Calanus. This would give about 6000 Copepods in the stomach of an average mackerel, or in a five minutes' haul of the tow-net, on this occasion.

It may be added that these mackerel were evidently not being nourished in accordance with the views of Pütter, and were clearly able to fill their stomachs from the plankton around them.

W. A. HERDMAN.

S.y. *Runa*, Tobermory, N.B., July 12.

Helium and Neon.

THE experiments communicated to the Chemical Society recently by Prof. Collie and Mr. Patterson, the lectures delivered by Sir J. J. Thomson, and the discussions which have taken place in NATURE, on the possible synthesis of the chemical elements have aroused great interest outside England. So far as I can ascertain, opinion is much divided. For my own part I may perhaps be permitted to say that I have always entertained the idea of a possible formation of elements of the helium group from other gases by *integration*, just as these are formed from other elements by disintegration (see *Chemical News*, 1896, and *Berichte*, 1899). When I put forward this view objection was taken that 4H is greater than He, 4·032 instead of 3·99, and the same kind of objection may be raised to-day that He+O, or 3·9+16, is less than Ne, 20·2 (unless Ne is a mixture of gases).

In order that the above question might be solved definitely, I would beg to suggest that experiments should be conducted in Röntgen-tubes from the electrodes of which every trace of the gases "occluded" or firmly held by them would be first removed by continued bombardment with kathode rays.

As regards the question put forward by Sir J. J. Thomson, whether the new gas X_3, discovered by him, may be a new element that fills the vacant space in VII. group, 1 series (VII–1), in Mendeléeff's periodic system, I may be allowed to remark that Mendeléeff's prediction of the properties of the elements Sc, Ga, Ge, could be successful, because it was an *interpolation*; whereas the prediction of the properties of the element X=3 includes an *extrapolation*, which is always rather uncertain; besides, the gases of the helium group were unknown at the time of the prediction. Its properties may be derived from the following equations:—(1) Ne : F=He : X; (2) Li : F=H : X; (3) Li : H=F : X; but also (4) Fe : He=Mn : X, and (5) Cu : H=Br : X, showing how uncertain the prediction of its properties becomes, so that it is indeed probable that it will be more negative than fluorine, but not necessary that the gas should combine with the silicon of the glass.

The delicacy of Sir J. J. Thomson's new method has superseded our old methods of investigation in a way similar to that based upon radio-activity, and the results of the study of the new gases discovered by this new method are awaited by chemists with the greatest interest.

BOHUSLAV BRAUNER.

Bohemian University, Prague, July 6.

Red Water and Brine Shrimps.

BY the kindness of Mr. A. W. Sheppard and Prof. A. Dendy, F.R.S., I have been enabled to examine specimens of the brine shrimps from Geelong mentioned by Mr. Whitteron in his letter (NATURE, June 12, p. 372). They belong to the species *Parartemia zietziana*, described by the late Mr. O. A. Sayce in 1903 (Proc. Roy. Soc. Victoria, xv., part ii., p. 232). In Parartemia the unpaired uterine sac is produced into two large dorso-lateral lobes lying on either side of the "tail," and appearing, as Mr. Whitteron says, "like the egg sacs of Cyclops." Mr. Sayce's specimens were obtained from a "brackish-water swamp near Lake Alexandrina, South Australia." It is interesting to learn that the species is able also to live in the brine of salt-pans.

The flagellate described by Mr. Whitteron is probably allied to, and perhaps identical with, *Dunaliella salina*, which has long been known to cause a red coloration in the brine of salt-pans in Europe and Algeria. A detailed account of this form and references to the somewhat extensive earlier literature of the subject are given by Clara Hamburger ("Zur Kenntnis der *Dunaliella salina*," *Arch. Protistenk.*, vi., 1905, p. 111).

W. T. CALMAN.

British Museum (Natural History), Cromwell Road, London, S.W., July 12.

The Maximum Density of Water.

PHYSIOGRAPHERS lead us to believe that the earth is defended from a profound glaciation, cumulative from year to year, by the law that water is heaviest at a temperature of four degrees above centigrade zero. If the main cause lies here, it is desirable that this measure should have its peculiar power set forth with more precision than has been customary.

The matter usually presents itself to students rather differently. The predominant fact is the floating power of ice. Hereby the water is screened from further attacks of the cold air, and dispersal is provided in the puzzling conditions of ground or anchor ice. Next perhaps in importance is the slow conduction of cold by water. Then comes the large value of the latent heat of water. It is not obvious why there should be disastrous results if the maximum density of water were at 0° C. The four units may be viewed as a helpful margin of safety rather than as an essential; but they would appear to be negligible in comparison with the 79 units of latent heat. Water at 0° C. is by no means unstable; each gram weight as it passes into ice throws out amongst its neighbours an amount of heat which is an effective safeguard against sudden and extensive solidifying.

W. B. CROFT.

The College, Winchester, July 5.

Radio-activity and the Age of the Earth.

I AM gratified to learn from Dr. Fermor's letter in NATURE for July 10 that there is a scientific possibility of conceiving how the interior of the earth may be devoid of radio-activity. But if "high pressure and temperature" can inhibit the dissociation of "potentially radio-active" substances, will they not do so also in the interior of the stars? If so, radio-activity will no longer be available to prolong their radiation of energy, and we shall be back in the old difficulty about the age of the sun. Indeed, it will be aggravated, because we now have positive evidence for a high antiquity of the earth, while still unable to explain that of the sun.

F. C. S. SCHILLER.

Corpus Christi College, Oxford, July 11.

THE GENERAL MAGNETIC FIELD OF THE SUN.[1]

THOSE who are familiar with Prof. Hale's brilliant discovery of magnetic fields in sun-spots, and are aware of the difficulties connected with that investigation, will greatly admire his courage in seeking to establish the much weaker general magnetic field of the sun itself. The following condensed account of the method adopted and results obtained is given, to some

[1] Based upon an advance proof of a paper by Prof. G. E. Hale which is to appear in *The Astrophysical Journal.*

extent, in Prof. Hale's own words. As a general problem of physics, Schuster's suggestion that every rapidly rotating body may produce a magnetic field is of fundamental importance. A direct test by laboratory experiments cannot be made because of the limitations of size and rotational velocity, but advantage may be taken of the heavenly bodies where these limitations do not obtain. The most promising object for such an investigation is the sun. It is here that the direct method of determining the magnetic field by observation of the Zeeman effect is most readily employed, since the sun is bright enough to permit the use of the very high dispersion required. Further, it is possible to observe at a great number of points on the surface, and since observations may be made in both hemispheres the most perfect test of the Zeeman effect can be applied by looking for a reversal of the sign of the displacement with the polarity. The present minimum of solar activity has furnished a particularly favourable opportunity for the investigation, in consequence of the general absence of local strong fields due to spots and other disturbances.

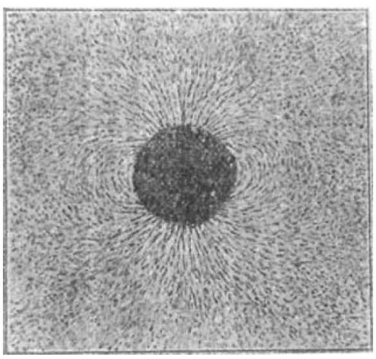

FIG. 1.—Lines of force of a magnetised sphere.

Assuming the sun's magnetic field to be similar to that of a magnetised sphere, with magnetic poles coincident with the poles of rotation, the lines of force would appear as in Fig. 1, the angle δ between them and the solar surface being given by $\tan \delta = 2 \tan \phi$, where ϕ is the heliocentric latitude. If the field were strong enough, and if the observer could look along the sun's axis and form an image of one of the poles on the slit of a spectroscope, certain solar lines would appear as doublets with components circularly polarised in opposite directions. If a Nicol prism were placed in front of the slit, with its long axis parallel to the slit, in combination with a quarter-wave plate set with its principal section at an angle of 45°, one of the components would be extinguished, while the other would be transmitted by the Nicol. Assuming the red component to be transmitted, a rotation of the quarter-wave plate through 90° would cause this to be extinguished and the violet component to be transmitted. If from the same place of observation the slit were directed to a point in 45° lat., the effect would still be clearly observable, though the transformation of the circularly polarised light of the components into elliptically polarised light would result in less complete extinction by the Nicol.

In the actual case the terrestrial observer is close to the plane of the sun's equator and must look in a direction nearly at right angles to the lines of force at the sun's poles.[2] He therefore cannot take full advantage of the fact that the total intensity of the sun's magnetisation is twice as great at the poles as at the equator. The angle between the lines of force and the line of sight, however, is reduced to zero at 35° north and south latitude; but the most favourable position for observation is 45° lat., where the effect of the ellipticity of the light is overcome by increased strength of the field.

On account of the weakness of the sun's magnetic field, complete separation into doublets is not to be expected, and the investigation must, therefore, depend upon the possibility of detecting very slight displacements of lines to red or violet, according to the position of the quarter-wave plate, with reversal of the sign of the displacements in passing from the northern to the southern hemisphere.

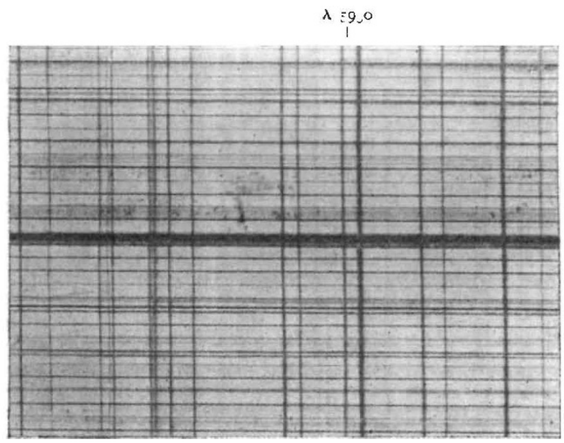

FIG. 2.—Region of λ5930 photographed in the third order with the 75-ft. spectrograph showing the division of the spectrum into 2-mm. strips by the compound quarter-wave plate. The heavy horizontal line marks the junction of two sections of the Nicol. The fifth stripe below is the "marked strip" used for reference purposes.

The first attempts to detect the solar magnetic field were made in 1908 with the 60-ft. tower telescope at Mt. Wilson, but it was not until the new 164-ft. tower telescope and 75-ft. spectrograph became available, in 1912, that definite results were obtained. With the latter instrument the sun's image is about 16 in. in diameter, and about λ5900 in the third order spectrum, where much of the work was done, the linear dispersion is 1 Ångström = 4·9 mm.; on this scale the distance between the D lines is 29 mm. For determination of focus and investigation of resolving power the extremely fine lines in the absorption spectrum of iodine were employed with advantage, and lines as close as 0·025 A.U. were found to be just resolved.

The polarising apparatus consists of a Nicol prism 18 mm. wide, built up of four sections, each 32·5 mm. long, so as to give a total length of 130 mm. The impossibility of rotating it is easily

2 The triplets produced by light from the poles would, of course, be too narrow for observation as such, and the use of a Nicol in different positions would not affect the symmetry of the lines.

overcome by the use of a half-wave plate, as a rotation of this through a given angle is equivalent to a rotation of the Nicol through twice the angle.

The quarter-wave plate was built up of strips of mica, 2 mm. wide, mounted so that the principal sections of successive strips make an angle of 45° with the slit and 90° with each other; the Nicol would thus transmit, say, the red components of the doublets for the odd strips and the violet components for the even strips. In a photograph of the spectrum the lines would thus have a dentated appearance (Fig. 2), the magnitude of the separation of the components shown in successive strips varying directly with the strength of the field.

Every conceivable precaution appears to have been taken in setting the desired portion of the sun's image on the slit of the spectrograph, and in securing full illumination of the grating in any exposure. A valuable check on the observations was obtained by making duplicate exposures with the quarter-wave plate in the normal and inverted positions, which should give displacements of opposite sign if they are caused by a magnetic field. As a further check, at least one atmospheric line was measured on most of the plates of the first series, but afterwards they were only occasionally measured, as they were invariably found to give no shifts exceeding the errors of measurement. Possible effects of polarisation produced in the spectrograph have also been carefully considered.

The region of the spectrum selected, λ5800 to λ6000, was determined by the consideration that the magnetic separation varies directly as the square of the wave-length; too great a wave-length, however, being undesirable since the average sharpness of the solar lines decreases as the wave-length increases. Numerous difficulties arising from distortion of the cœlostat mirrors of the tower telescope and other causes were successfully overcome, and 280 photographs were obtained. For purposes of discussion the photographs and measures have been divided into four series.

For the preliminary observations it was decided to obtain a large number of measures of a few lines rather than a smaller number of measures of many lines. Three lines, showing the largest displacements, were accordingly selected for systematic investigation, namely, λ5812·139 (Fe,0), λ5828·097 (–,0), λ5929·898 (Fe,2).

The measurement of the minute displacements, amounting only to a few thousandths of a millimetre, presented great difficulties, largely arising from the natural diffuseness of the solar lines. Full details of the individual measures are given in the paper, and discordances appear to have been as faithfully recorded as the measures on which the final conclusions are based.

The tables and curves show a marked grouping of positive displacements in the northern and of negative displacements in the southern hemisphere, with values decreasing, on the average, from middle latitudes towards the equator or poles. It is also shown that the displacements were reversed in direction by turning the half-wave plate through 45° (equivalent to a rotation of the Nicol through 90°), or by inversion of the compound quarter-wave plate. Hence it is concluded that the light from the red and violet sides of the solar lines in question is circularly or elliptically polarised in opposite directions. In the northern hemisphere the light of the violet component is circularly polarised in the right-handed direction.

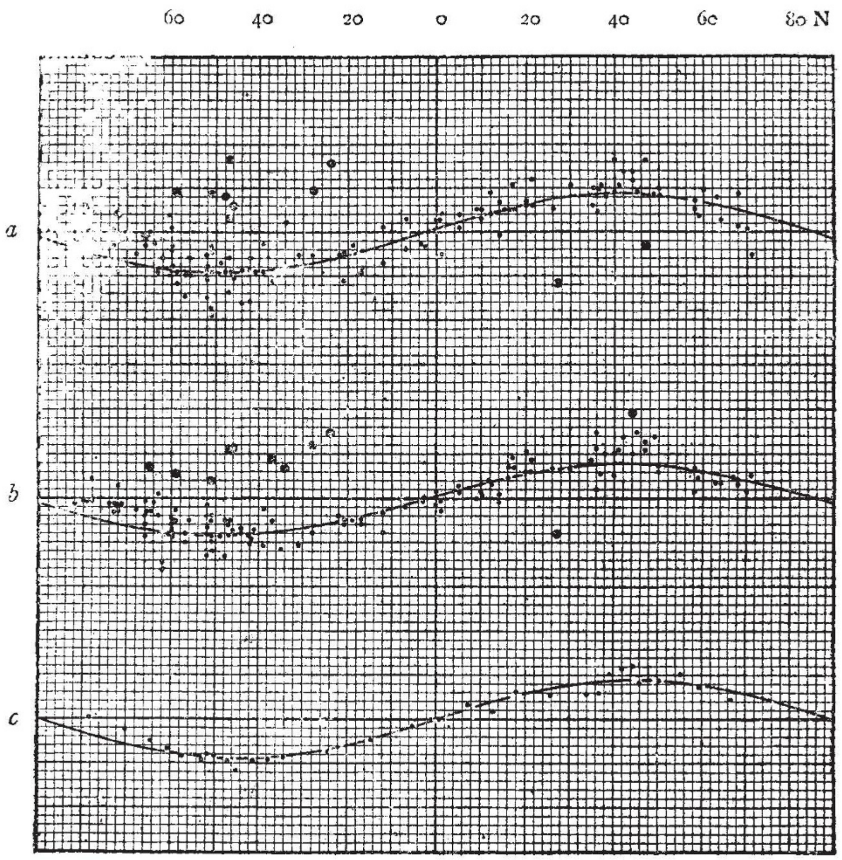

FIG. 3.—Displacements observed in different latitudes, fourth series. *a*, λ5812; *b*, λ5828; *c*, Mean curve of displacements including λ5930 from first and third series and λλ5812 and 5828 from fourth series. Vertical Scale: 1 division=0·001 mm.

Some of the evidence for the systematic shifts is reproduced in the appended table, giving the mean displacements for λ5930 in the first and third series, and λλ5812 and 5828 in the fourth series, as measured by Mr. Van Maanen:—

Lat.	Δ (unit = 0·001 mm.)	No. of observations	Lat.	Δ (unit = 0·001 mm.)	No. of observations
N. 68°.8	+2·2	15	S. 5°·1	−0·8	15
59·4	+3·6	15	14·3	−2·4	15
55·4	+5·1	16	24·2	−3·6	15
50·3	+4·4	15	34·1	−4·3	15
46·1	+4·1	15	37·7	−4·6	15
44·5	+6·0	15	41·0	−4·7	15
41·9	+5·7	15	45·1	−5·8	16
39·3	+5·1	15	47·1	−4·7	15
36·7	+3·0	15	49·9	−4·1	15
33·9	+2·9	15	51·7	−4·1	15
25·7	+2·7	15	52·8	−4·7	15
18·0	+3·1	16	57·3	−4·1	15
12·7	+0·8	15	60·5	−3·5	15
7·3	+1·6	15	64·5	−2·5	15
0·5	0·0	15	70·0	−1·1	15
			78·1	+0·1	15

A graphical representation of the results of this series of measures is given in Fig. 3, in which the horizontal scale is that of solar latitude, and the vertical scale that of displacements. The agreement of the data of the foregoing table with the theoretical curve derived from the average of the ordinates at 45° is shown in Fig. 3*c*.

It is considered that within the limits of precision the observations agree satisfactorily with the displacements calculated for lines originating in a source on the surface of a magnetised sphere, and observed from a point in or near the plane of the equator. On the assumption that the field is due to the rotation of a charged body, or of a body composed of neutral molecules which act as though they carried a charge, it is concluded that the sign of the dominant solar charge is negative, and that the north magnetic pole of the sun lies at or near the north pole of rotation.

The determination of the strength of the sun's field has presented some difficulty because the lines measured are so weak in the arc or spark that their separations in a magnetic field can only be determined experimentally with the greatest difficulty, or not at all. In the case of 5929·898, the procedure has been to observe the separation of the line in a sun-spot the strength of field of which was determined from other lines; as indicated by this line, the field strength of the sun at its pole is 28 gausses. The line 5812 and a nickel line 5831·821 (not yet fully discussed), by comparison with laboratory observations, lead to the values 48 and 29 gausses, but for comparison with the foregoing determination these should be increased by about 60 per cent. on account of systematic differences between the measurers. The general result is to indicate that the field strength at the sun's pole is of the order of 50 gausses. Various higher level lines, which show large Zeeman effects in the laboratory, have hitherto failed to show the effect of the sun's field, and it is therefore concluded that the intensity of the general field falls off very rapidly in passing upward through the reversing layer, more rapidly than in the case of spots.

Prof. Hale gives a careful discussion of the question as to whether the magnetic fields indicated by the observations are due to local phenomena or to the magnetic effect of a rotating sphere. In the case of spots, the Zeeman effect frequently extends beyond the penumbra, and the structure of the Hα flocculi sometimes suggests that local magnetic fields may also be caused by invisible spots, or by whirls in which no umbræ or penumbræ have appeared. There is also some evidence that the pores which occur in all parts of the sun may be small vortices which develop into spots under favourable conditions. Reasons are given for believing that the line displacements in question are not due to any of these causes. Right and left-handed whirls about spots are equally common in the northern and southern hemispheres, and there is no reason to suppose that they could produce the systematic displacements, of opposite sign in the two hemispheres, which have been observed. In fact, in the majority of the observations no spots whatever and very few calcium flocculi were visible on the sun. If the pores are electric vortices, like the spots, there is no reason to suppose that pores of one polarity preponderate in the northern hemisphere and those of opposite polarity in the southern, unless local differences in rotational velocity are sufficient to account for such small vortices as the pores may represent; this possibility, says Prof. Hale, deserves more careful consideration than he has yet been able to give it, but even if there were a clear preponderance of pores of opposite sign north and south, it would be difficult to account for the curve of observed displacements.

Serious objections having been urged against all theories of terrestrial magnetism, it can scarcely be hoped that any one of them can be applied without modification to the sun, especially in view of its high temperature, low density, and gaseous condition. In the case of spots, neutral molecules cannot produce the observed fields unless an improbable degree of separation of the positive and negative electrons is assumed. Harker's experiments,[3] however, have led Prof. Hale to suppose that in a spot there must be a flow of negative electrons from surrounding regions into the cooler umbra, and that the whirling of these in the vortex may account for the strong magnetic fields observed.

An extension of Dr. Harker's work made at Pasadena by Mr. King has further shown that although the ionisation current decreases as the pressure increases, it is still appreciable at pressures up to twenty atmospheres. On account of the greater mobility of the negative electrons, their tendency to flow towards regions of lower temperature, and the evidence afforded by Mr. King's experiments that solar ionisation is not limited to the region above the photosphere, it is evident that the electrical and magnetic phenomena of the interior of the sun must differ radically from those of the earth. But since the negative electrons will tend, on the average, to lie farther from the

[3] NATURE, July 18, 1912, p. 517.

sun's centre than the positive, the polarity of any general field that may thus result from the solar rotation should correspond with that of the earth's field.

There is reason to believe that in the solar atmosphere the negative electrons lie farther from the photosphere, on the average, than the positive electrons. The rotation of the atmosphere with the sun would thus tend to set up a magnetic field of the same polarity as that of the earth. At the base of the atmosphere this field would oppose the field due to the rotation of the body of the sun. Hence, assuming a suitable distribution of the positive and negative electrons, it may be possible to account in this way for the observed decrease in the strength of the general field at increasing distances from the photosphere. Prof. Hale thinks that it may even turn out that the Zeeman effect observed is due to the rotation of the solar atmosphere, and not to the rotation of the body of the sun.

Further work will be necessary before such questions as these can be fully discussed, and an extended series of observations, including lines representing a wide range of level, is contemplated.

The space at our disposal is too restricted to permit full justice to be done to this fine piece of work. It will be sufficiently evident, however, that Prof Hale has conducted the investigation with his accustomed skill and with due regard to the numerous possible sources of error.

THE BIRMINGHAM MEETING OF THE BRITISH ASSOCIATION.

THE arrangements for the Birmingham meeting (September 10–17) are almost completed. In order to avoid the competition for places at the various functions, which so often causes inconvenience to visitors, the local secretaries intend to obtain beforehand from members an indication of their wishes with regard to the general meetings, lectures, entertainments, and excursions; and a circular for that purpose will be issued shortly.

A new arrangement has been made for the convenience of the delegates of corresponding societies. Thanks to the council of the Birmingham Natural History and Philosophical Society, the meeting-room and library at 55 Newhall Street is to be placed at the disposal of the delegates for the display of their publications, and also to act as a meeting-ground for the representatives of these corresponding societies during the meeting. The addresses to the delegates will be given in the Technical School, Suffolk Street.

The lectures to citizens, which were inaugurated at Dundee last year, will be given on a more extended scale this year at the Digbeth Institute, Birmingham. Five lectures have been arranged by the council of the association. The first of these—"The Decorative Art of Savages"—will be given by Dr. A. C. Haddon, F.R.S., on Thursday, September 11, at 8 p.m. Other lectures will be "The Panama Canal," by Dr. Vaughan Cornish; "Heredity in relation to Man," by Dr. Leonard Doncaster; "The Microscopic Structure of Metals," by Dr. W. Rosenhain; "Radio-activity," by Dr. F. Soddy, F.R.S. These lectures are arranged for that section of the public which is interested in the progress of science, but cannot take part in the meetings of the association. They are not intended for members or associates. The chief points in the programmes of the sections are described below.

SECTION A (MATHEMATICAL AND PHYSICAL SCIENCE).—The section meets this year under the presidency of Dr. H. F. Baker. It is expected that greater interest will be taken in the proceedings of the pure mathematics subsection than in former years. There is a possibility of a discussion on non-Euclidean geometry, which will be of interest to many in addition to the pure mathematicians. In the full section the chief item after the presidential address is a discussion on radiation, arranged for the Friday morning, which will be opened by Mr. J. H. Jeans. Profs. H. A. Lorentz and E. Pringsheim have accepted invitations to be present at the meeting, and will add greatly to the interest and value of this discussion. Prof. Planck may also possibly be there. Of the English scientific men who will be there, Profs. Love and Rutherford will take part in the discussion. Two other discussions have been arranged in conjunction with other sections. With the Engineering Section a joint meeting will be held at which reports of a committee which has been investigating problems of stress distribution will be discussed. The other meeting is with the Geography Section, at which problems of geodesy and mathematical geography will be considered. One paper of great interest to many will be presented by Capt. H. Winterbotham, on the accuracy of the principal triangulation of Great Britain.

Amongst the papers to be contributed to the section, one, by Prof. Barkla, on the nature of X-rays, will be of considerable interest, and will probably give rise to an animated discussion. This paper will probably be read in full section immediately after the presidential address at eleven o'clock on Thursday morning.

The meeting will be of special interest because of the close association of the president of the association, Sir Oliver Lodge, with the section. It is expected that a large number of leading English scientific men will be present, and already the published list of papers shows that a stimulating session may be expected.

SECTION B (CHEMISTRY).—The programme of this section has been framed so as to appeal as widely as possible to chemists, as many as five different subjects being down for discussion. Taking first those which have a practical bearing, the subject of the economical use of fuel is of national importance. The chemist can emphasise the wasteful nature of present practice and describe alternative and more economical practices, free from the bias of the commercial advocate. It is hoped to present at the meeting the views of authoritative speakers on all branches of the subject; the details will be announced later. The subject of metallurgy is of particular interest in Birmingham, and a number of papers are promised by Prof. Cohen, Prof. Turner, Dr. Desch, Dr. Rosenhain, Dr. Holt, and others, which will deal from the scientific side with problems of practical interest. Turning to pure chemistry, the discussion on optical activity should prove of particular value, as all the workers in this country who are specially competent to speak on the subject are expected to be present. The ground has been prepared by Prof. Frankland's