; ϕ Johnston & Grilly ; Z Thomas & Golike; × Keyes; δ Lenoir Comings; ▽ Waelbraeck & Zuckerbrodt.

The calculated values are in good agreement with our experimental values only at temperatures above 60°C. At lower temperatures the disagreement is somewhat pronounced but not alarming. It is to be noted that until the theory is properly modified inherent presence of thermal diffusion is liable to limit the applicability of the column method to mixtures. Our experimental values of λ treating air as a pure gas agree with the direct measurements of Gambhir *et al*[13] using a hot wire cell. The reason for this lies in the small thermal diffusion effect.

Fig. 8 compares the thermal conductivity data[12, 18—25] on helium with our experimental values. The continuous curve shown in Fig. 8 is obtained on the basis of theory in conjunction with the modified Buckingham exp-six potential and the parameters given by Mason & Rice[26]. ($\epsilon/k = 9{\cdot}16$°K, $r_m = 3{\cdot}135$A, and $\alpha = 12{\cdot}4$). Although the experimental values agree with the existing data, they are systematically lower than the theoretically calculated values. This is beyond expectation and needs a thorough check up. In an effort to analyse this we shall report additional measurements on this gas in the high temperature region in due course. It is interesting that Mason & Rice[26] have found good agreement with theory in the case of viscosity and second virial coefficient.

ACKNOWLEDGEMENTS

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