only 21,000 times the push. Halve the diameter again, and the pull would be only 10,500 times the push. Reduce the diameter to 1/42,000 of its original value, that is, to about 20 miles, and the pull would equal the push.

In other words, a sun as hot as ours and 20 miles in diameter would repel bodies less than 1 cm. in diameter, and could only hold in those which were larger.

But it is, of course, absurd to think of such a small sun as this having so high a temperature as 6000°. Let us then reduce the temperature to 1/20, say 300° absolute, or the temperature of the earth. Then the radiation would be reduced to the fourth power of 1/20, or 1/160,000, and the diameter would have to be reduced to 1/160,000 of 20 miles, or about 20 cm., say 8 inches, when again radiation would balance gravitation.

It is not very difficult to show that if we had two equal spheres each of the density and temperature of the earth they would neither attract nor repel each other—their radiation pressure would balance the gravitative pull—when their diameters were about 6·8 cm., when, in fact, they were about the size of cricket balls.

It must be remembered that this is only true for spheres out in space receiving no appreciable radiation from the surrounding region.

It would appear that we have arrived at a result of some importance in considering the aggregation of small meteorites. Imagine a thinly scattered stream of small meteorites at the distance of the earth from the sun. Then, even if they be as large as cricket balls, they may have no tendency to move together. If they are smaller they may even tend to move apart and scatter.

In conclusion, let me mention one more effect of this radiation pressure. You will remember that radiation presses back against any surface from which it issues. If, then, a sphere at rest in space is radiating equally on all sides it is pressed equally on all sides, and the net result is a balance between the pressures. But suppose that it is moving. It is following up the energy which it pours forth in front, crowding it into a smaller space than if it were at rest, making it more dense. Hence the pressure is slightly greater, and it can be shown that it is greater the greater the velocity and the higher the temperature. On the other hand, it is drawing away from the energy which it pours out behind, thinning it out, as it were, and the pressure at the back is slightly less than if the sphere were at rest.

The net result is a force opposing the motion, a force like viscous friction, always tending to reduce the speed.

Thus calculation shows that there is a retarding force on the earth as it moves along its orbit amounting in all to about 20 kgm., say 50 lb. Not very serious, for in billions of years it will only reduce the velocity by 1 in a million, and it will only have serious effects if the life of the earth is prolonged at its present temperature to hundreds of billions of years.

But here again size is everything. Reduce the diameter of the moving body, and the retarding effect increases in proportion to the reduction. If the earth were reduced to the size of a marble, the effect would be appreciable in a hundred thousand years. If it were reduced to a speck of dust a thousandth of a centimetre in diameter, the effect would be appreciable in a hundred years.

Note what the effect would be. Imagine a dust particle shot out from the earth and left behind to circulate on its own account round the sun. It would be heated by the sun and would be radiating out on all sides. As it journeyed forward there would be a resisting force tending to stop it. But instead of acting in this way the resistance would enable the sun to pull the particle inwards, and the fall inwards would actually increase the velocity. This increase in the velocity would increase the resistance, and at the same time the approach to the sun would raise its temperature, increase the radiation, and so increase the resistance still further. The particle would therefore move in a more and more rapid spiral orbit, and ultimately it would fall into the sun. Small marble-sized meteorites would fall in from the distance of the earth probably in a few million years. Small particles of dust would be swept in in a few thousand years.

Thus the sun is ever at work keeping the space round him free from dust. If the particles are very minute he drives them forth into outer space. If they are larger he draws them in. It is just possible that we have evidence of this drawing in in the zodiacal light, that vast dust-like ring which stretches from the sun outwards far beyond the orbit of the earth, and is at once the largest and the most mysterious member of the solar system.

PHYSICS AT THE BRITISH ASSOCIATION.

THE number of communications made to Section A this year was again so large as to necessitate duplicate sittings on several days, an arrangement which appears to bring home to members in a forcible manner the impossibility of being in two places at once. For some undiscovered reason the subcommittee which arranges the order of the papers is generally held responsible for this limitation, and gets a considerable amount of abuse. The disadvantage of the division was particularly evident at the discussion on the units used in meteorological measurements opened by Dr. W. N. Shaw. A subcommittee of the council of the association appointed to consider the question, recommends the use of the absolute zero of temperature with either the centigrade or Fahrenheit degree as the unit, but preferably the former, and the introduction of a new "degree of pressure" which is equal to 2000 C.G.S. units, and involves a graduation of the barometer in nearly 1/16th of an inch (0·06 in.), and the use of a vernier down to 1/160 inch. The meeting before which the matter was discussed was disposed to dwell mainly on the cost of effecting the changes proposed, and owing to the scant attendance of physicists, rather lost sight of the advantages of adopting what is practically equivalent to the C.G.S. system.

Attwood's machine as an aid to the teaching of dynamics was much discredited during the discussion of a paper by Mr. Eggar on an apparatus for verifying Newton's second law. Mr. Eggar finds that the movement of a truck down an inclined plane the angle of tilt of which can be altered, is much more convenient and effective than the fall of a weight.

The coefficient of expansion of hydrogen at various pressures down to low temperatures was the subject of a communication from Prof. Witkowski. He finds that the coefficient increases with decrease of temperature, and decreases with increase of pressure, a result which must have an important bearing on our standards of temperature.

Dr. Glazebrook's account of the recent work of the National Physical Laboratory made one hope that the efforts to cope with the demands made on it by our manufacturers for tests of materials and for scientific help of other kinds, will not be hampered by the insufficiency of the financial support the institution receives from the Government. In order to establish a scale of temperature, Dr. Harker has compared up to 1000° C. the constant volume nitrogen thermometer with a thermojunction previously standardised at the Reichsanstalt, and a platinum thermometer. Mr. Smith has constructed and compared a number of mercury standards of resistance, Dr. Stanton has been engaged in determining the amount and distribution of the pressure on structures due to wind, Dr. Carpenter has investigated the solidification of iron-carbon alloys, and a number of other important investigations have been carried out for manufacturers and for the Government.

Problems connected with radiation played a prominent part in the proceedings of the section. Prof. Poynting's interesting afternoon address, which appears in another part of the present issue, dealt with the applications of the laws of radiation to the solar system. Taking Stefan's law as a basis, the temperature of the sun works out as 6250° C., and that of a black body at the distance of the earth from the sun at 27° C., which agrees well with the average temperature of the earth. A description of an apparatus by means of which he had measured the tangential stress on a surface due to the oblique impact of light, was also given to the ordinary sectional meeting by Prof. Poynting. If E is the stream of momentum per sq. cm. per second due to the light incident at an angle θ, and μ is the fraction of the incident light reflected, the tangential pressure on the surface is $(1-\mu)/2.E \sin 2\theta$, and although in general it is smaller than the normal pressure, the difficulties of its measurement are less owing to the reduction of the disturbing effects due to the surrounding gas.

Prof. Rubens gave an account of his recent work on the optical properties of metals for long waves obtained by his method of "Reststrahlen." The radiation had about 100 times the wave-length of the sodium line, and it was found that in this region the reflecting powers of metals are independent of the wave-length. In these circumstances Maxwell's theory gives for a good conductor $1-R=36\cdot5/\sqrt{\kappa.\lambda}$, where R is the amount reflected from the surface when unit radiation is incident on it, κ is the conductivity of the metal, and λ is the wave-length. The observations on pure metals and alloys agree with the theory, and show that the electrical conductivity of a metal may now be determined by a measurement of its reflecting power.

Prof. Wien, in discussing the question as to whether the ether moves with the earth or not, pointed out that according to the recent work of Lorentz, in which the electron is assumed to be ellipsoidal in form, attempts to settle the question based on interference or the rotation of the plane of polarisation would be without result. He thought himself the most promising method was a duplication of Foucault's revolving mirror method, the reflection taking place at the two ends from mirrors revolving with the same velocity. If the ether has a component movement along the line joining the mirrors the deflections observed at the two ends should differ.

Prof. Kayser directed attention to the defects of Rowland's scale of wave-lengths in view of the accuracy now attainable by interference methods of measuring wave-lengths. He considered that concave grating spectra were only suitable for interpolation purposes, and that the preparation of a standard scale should be taken in hand at once. Mr. Newall suggested that dark lines were more suitable than bright ones for this purpose.

Dr. Lummer, in describing his parallel plate spectroscope for the resolution of close spectral lines, pointed out the importance of high resolution if the effects of the mode of excitation or of an electrostatic field on the lines of a gas are to be investigated. Dr. Lummer showed his instrument in use in the Cavendish Laboratory, and was able to detect a difference between the lines of mercury, sodium, hydrogen, and helium when produced by Hertzian waves and when produced by the induction coil spark.

In connection with the preparation of the plates of the spectroscope, Lord Rayleigh mentioned that he had found the use of dilute hydrofluoric acid very effective in putting on the finishing touches to glass surfaces.

Prof. Wood described the interference method he had used to determine the dispersion of sodium vapour. The vapour was produced in an exhausted tube with plane ends surrounded by a wire by which the tube was electrically heated. Over a range extending to $\lambda^2/(\lambda^2-\lambda_m{}^2)=3900$ the results agree well with the formula $n^2=1+m\,\lambda^2/(\lambda^2-\lambda_m{}^2)$.

The discussion on "*n*-rays" was very one sided, as no one who spoke had succeeded in convincing himself that any effects he may have observed were not subjective.

Throughout the whole of the meeting communications dealing with radio-activity attracted a large amount of attention. Lord Kelvin described his models of radium atoms to give out α and β rays respectively. The former consisted of an "electrion" e placed at the point of contact of two spheres, through the volumes of which charges $-4e$ are uniformly distributed. When equilibrium is destroyed and the spheres move apart the electrion accompanies one sphere and we have the α particle. In the same way if two electrions e are in equilibrium at opposite extremities of a diameter of a sphere through the volume of which a charge $-\frac{1}{4}e$ is uniformly distributed, and equilibrium is destroyed, one of the electrions moves away from the sphere and gives the β ray.

Prof. Schuster described his apparatus in which radium is utilised in measuring the rate of production of ions in the atmosphere. Changes in the state of the atmosphere are found to take place much more rapidly than was anticipated, so that it is not advisable to use any method of measurement which involves the constancy of the state for more than five minutes.

Prof. Thomson gave an account of the work which has been done recently at the Cavendish Laboratory to determine whether ordinary matter possesses to a small extent the property of radio-activity so strongly shown by radium and polonium. His criterion for the possession of this property is that the substance shall be capable of producing electrical conductivity in the gas in a closed vessel in its neighbourhood. The difficulties of the investigation are due to the wide distribution of radium in soil, water, and air, and to the fact that the emanation from it settles on bodies left exposed to the air. A small quantity of radio-active material present in the body from either of these causes may be sufficient to mask the effect due to the substance itself.

From his observations Prof. Thomson concludes that each metal gives out a specific radiation which differs in its properties from the radiation sent out by other substances, and appears not to be a secondary radiation due to the impact on the substance of some form of penetrating radiation present in the atmosphere. The search for a radio-active gas produced by each metal has so far proved unsuccessful, but Prof. Thomson thinks there is some indirect evidence for the existence of such a gas.

Dr. Elster and Dr. Geitel pointed out that any results obtained by the use of the conducting property of a gas were open to the objection that the effects observed might still be due to traces of radio-active matter left in the apparatus, and not to the metals themselves.

Prof. Thomson's description of his work was necessarily much condensed, and physicists will look forward to the publication of a more complete account which will set aside this objection.

On the last morning of the meeting Prof. Fleming exhibited his apparatus for measuring the lengths of Hertzian waves such as are used in wireless telegraphy. A wire helix has attached to one end a metal plate which, with a similar plate attached to the apparatus in which the electrical oscillations originate, forms a condenser. The effective length of the helix is altered by a sliding conducting saddle, and the positions of the antinodes along the helix are determined by a Neon vacuum tube held perpendicular to the axis of the helix. From the dimensions of the helix the velocity of the waves along it can be calculated, and hence the frequency of the oscillation and its wave-length in air. Prof. Rubens stated that a similar method had been in use in Berlin for some time in connection with a portable apparatus for measuring the lengths of the waves used in the Slaby system of wireless telegraphy.

From the above notes of some of the matters brought forward it will be evident that the Cambridge meeting will hold its own as one of the most interesting of recent years.

C. H. LEES.

CHEMISTRY AT THE BRITISH ASSOCIATION.

THE proceedings of Section B (chemistry) were characterised not only by the general interest attaching to the numerous papers presented, but also by the unusually large attendances at the meetings, and chiefly by the presence of more than twenty distinguished Continental chemists, who made several important contributions to the business of the section.

The foreign visitors included Prof. Aschan (Helsingfors), Prof. Brühl (Heidelberg), Prof. Max Busch (Erlangen), Prof. Dieterici (Hanover), Dr. Étard (Paris), Prof. Franchimont (Leyden), Prof. M. Freund (Frankfurt), Prof. Gabriel (Berlin), M. le Comte de Gramont (Paris), Prof. Groth (Munich), Prof. Guye (Geneva), Prof. Haller (Paris), Prof. Kayser (Bonn), Prof. Knoevenagel (Heidelberg), Prof. Leduc (Paris), Prof. Richard Meyer (Brunswick), Dr. E. Noelting (Mülhausen), Prof. van Romburgh (Utrecht), Dr. Rupe (Bâle), Prof. I. Traube (Berlin), Prof. Walden (Riga), Prof. Wedekind (Tübingen), Prof. Wegscheider (Vienna), Prof. Wien (Würzburg), and Prof. Wolffenstein (Berlin).

The following papers were read:—On the bearing of the colour phenomena presented by radium compounds: W. Ackroyd. On the pentavalent nitrogen atom: Prof. O. Aschan. Saponarin, a glucoside coloured blue by iodine: Dr. G. Barger. The relation between the crystalline and the amorphous states as disclosed by the surface flow of solids: G. T. Beilby. The action of certain gases on glass in the neighbourhood of hot metals: G. T. Beilby. The change of conductivity in solutions during chemical re-