The Carnegie United Kingdom Trust.

THE seventeenth annual report of the Carnegie United Kingdom Trust gives, by way of introduction to its record of the events of 1930, a short general survey of the five years 1926-1930 and a statement of the main heads of policy which the trustees have decided to pursue during their fourth quinquennium, 1931-1935. Their operations range over a wide field, shared now with the Pilgrim Trust, of charitable enterprise in Great Britain and Ireland. They give preference among charitable objects to such as are of an experimental and national character and to schemes which are likely to become self-supporting within a reasonable time, since it was the founder's desire to provide means for fostering a perpetual succession of pioneer enterprises calculated to meet new needs as they arise. The fairy-godmother, in fact, whilst guaranteeing her protégées a fair chance of showing their quality and merits, is careful to disclaim all responsibility for their future maintenance.

The Trust's income of, roughly, £120,000 a year has been distributed since 1925 mainly in grants under the headings: libraries (47 per cent), playing fields and play-centres (21 per cent), rural development, adult education, and music and drama. In their library development work the trustees have exploited to the utmost the possibilities of co-ordination and co-operation, and this policy led to the establishment in December and January last of two regional schemes of the greatest experimental importance, one in the north of England, based on the library of the Newcastle Literary and Philosophical Society and embracing libraries in the four northern English counties; the other serving Warwickshire, Staffordshire, Worcestershire, Shropshire, and Herefordshire, and based on Birmingham City Library. In each area the trustees are meeting the initial cost of creating the necessary union catalogue. If these schemes, after a short trial period, turn out to be on sound economic and administrative lines, the trustees hope to invite the libraries of two or three other areas to adopt the same policy.

To 'special' libraries, including those of many industrial research and other scientific associations, grants amounting to more than ten thousand pounds were paid last year. These, in return, have made their collections available to the general public on application from the National Central Library. The Association of Special Libraries and Information Bureaux, which has enjoyed the financial support of the Trust during the six years of its existence, has recently decided against a projected amalgamation with the Library Association—a decision involving, the trustees observe, competition and possible over-

lapping with the university and research section of the Library Association.

The Trust's playing-fields policy, inaugurated in 1927 with an allocation of £200,000 spread over four years, has been carried into effect in collaboration with the National Playing-Fields Association. It has aimed at stimulating and encouraging local effort, and its success may be gauged by the fact that already 356 grants, varying in many cases from only one-tenth to one-sixth of the total cost, have sufficed to enable some 5000 acres to be preserved permanently for the playing of organised games. Apart from this playing-fields programme, the trustees have not during the past year been pursuing any concerted policy for ameliorating the physical welfare of the masses, but they have offered a grant of £30,000 for the erection of a Physical Training College for Men Teachers at Leeds and have helped the National Council of Girls' Clubs to employ two physical training instructresses. The main feature of the college will be a one-year course based on the principle that physical instruction is better given by teachers who also take part in the ordinary work of the school than by specialists with no other qualification and with little, if any, hope of being usefully employed after they reach 40-45 years of age. The Girls' Clubs instructresses conduct short intensive courses in large towns, giving special attention to instruction in the organisation of team games for clubs with limited playing spaces. The experiment is an entirely new one and the results so far are reported to be most encouraging.

A new policy in reference to public museums has recently been decided on by the trustees. Its main feature is a demonstration in public museums, in small towns, designed to show what can be done at a very small cost to make them interesting and educationally valuable. The amount set aside for this purpose is £7000, and will be available solely for re-organisation purposes, in general accordance with the recommendations contained in the report prepared for the Trust by Sir Henry Miers and published in 1928, on "Public Museums of the British Isles". The trustees are also examining the possibility of encouraging the circulation of museum exhibits from urban or county centres to village schools and institutes, and, as a preliminary step, will assist the Museums Association to hold an exhibition of suitable objects, cases, etc.

Appended to the report are useful supplementary notes on the National Central Library and branches, regional library schemes, village halls, and rural community councils.

Atomic Synthesis and Stellar Energy.

By DR. R. D'E. ATKINSON, Rutgers University.

SOME time ago F. G. Houtermans and the present writer investigated the possibility of synthesis of elements, in stellar interiors, by the wave mechanics process of penetration of nuclei by protons.¹ The theory was not strictly correct, and various modifications have been proposed since, of which the theory of Wilson² is perhaps the most important; all theories, however, lead to a probability of proton penetration having the same exponential dependence on both the temperature, T , and the atomic number, Z . The importance of this factor far outweighs that of the multiplicative forefactor which alone is different in the different theories, and it seems therefore desirable

to discuss somewhat more fully the consequences of the assumption that any of these theories will give the right order of magnitude for the temperature at which synthesis will occur in large amounts. The effect of the exponential is roughly to make the synthesis probability vary as T^{20} , or some comparable power, and thus even a change of 1000 in the forefactor does not seriously affect T . The investigation is being discussed fully in the *Astrophysical Journal*, but in view of the interest of the subject at present, and also of the comparative unfamiliarity of the line of attack, a short summary may both appeal to a wider audience and prepare the way for the more detailed treatment.

Direct synthesis of helium from hydrogen is clearly a very unsatisfactory process, but we do not need to assume its existence at all; as in the above paper, we assume that helium is produced entirely indirectly, by the spontaneous disintegration of unstable nuclei that must first themselves be formed. In addition to the known radioactive elements, Gamow's theory of nuclear stability³ now indicates that we may expect a large number of lighter elements to be unstable if they were to be formed, and in fact we rely mainly on these. For example, if above argon the incorporation of electrons, which we clearly must suppose can occur, is somewhat difficult (and the existence of apparently permanent non-radioactive *isobars* seems to show that it can be extremely difficult), nuclei such as Fe^{52} , Ni^{56} , and Zn^{60} may be formed; according to Gamow, the last of these, and quite possibly all three, should be unstable. After emitting one α -particle, they would again collect four protons and two electrons in such order and at such intervals as they could, combine them into a fresh α -particle, and re-emit this one also in due course. At various points in this cycle they would also have to emit a total of just as much energy as would be set free by the direct synthesis of a helium nucleus; this energy can then be used to maintain the star's radiation. This method of evading the well-known difficulty of the 6-body collision as a source of helium obviously opens up important avenues; it is, however, not at all necessary to regard helium as the final product. In fact, since small Z -values favour synthesis, all the helium formed will be rapidly built up again. The energy developed is roughly the same, however, *per proton consumed*, whatever the products.

Since no other theory proposes a lower temperature for an energy source than ours turns out to do, we may take it that stars will at any rate contract until this process becomes operative; they will then be unable to contract further, since even a small contraction will enormously stimulate the energy development and force them to expand again. Milne's theory seems in this way to be ruled out until such time as the hydrogen supply near the centre has run low.

Rosseland has shown that when there is no great excess of hydrogen, electrostatic forces will tend to drive it from the centre, and the centre is in any case the only place where it is being consumed. Thus in any star a time will arrive when the disappearance of hydrogen near the centre prevents the generation of energy there altogether; the star must then condense towards the degenerate state. It is known that the energy of the white dwarfs may be entirely gravitational if their lifetimes may be supposed to be only of the order of 10^{11} years; in addition to explaining why stars intermediate between white dwarfs and the main sequence seem to be scarce, this theory explains why heavy white dwarfs should be the commonest⁴ (the minimum radius is smaller and the square of the mass larger, so that they have very much more gravitational energy available).

So long, however, as hydrogen is present, synthesis should continue. Since, now, the star's mass remains practically constant, its energy generation must remain moderately so, and it is easily seen that this involves an approximate constancy of the helium supply, but with an ever-present possibility of adding a little to it. This is the fundamental condition for stellar stability, and determines the central temperature. For a star to keep control, it must slowly decrease its central temperature, since the number of helium sources is being added to; thus, after an initial contraction to start the process, stars spend probably the greater part of their lives *expanding*. During most of their lifetime the expansion is very slow, and

the central temperature at any one mass is almost determinate; this accounts for the main sequence.

The actual value for the central temperature cannot, however, be what this simple theory would indicate. If iron is to be synthesised, a temperature of perhaps 200 million degrees would be necessary, and at this temperature all the light elements would be so readily converted to heavier ones that they could not become abundant at all. With a constant helium supply we can use the ordinary equilibrium law of radioactivity theory, namely, that the amounts of the various elements should be directly as their 'average lives'; the fact that we are dealing with synthesis and not disintegration does not affect the validity of the principle. Since the atomic number, Z , affects the synthesis probabilities, that is, the average lives, exponentially, all light elements ought to be very scarce; oxygen is, however, more abundant than anything except hydrogen, and a number of other elements near it are also at least as plentiful as iron.

In fact, it is easily seen that the most abundant element of all in a star must have an average life (until further synthesis) comparable with the past life of the star itself; otherwise some heavier element would be more abundant. If now we assume the central temperature is so low that oxygen is as long-lived as this, we find that it and the lighter elements are nevertheless abundant enough for their synthesis alone to supply enough energy, and that the actual temperature is about 16 million degrees in the sun. This is in agreement with the figure obtained on Eddington's theory for a polytrope of index about three and constitution rather above 50 per cent hydrogen by weight.

At this temperature there is, however, no synthesis of iron, and thus no further supply of helium, and the process will soon exhaust itself. The difficulty may be overcome by an arbitrary assumption, and it has been found possible to make one that accounts at the same time for the permanence and actual position of the main sequence, and for the relative proportions of all the elements in main sequence stars. The assumption is that there is a second synthesis process, which is more probable than the first when $Z > 8$ and has a probability that increases somewhat with increasing Z ; it must depend about as extremely on the temperature as the other process. Even if this assumption is wrong, it is probably valuable to have the theory investigated in detail; in point of fact, it does at least lead to a number of correct results.

Oxygen will now certainly be the longest lived element, and the products of synthesis will 'pile up' at and near this value of Z . It is, as a matter of fact, desirable to keep them from adding to the iron group which is supplying the helium, for a constant supply is wanted. The iron group itself must, however, be abundant enough to be in 'equilibrium' with the lightest elements, since it must produce as many α -particles per second as there are helium-lithium syntheses. It is found that the situation which will develop involves a marked minimum between the oxygen and the iron maxima and a marked fall after, say, zinc, in very good qualitative agreement with observation.³ A consideration of Gamow's theory leads us to expect in addition a maximum among and below the lightest rare earths, and possibly one in the lead region; both are found. Practically the entire range of elements thus shows a qualitative agreement with what the theory requires.

The same will be true of any main sequence star; but since the age of the star at a point when it is, say, half hydrogen is much greater for small stars than for large ones, and the density is also larger in small stars, the central temperature must be smaller in them if oxygen is still to have a long enough lifetime. This is

satisfactory, for Jeans's modification of Eddington's theory does involve a polytropic index varying systematically with the mass in about the right sort of way to produce this effect. Jeans's modification results from using the theoretical Kramers value for the absorption coefficient, and the main reason why it has not been more generally adopted (by followers of Eddington) than it has is probably that the absolute values obtained by Kramers' theory did not seem to fit the facts. When, however, we adopt Russell's high value for the hydrogen content of stars the discrepancy disappears.

The vast majority of the stars are thus accounted for. The main sequence consists of stars built on the Eddington-Jeans model, with central temperatures fairly sharply defined at any one mass and rising very slowly with the mass, and with a constitution very similar to that actually observed; the central temperature seems to be about 16-20 million degrees in the sun. The white dwarfs consist of a roughly parallel band of stars built nearly on the Milne degenerate model, with central temperatures up to about 3×10^9 degrees; they should have about the same constitution except for a shortage of hydrogen at the centre, and will be fainter for a given mass.

In addition to these two main classes we may account for the low density giants. These have a comparatively low central temperature and can only obtain their energy (a) if they have a large amount of free helium or unstable atoms already present, or (b) if some very light element can also be unstable. In case (a) they will not be able to live very long; but if they are very heavy their total lifetimes will be short anyway, and their life in this state may be a fairly large fraction of the total. The wave mechanics formula used shows that a star of mass 30 suns, if 10 per cent of it were helium and 80 per cent hydrogen, could develop enough energy for an absolute magnitude of -6 even at the density of an *M5* supergiant, with a central temperature of only 4 million degrees. Such stars will, however, be 'overstable', that is, they will be liable to develop pulsations; these are well known to be a common feature of very massive red stars. If they are not very massive, only a small fraction of their lifetimes can be spent in this state, and they would, in addition, have a very large colour index indeed; we should thus scarcely expect to see any. In case (b) a long life would be possible, but as synthesis would now certainly result in an immediate

increase in the amount of the unstable element, the stars would have to change their central temperatures over a fairly large range during their lifetimes. The unstable element is assumed to be the isotope Be^8 , which exists in very small quantities on the earth and probably has in fact a mass defect (referred to helium as a unit) of very nearly zero. Many beryls contain a large and otherwise unexplained amount of helium, and when the idea of the instability of Be^8 was first proposed, Lord Rayleigh at once pointed out the significance of this fact.⁶ The 'Hertzsprung gap' and its prolongation between the Cepheids and the *B* stars may be shown to follow if Be^8 has a long life, and its presence on the earth guarantees this. A long life is also in harmony with the Be^8/Be^9 ratio and the He/Be ratio.

A number of other observations may readily be fitted into the theory. We may mention in particular the absence of low density stars at medium and small masses, the occurrence of *R* and *N* types among giants but not among dwarfs, the existence of binaries in which the brighter star is the cooler and less dense, and the fact that the brightest stars in clusters are usually all red or all blue.

The arguments that have been urged in support of the 'long time scale' (10^{13} - 10^{14} years) may all be met with some plausibility. In particular the well-known theory of Jeans for the eccentricities of binaries, and similar 'kinetic theory' arguments can all be reconciled with the 'short time scale' (10^{11} years) if the galaxy is expanding as fast as the universe in general is; this expansion (for the universe as a whole) seems to be demanded by the general theory of relativity.

It thus appears that as a result of the wave mechanics on one hand, and the general theory of relativity on the other, the universe may have developed its present complexity of stars and of atoms from an initial state consisting of a fairly dense, nearly uniform, nearly stationary mass of cold hydrogen. This comparatively simple beginning constitutes at least a pleasant ornament, if not an actual support, for our theory. It must, however, be admitted that there are still some serious difficulties; those that have been noticed are discussed in the full account which will shortly appear.

¹ *Zeits. f. Physik*, **54**, 656; 1929.

² *Mon. Not. R.A.S.*, **91**, 283; 1931.

³ *Proc. Roy. Soc.*, **126**, 632; 1930.

⁴ Cf. Russell and Atkinson, *NATURE*, May 2, p. 661, 1931.

⁵ Russell, *Astr. Jour.*, **72**, 11; 1929.

⁶ *NATURE*, **123**, 607; 1929.

Empire Travel for British Students.

FOR the past eight years, parties of Canadian undergraduates, numbering from 50 to 150, and representing most of the universities of Canada, have made a summer tour in Europe under the auspices of the Overseas Education League. The party usually leaves Montreal for Glasgow towards the end of June, and spends about a month in Great Britain, visiting such centres as St. Andrews, Edinburgh, Grasmere, Bangor, Stratford-on-Avon, Oxford, Cambridge, London, and the south coast of England. A further fortnight is then spent in Switzerland, Germany, and France, before the party embarks for Quebec. Last year the continental section of the tour included visits to Geneva, Innsbruck, Oberammergau, Munich, Stuttgart, and Paris.

These tours, of which the great educative value is obvious, represent one activity only of the Overseas Education League. Organised in 1910, on a definitely non-commercial basis, by Major Ney, of Winnipeg, the League was originally designed to foster understanding between Canada and Great Britain. Its scope has gradually widened, and now it "seeks to em-

phasise the significance attaching to citizenship in the British Commonwealth of Nations, to interpret Britain and France to the two great branches of the Canadian people through a closer educational and cultural association, and to develop a consciousness of the rôle of education as a means to international understanding and amity". It organises summer schools of English, French, music, drama, etc., at Oxford, Paris, and other centres; and, in all, some six thousand teachers and undergraduates have taken advantage of its arrangements. The Governor-General of Canada is honorary president of the League, and among other patrons and supporters are the Governor-General of the Union of South Africa, Lord Plumer, the Right Hon. L. C. Amery (honorary vice-presidents), the Primate of all Canada (president), and Major F. J. Ney (vice-president and honorary organiser).

This summer, for the first time, a return visit to Canada of a party of university students from Great Britain has been arranged under the auspices of the League. A group of about twenty men and women students of the University of St. Andrews, representa-