there must be another characteristic temperature T_s for the electron gas in graphite, much higher than 520° K, such that k T_s will represent the energy of dissociation of the components of a pair of electrons with opposite spins.

11. The Electronic Specific Heat

With the above number of free electrons in graphite, namely one per atom, and the very low degeneracy temperature of the electron gas, we should naturally expect a large contribution from these electrons to the specific heat —— indeed at room temperature and at lower temperature, much larger than in most metals. Now the electronic contribution to the specific heat is most easily estimated either at very low temperatures, at which the contribution from the lattice becomes relatively insignificant, or at very high temperatures, at which the lattice contribution to C_v has reached its maximum value of 3 R. For graphite, because of its very high Debye temperature for the vibrations in the basal plane, and the limited range of the high temperature measurements that have been made, the latter method is not available. At the other end, measurements by Nernst (1911) and Magnus (1923) extend to about 29° K. Magnus has tried to fit the observed values with a formula of the type

$$C_v = \tfrac{2}{3} D \frac{\quad}{T} + \tfrac{1}{3} D \frac{\quad}{T} , \qquad \ldots \qquad (26)$$

where D —— denotes the Debye function for a characteristic temperature , and $_1$ corresponds to vibration in the basal plane of the crystal and $_2$ to vibrations along the normal to the plane. He finds that the best fit is obtained with

$$\begin{aligned} {}_1 &= 2280^\circ \text{ K} \\ {}_2 &= 760^\circ \text{ K} , \end{aligned} \qquad \ldots \qquad (27)$$

and that at the lowest temperatures the observed value of C_v is much higher than that predicted by (26) and (27). For example at 29° K the observed specific heat is 0·06 cal. deg.$^{-1}$ per gm atom, whereas the calculated value for the lattice is less than 0·01 in the same unit. Hence practically the whole of the observed specifc heat of graphite at this temperature should be attributed to the free electrons, and since the contribution ought to be proportional to T, we may roughly estimate the electronic specific heat of graphite at these low temperatures as

$$C_{ve} = 20 \times 10^{-4}\, T \text{ cal. deg}^{-1} \text{ per gm atom} \quad \ldots \quad (28)$$

With this may be compared the following values for other metals —— all of which are expressed in terms of the unit 10^{-4} cal. deg.$^{-1}$ per gm atom; Cu 1·88, Ag 1·6, Ni 17, Pd 31, Pt 16. At these low temperatures the electronic specific heat of graphite is thus more than ten times that of the noble metals Cu and Ag, and is of the same order of magnitude as the specific heats of some of the transition metals, which are known to be abnormal.

Judging from the above magnitudes it is clear that even at room temperature the electronic contribution to the specific heat will be no small part of the total specific heat observed. Owing to the neglect of this contribution by Magnus in calculating the Debye temperatures given in (27), these temperatures will require revision, and the actual Debye temperatures may be appreciably higher.

For a free-electron gas the specific heat per electron is given by the expression

$$c_{ve} = \frac{1}{2}\quad{}^{2}\, k\, \frac{T}{T_o}, \quad \ldots \quad (29)$$

and this expression will hold even when the surfaces of constant energy in the k-space do not conform to those of free electrons, but are given by equation (10), namely

$$E = \frac{h^2}{2m}\left({}_{1}\quad{}^{2} + {}_{2}\quad{}^{2} + {}_{3}\quad{}^{2} \right),$$

provided we use for T_0 the appropriate degeneracy temperature. In graphite, however, from a consideration of the Brillouin zones, we found that the surfaces of constant energy, instead of being complete ellipsoids, approximate more closely to right cylinders, whose axes are along the 'c' axis of the crystal, and whose heights are limited to the distance between the two 000,2 planes of energy discontinuity. For such cylindrical surfaces, with their heights fixed, the expression for the specific heat per electron will be

$$c_{ve} = \frac{1}{3} \quad \frac{T}{T_0}, \qquad \ldots \qquad (30)$$

which differs from (29) by a factor 2/3. Using this expression, and taking the number of free electrons per atom as one, we obtain for the electronic specific heat of graphite per gm atom

$$C_{ve} = 120 \times 10^{-4}\ T \text{ cal. deg}^{-1}.$$

The experimental value, as we roughly estimated from the available date, is only a sixth of this.

The reason for this discrepency is not clear. It can be explained by takin = 1/6, which, in view of (22), would correspond to

instead of 1 see (25) $\quad 1 \quad 2 \quad 6$. But the experimental data on which our estimate of electronic specific heat was made do not extend to temperatures sufficiently low to ensure the estimate's being correct. Accurate measurements of the specific heat of graphite at liquid helium temperatures, particularly of large-sized crystals, are desirable, before an explanation of the discrepency may be attempted.

12. The Principal Electrical Conductivities of Graphite

The conclusions reached above from the magnetic data regarding the mobile electrons in graphite and the restriction of their free migrations to the basal plane, indicate that the electrical conductivity of graphite in the basal plane should be very large, and of the same order as in metals, whereas along the perpendicular direction the conductivity should be relatively very feeble. This, as we shall see presently, is verified experimentally.

The conductivity of single crystals in the basal plane has been measured by several investigators. Though the values obtained by them differ widely —— which is to be expected in view of the difficulty of obtaining well-developed single crystals of graphite free from impurities, and also as we shall find in the next section, for other reasons connected with the large anisotropy of electrical conductivity of the crystal —— they all agree in giving a high value for the conductivity in the basal plane. The best measurements are probably those of Roberts (1913), who, using very thin well-developed crystals of Ceylon graphite, obtained for the specific resistance in the basal plane, at room temperature, as low a value as 50 micro-ohm cm. This value agrees well with 42 to 64 micro-ohm cm obtained by Ryschkewitsch (1923) with an artificially prepared single crystal, about 0·004 cm thick. Very much larger values, of the order of 1000 micro ohm cm, and even more, have been reported by other observers, and also by Roberts for other crystals of graphite. However, for reasons to be discussed in the next section, these high values are much less reliable, and we may therefore adopt

$$50 \text{ micro-ohm cm} \quad \ldots \quad (31)$$

as the most probable value of the specific resistance in the basal plane.

For the specific resistance along the hexagonal axis, which we shall denote , there is only one measurement reported, namely that by Washburn (1915). For the specimens measured by him the resistance was 8000 to 9000 micro-ohm cm. This is more than 100 times the resistance in the basal plane, and indicates a high anisotropy of conductivity.

13. New Measurements: The Influence of the Large Anisotropy on the Conductivity Measurements in the Basal Plane

Recently we were able to obtain some exceptionally well-developed single crystals of Ceylon graphite, through the kindness of Dr D. N. Wadia, Government Mineralogist at Ceylon, and we have made resistance measurements with these crystals, both along the hexagonal axis and along directions in the basal plane.

Fig. 3

The apparatus used for measuring the resistance along the hexagonal axis is shown in Fig. 3. The graphite flake is held between the flat parallel ends of the stout brass rods R and R'. The lower rod, R, is fixed, while the upper one, R', can be moved vertically by screw motion. The crystal is cleaned by treatment with dilute hydrochloric acid, washed, and dried in a dessicator, before use. It is placed in position on the flat end of R and the upper rod R' is screwed down tightly on it. The resistance between the two terminals S and S' , which is practically the resistance of the crystal, is measured by the usual potential fall method, and the specific resistance along the direction concerned, namely along the hexagonal axis, calculated therefrom.

Using the same crystal, and cleaving it successively into thinner and thinner flakes, the specific resistance was determined in the above manner for flakes of different thicknesses. The results obtained with some typical crystals are given in Table II

Table II

Crystal number	thickness in cm	in ohm cm
1	·048	0·9
	·027	1·0
	·010	1·8
2	·026	0·9
	·016	1·6
	·010	2.1
3	·021	1·3
	·011	1·6

As the crystal flake is cleaved very thin it becomes also very imperfcet as a crystal, showing many tiny holes. For this reason the measurements with the very thin crystals are likely to give too high a value for the specific resistance, and the apparent increase of specific resistance with diminishing thcik-ness, indicated by the values given in Table II, is presumably due to this cause.

We may therefore take for our crystals

1 to 2 ohm cm. .... (32)

The apparatus used for the measurement of the specific resistance in the basal plane is given in section in Fig. 4.

Fig. 4.

E is an ebonite block, on which are mounted two thick rectangular brass blocks B and B' separated by the ebonite piece e, the upper surfaces of B, e and B' being in the same plane. A is a stout brass block fitted to B and co-terminal with it, and can be pressed tightly into good contact with B by means of the brass binding screw S. The brass block A' is similarly fitted to B', and can be tightly pressed into contact with the latter by the binding screw S'.   in the figure denotes the flake of graphite, cut to a rectangular shape. The blocks A and A' are lifted up, the graphite rectangle, cleaned as before, is placed in position, its length lying along the direction of B B' and extending some distance over both B and B'. A and A' are replaced in the positions indicated in the figure and screwed down tightly, and the resistance between the terminals S and S' measured as before by the potential fall method. If   is the effective length of the crystal flake intercepted between the blocks A B on one side and A' B' on the other, and   is the breadth of the flake and t its thickness, its specific resistance will evidently be given by the expression

$$P = \frac{bt}{\quad} \qquad \ldots \qquad (33)$$

As in the measurement of   , in the present measurements also, the crystal was cleaved successively into thinner and thinner flakes and the measurements of   were made for different thicknesses. The results are given in Table III. The crystals that bear the same number in Tables II and III originally formed parts of the same piece.

It will be seen from the values of   given in the third column of the Table that for all the crystal the smaller the thickness the smaller is the value of the observed specific resistance. This result is rather unexpected, since the thinner flakes obtained by cleavage owing to their imperfect ness, may be expected to yield higher values for the specific resistance . An obvious explanation which suggests itself for this unexpected diminution of the observed specific resistance with the thickness of the crystal is as follows. Owing to the very much larger resistance of the crystal flake for current along the normal to its plane than for current in the plane, the electric current

Table III

Crystal number	Thickness in cm	in micro-ohm cm without mica sheet	with mica sheet interposed	R
1	·043	260	520	2·0
	·026	220	360	1·6
	·008	160	210	1·3
	·005	140	170	1·2
2	·040	490	960	2·0
	·022	250	370	1·5
	·009	210	270	1·3
	·004	130	150	1·2
3	·040	420	720	1·7
	·022	340	460	1·4
	·010	180	230	1·3
4	·027	280	540	1·9
	·012	160	210	1·3
	·006	150	180	1·2
Other stray	·002	100		
thin crystals	·002	110		
from the	·001	60		
same collection	·001	50		

between the two electrodes, which make contact on the surfaces of the crystal flake near the two ends, will be confined to small thicknesses near the upper and the lower surfaces of the crystal flake, the penetration of the current inside the crystal being small. In other words the conduction will simulate a surface conduction, the effective thickness of the crystals flake taking part in the conduction being much smaller than the actual thickness of the flake. The specific resistance calculated from the observational data on the assumption that the whole of the thickness of the flake is effective, as the values of given in Table III have been, will naturally be too high, indeed the higher the larger the thickness of the flake.

The correctness of the above explanation is verified by the following observation. The measurement of resistance for any given crystal flake in the manner described above was repeated after inserting a thin sheet of mica of suitable size between the flake and the surface B e B' so as to insulate the flake from direct contact with the lower brass blocks B and B', but without disturbing the contacts with the upper blocks A and A'. If the crystal is sufficiently thick, we should expect under these conditions the effective thickness to be just one half of what it was in the previous measurement made without the mica sheet. In other words the specific resistance calculated on the assumption that the whole of the thickness of the flake is effective, should now be twice the previous value. The apparent specific resistances so calculated from the resistance measurements made (a) without the mica sheet and (b) with the mica sheet inserted, are given in Table III in columns 3 and 4 respectively. The last column in the Table gives the ratio R of the resistances obtained with and without the mica sheet inserted. It will be seen that for the thick crystals R is near about 2 as expected, and it remains appreciably greater than 1 even for the thinnest crystals, t = ·004 cm.

We should mention here that the electrical connexions between the brass electrodes and the surfaces of the crystal are made by pressing them tightly into contact, and the resistance of the contact is found to vary to some extent with the applied pressure. For this reason, and also on account of the fact that the thinner the flake obtained by cleaving the less perfect it is, the values given in the Table are not precise enough to be used for finding by extrapolation the limit which the observed value of tends to reach when the thickness of the crystal is diminished indefinitely. One can, however, see in a general way that as the thickness is reduced R tends to reach the value unity, as should be expected, and that tends approximately to the value 40 micro-ohm cm. This is in satisfactory agreement with the values obtained by Roberts, Ryschewitsch and others for very thin crystals.

With the values for and obtained here, namely

$$\begin{aligned} &1 \text{ to } 2 \text{ ohm cm} \\ &40 \text{ micro-ohm cm} \end{aligned} \quad , \qquad \ldots. \qquad (34)$$

the ratio of the two principal resistivities is of the order of 10^4. This is a very high value indeed for the anisotropy of conduction of the crystal, but not unexpected in view of the large difference between the effective masses of the conduction electrons along the two directions.

14. The Relaxation Time and the Mean Free Path of the Electrons

Defining the relaxation time , the mean free path , and the velocity , of the electrons near the Fermi surface, by the expressions

$$= \frac{m}{n\, e^2}$$

$$= 2 \quad u \qquad \ldots \qquad (35)$$

$$\tfrac{1}{2}\, m\, u^2 = k\, T_o$$

(see Mott and Jones, 1936, p. 268), where T_o is the degeneracy temperature, equal to 520^o K, we obtain

$$= 8 \times 10^{-16} \text{ sec.}$$

and $= 2 = \text{A. U.}$

The mean free path is thus of the same order as the distance between adjacent carbon atoms in the basal plane of the crystal, i.e. of nearly the same length as the side of the hexagonal rings. The usual description of the mobile electrons in aromatic compounds, and therefore also in graphite, as being capable of migration <u>from atom to atom</u> over the whole of the condensed ring system, has thus a deeper significane than is intended.

The mean time between successive collisions which should be equal to 2 , is of the order of $1 \cdot 6 \times 10^{-15}$ sec.

15. Temperature Variation of the Resistance in the Basal Plane

In a previous section we found that the Debye temperature of graphite for oscillations in the basal plane is much greater than for oscillations along the normal to the plane, the values for the two directions being 2280° and 760° K respectively. These values suggest that for conduction electrons moving in the basal plane, firstly the scattering at all ordinary temperatures should be due mainly to the thermal oscillations perpendicular to the basal plane, and secondly the temperature variation of the resistance in the basal plane should be much more rapid than in proportion to the absolute temperature.

Measurements have been made of the temperature variation of the specific resistance in the basal plane from room temperature down to about 1° K by de Haas and van Alphen (1931), and by Meissner, Franz and Westerhoff (1932), and at high temperatures, up to 452° K, by Roberts (1914). Though at very low temperatures the *reduced* resistance varies rapidly enough, at the higher temperatures the observed variation is far too low. This result, however, is not surprising, since the temperature variation of resistance even of crystals which are apparently well developed, are found to differ widely from crystal to crystal, and even a *negative* temperature coefficient is not uncommon.

16. The Influence of the Magnetic Field

We shall now consider briefly some of the interesting results obtained by Roberts regarding the influence of a magnetic field on the resistance. Considering first the case when the electric current is in the basal plane, it is found that (a) if the magnetic also is in the basal plane, the increase in resistance is small, and is practically the same whether the field is along the direction of the current or perpendicular to it, (b) if the magnetic field is perpendicular to the basal plane the increase in resistance is very large, and is nearly 50 times that obtained in (a). This result is indeed to be expected from the freedom of the mobile electrons to migrate over the basal plane, and the restriction of the freedom to this plane only. That the ratio of the change in resistance produced by a magnetic field perpendicular to the basal plane (case (b)   to that produced by the same field when it lies in the basal plane   case (a), namely 50, is nearly equal to the ratio of the diamagnetic susceptibilities for the two fields, may be fortuitous, but that the direction of the field which induces a large susceptibility in the crystal is also the direction which produces a very large change in its resistance is indeed to be expected.

The detailed relation between the two ratios, however, will be difficult to work out, since the observed change in the resistance produced even in weak magnetic fields deviates considerably from the simple H^2 law predicted by the theory. For example at room temperature, 18^{o} C, Roberts finds that for most of the graphite crystals studied by him the change in resistance is given by a formula of the type

$$= A\, H^{1.745}, \qquad \ldots \qquad (36)$$

where A varies slightly from crystal to crystal, and has approximately the value 0·0004 when the field is in the basal plane, and the value 0·020 when the field is perpendicular to the plane, H in both cases being expressed in kilo gauss. The only other measurements available on the change of resistance of single crystal of graphite produced by magnetic fields are those of Heaps (1918), with the electric current in the basal plane and magnetic field perpendicular to the plane. His results, obtained with fields up to 11·3 kilo gauss are found to fit well with the formula

$$= \cdot 0212\, H^{1.739},$$

which agrees satisfactorily with that of Roberts. Thus the large deviation from the H^2 law seems to be genuine.

Roberts has made measurements at other temperatures also, with the electric current in the basal plane and the magnetic field perpendicular to the plane. The change in resistance produced by the magnetic field is found to increase rapidly with the lowering of the temperature. For example with a field of 38·8 kilo gauss, the increase in resistance at 179° C is about 3½ times, at 18° C 12½ times, whereas at the temperature of liquid air it is 93 times, and at the temperature of liquid hydrogen 129 times. This rapid increase with the fall of temperature of the change in resistance produced by the magnetic field accords in a general way with the metallic character of graphite in the basal plane, with which we are concerned here.

We shall close this section with a brief reference to the results obtained by Washburn (1915) with the electric current along the hexagonal axis of the crystal. (c) With the magnetic field in the basal plane, the change in resistance is small, and is nearly the same as when the electric current also lies in the basal plane case (a) . (d) With the magnetic field also along the hexagonal axis, the change in resistance is nearly 8 times that obtained in (c). Thus with a field of 30 kilo gauss, the increase in resistance is 14% when the field is in the basal plane, and 112% when it is along the hexagonal axis.

17. The Hall Coefficient of Graphite

The Hall coefficient of graphite measured with the electric current in the basal plane, and the magnetic field perpendicular to it, is about -0·6 e.m.u in weak fields (Heaps, 1918). This is nearly a thousand times greater than the coefficients of the noble metals, and is about a tenth of that of bismuth, which exhibits the phenomenon most conspicuously among all the substances investigated till now.

According to Sommerfeld, (Sommerfeld and Bethe, 1933) the Hall coefficient of a degenerate free-electron gas is given by the relation

$$A = c/en, \qquad \ldots \qquad (37)$$

where n is the number of electrons per c.c. A is expressed in e.m.u. and e, as usual in e.s.u. Even when the surfaces of constant energy do not conform to those of a free-electron gas, but form a family of similar ellipsoids

$$E = \frac{h^2}{2m}(\ _1{}^{2} + \ _2{}^{2} + \ _3{}^{2}),$$

the simple Sommerfeld formula (37) is applicable (See Mott and Jones, 1936, p. 283). A high value of A can then be explained only in terms of a small density of free electrons. Denoting as before the number of free electrons per atom by , the observed Hall coefficient for graphite will then correspond to

$$= 9 \times 10^{-4} ;$$

i.e. only one electron in about 1100 atoms should be regarded as free. If this conclusion is correct, we should regard the 4-electron Brillouin zone as nearly filled up, and about 1 electron in 1100 atoms as overlapping into the next zone. Using this value of , and the relations (23) and (25), we then obtain

$$\ _1 \ _2 = 1100$$

$$\ _3 = 1/6200.$$

The above value of $\ _1 \ _2$ is not unacceptable, since it would require an energy discontinuity at the 2 2 0,0 faces if reasonably small magnitude. But then we should have expected $\ _3$ to be of the order of unity, whereas the value obtained for it is only 1/6200. Thus the explanation of the observed large Hall coefficient of graphite presents a difficulty. It should, however, be mentioned here that expression (37) is applicable only for temperatures large in comparison with the Debye temperature, whereas in graphite we are dealing with very much smaller temperatures. But it is doubtful whether the large discrepency noticed above can be attributed to this cause.

17. The Optical Properties of Graphite

The electronic structure of graphite outlined in the previous sections, leads to easily predictable optical properties for the crystal, especially when the electric vector of the light-wave lies in the basal plane. For example for electromagnetic waves of sufficiently long wave-length for which the induced electric current may be regarded as being practically in phase with the incident electric vector, the normal reflectivity R of the polished cleavage surface of the crystal will be given by the usual Hagen-Rubens relation

$$R = 1 - 2\ c\ /\ \quad , \qquad \ldots \qquad (38)$$

where is the wave-length of the radiation, and c is the velocity of light in vacuum. Now = 10 will be a sufficiently long wave-length for the applicability of this expression, since the corresponding value of the period, namely / c = $3{\cdot}3 \times 10^{-14}$ sec., is nearly 20 times the mean interval between two collisions. For this wave-length, taking as 40 micro-ohm cm, or $4{\cdot}5 \times 10^{-17}$ e.s.u, we obtain for the reflectivity

$$R = 0.93, \text{ or } 93\% \qquad \ldots \qquad (39)$$

Coblentz (1911) has measured the reflectivity of graphite in the visible region and in the infra-red up to 10 . For the last wave-length, namely 10 , he obtains a reflectivity of about 60%. He uses for reflection a large polished surface, 4 cm x 5 cm, of a block of the mineral which he describes as very compact but as showing the rays and fibrous structure of the original plant or tree from which the mineral was formed. From the above description it is evident that the mineral used by him was not a single crystal, but an aggregate of micro-crystals. Assuming that the micro-crystals at the polished reflecting surface of Coblentz were randomly orientated, one can roughly estimate from Coblentz's observed value of the reflectivity, namely 60%, what the reflectivity of the polished basal plane of a single crystal should be; it should be 3/2 x 60% or 90%. This estimate agrees well with the value (39) calculated from the Hagen-Rubens relation.

Again when one goes sufficiently far into the ultra-violet, one should reach a critical wave-length beyond which the absorption of light by the free electrons in graphite and their reflectivity should become very feeble, as in the alkali metals investigated in detail by Wood (1933). This critical wave-length is given approximately by the expression (Zener, 1933)

$$\frac{n e^2 \;^2}{m c^2} = E, \qquad \ldots. \qquad (37)$$

where E is the contribution to the refractive index from the atomic cores, i.e. from the part of the crystal other than the mobile electrons. With equal to one electron per carbon atom, the above expression reduces to

= E x 1000 A.U.

It is difficult to estimate E accurately. Taking it to be roughly 1·5, the critical wave-length should be about 1500 A.U.

Here again the available experimental data refer to an aggregate of presumably oriented at random, micro-crystals, and extend to 1800 A.U. only. The data are those of Hulbert (1915), who has measured the reflectivity of a thin film of carbon obtained by the sputtering in vacumm from a piece of graphite. He finds that the reflectivity of the film, measured for an angle of incidence of 18°, remains practically constant at 19% from 3800 A.U. down to about 2100 A.U., and then begins to drop, reaching the value of 10% at 1800 A.U. The progress of the curve fits well with the predicted existence of the critical wave-length at about 1500 A.U. at which the reflection and absorption coefficients should become very small.

Detailed measurements on the reflectivities of fresh cleavage surfaces of single crystals of graphite, and on the absorption coefficients of extremely thin flakes, over the whole of the spectral region from about 0·1   to 10   are very desirable. We have started some of the measurements.

Summary

1. Graphite crystal has a large free-electron diamagnetism which is directed almost wholly along its hexagonal axis. Over the whole range of temperature over which measurements have been made, namely, from 80°K to 1270°K, this free-electron diamagnetism of graphite per carbon atom is found to be equal to the Landau diamagnetism per electron of a free-electron gas obeying Fermi-Dirac statistics and having a degeneracy temperature of 520° K.

2. From this experimental result it is concluded (a) that the number of free electrons in graphite is just one per carbon atom; (b) that the effective mass of these electrons for motion in the basal plane, is just their actual mass, showing that the movements in this plane are quite unrestricted by the lattice field; (c) that on the other hand their effective mass for motion along the normal to the basal plane is enormous, about 190^3 times the actual mass, which indicates that the free electrons belonging to any given basal layer of carbon atoms are tightly bound to the layer, though as was mentioned just now, they can migrate quite freely over the whole of the layer; (d) that this tight binding accounts for the observed low degeneracy temperature of the electron gas in the crystal.

3. These conclusions are in accord with the modern quantum mechanical views of the electronic structure of graphite, and also with its Brillouin zones. There is one zone which can just accommodate 3 electrons per atom, and the energy discontinuities at all of its boundary surfaces are large. There is a bigger

zone which can just accommodate all the 4 valency electrons, but the energy discontinuities at those of its faces that are perpendicular to the basal plane, are very small.

4. The specific resistance of the crystal in the basal plane is about 40 x 10^{-6} ohm cm, whereas along the perpendicular direction it is 1 or 2 ohm cm, i.e. more than 10^4 times larger. This large anisotropy of electrical conductivity is a result of the large disparity of the effective electronic masses along the two directions. The effects of temperature and magnetic field on the principal resistances are discussed.

5. On the basis of the electronic structure given above the reflectivity of the basal plane for long infra-red waves is calculated. It is also shown that in the far ultra-violet there should be a critical wave-length o 1500 A.U., beyond which the reflectivity of the free electrons in graphite and also their light-absorption, should become very small, as in the alkali metals. These results are discussed in relation to the available experimental data.

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