the sun—at about 6700°, shielded by an atmosphere at an average temperature of 5500°, and that such an atmosphere itself provides about 0·3 of, the total radiations that reach us.

In connexion with this subject it may be mentioned that the highest measured temperature produced terrestrially, that of the arc, is about 3500° to 4000° abs.

|  |  |  |  |
| --- | --- | --- | --- |
| λ. | γ=0∙5. | γ=0∙75. | γ=0∙95. |
| mm.  1500 | 0∙959 | 0∙95o | 0∙856 |
| 1010 | 0∙943 | 0∙894 | 0∙765 |
| 781 | 0∙941 | 0∙885 | 0∙749 |
| 615 | 0∙948 | 0∙845 | 0∙681 |
| 550 | 0∙933 | 0∙831 | 0∙587 |
| 468 | 0∙902 | 0∙764 | 0∙462 |
| 416 | 0∙858 | o∙744 | 0∙471 |

The energy which the sun pours out into space is, so far as we know, and except for the minute fraction intercepted by the disks of the planets (1/120000000) absolutely lost for the pur­poses of further mechanical effect. The amount is such that, supposing the average specific heat of the sun’s body as high as that of water, there would result a general fall of temperature of 2∙0° to 2·5° C. in the lapse of each year. Hence, if no other agency is invoked, at an epoch say *x*×1000 years ago, the sun’s heat would have been greater than now by the factor 1 + *x*/3*n*, where n×6000° is taken, for the sun’s present mean temperature. It seems possible that *n* is not a large number, and if we take *x* equal, say, to 200, we come to the most recent estimate— the astronomical—of the date of the earth’s glacial epoch, when the sun’s radiation was certainly not much more than it is now, while this factor would differ materially from unity. Hence loss does not go on without regeneration, and we are apparently at a stage when there is an approximate balance between them. It is in fact an impossi­bility that loss should go on without regeneration, for if any part of the sun’s body loses heat, it will be unable to support the pressure of neighbouring parts upon it; it will therefore be compressed, in a general sense towards the sun’s centre, the velocities of its mole­cules will rise, and its, temperature will again tend upwards. In consequence of the radiation of heat the whole body will be more condensed than before, but whether it is hotter or colder than before will depend on whether the contraction set up is more or less than enough to restore an exact balance. If we are dealing with com­paratively recent periods there is no evidence of progressive change, but if we, go to remote epochs and suppose the sun to have once been diffused in a nebulous state, it is clear that its shrinkage, in spite of radiation, has left it hotter, so that, the shrinkage has outrun what would, suffice, to maintain its radiation. It is equally clear that there is a point beyond which contraction cannot go, and thereafter, if not before, the body will begin to grow colder. There is thus a turning-point in the life of every star. The movement towards contraction and consequent rise of temperature which radiation sets up, like other motions, overruns the equilibrium-point, only however by a minute amount; the accumulated excesses from all past time now stored in the sun would maintain its radia­tions at their present rate for n×3000 years, that is, for a few thousand, years only.

There is a superior limit to the quantity of energy which can be derived, from contraction. If we suppose the sun’s mass once existed, in a state of extreme diffusion, the energy yielded by collect­ing it into its present compass would not suffice to maintain its present, rate of radiation for more than 17,000,000 years in the past; nor if its mean density were ultimately to rise to eight times its present amount, for more than the same period in the future. This supposes the present density nearly uniform; if it is not uniform, any amount added to the former period is subtracted from the latter. , A contraction of 0∙2" or 90 m. in the sun’s radius would maintain the present emission for 3500 years. Such a rate of change would be quite insensible, and we can affirm that for recent times there is no reason to look for any other factor than contraction ; but if we consider the remote past it is a different matter. We know nothing quantitatively of the radiations from a nebulous body; and it is quite possible that the loss of radiant energy in this early stage was very small ; but it is at least as certain as any other physical inference that 17,000,000 years ago the earth itself was of its present dimensions, a comparatively old body with sea and living creatures upon it, and it is impossible to believe that the sun’s radiations were wholly different; but, if they were not, they have been maintained from some other source than contraction.

The fall of meteoric matter into the sun must be a certain source of energy; if considerable,, this external supply would retard the sun’s contraction and so increase its estimated age, but to bring about a reconciliation with geological theory, very nearly the whole amount must be thus supplied. It is easy to calculate that this would be produced by an annual fall of matter equal to one nineteen millionth of the sums mass, which would make an envelope eight metres thick, at the sun’s mean density; this would be collected during the year from a spherical space extending beyond the orbit of Jupiter. The earth would intercept an amount of it proportional to the solid angle it subtends at the sun; that is to say, it would receive a deposit of meteoric matter about one-tenth of a millimetre, of density say 2, oyer its whole surface in the course of the year. So far there is nothing impossible in the theory. But there are two fatal, objections. The sun is a small , target, for a meteorite coming from infinity to hit, and if this considerable quantity reaches its mark, a much greater amount will circulate round the sun in parabolas, and there is no evidence of it where it would certainly make itself felt, in perturbations of the planets. A second objection is that it fails in its purpose, because 20,000,000 years ago it would give a sun quite as much changed as the, contraction theory gave. If we examine chemical sources for maintenance of the sun’s heat, combustion and other forms of combination are out of the question, because no combinations of different elements are known to exist at a temperature of 6000°. A source which seems plausible, perhaps only because it is less easy to test, is rearrangement of the structure of the elements’ atoms. An atom is no longer figured as indivisible, it is made up of more or less complex, and more or less permanent, systems in internal circulation. Now under the law of attraction according to the inverse square of the distance, or any other inverse power beyond the first, the energy of even a single pair of material points is unlimited, if their possible closeness of approach to one another is unlimited. If the sources of energy within the atom can be drawn upon, and the phenomena of radio-activity leave no, doubt about this, there is here an incalculable source of, heat which takes the cogency out of any, other calculation respecting the sources maintaining the sun’s radiation. An equivalent statement of the same conclusion may be put thus: supposing a gaseous nebula is destined to condense into a sun, the elementary matter of which it is composed will develop in, the process into our known terrestrial and solar elements, parting with energy as it does so.

The continuous spectrum leads to no inference, except that of the temperature of the central globe; but the multitude of dark lines by which it is crossed reveal the elements composing the truly gaseous cloaks which enclose it. A table of these lines is a physical document as exact as it is intricate. The visual portion extends from about w.l.3700 to 7200 tenth-metres; the ultra-violet begins about 2970, beyond which point our atmosphere is almost perfectly opaque to it; the infra­red can be traced for more than ten times the visual length, but the gaps which indicate absorption-lines have not been mapped beyond 9870. The ultra-violet and the visual' portion are re­corded, photographically; Rowland’s classical work shows some 5700 lines in the former, and 14,200 in the latter, on a graduated scale of intensities from 1000 to 0, or 0000, for the faintest lines; between a quarter and a third of these lines have been identified, fully 2000 belonging to iron, and several hundred to water vapour and other atmospheric absorption. The infra-red requires special appliances; it has been examined visually by the help of phosphor­escent plates (Becquerel), and with special photographic plates (Abney); but the most efficient way is to use the bolometer or radiomicrometer; by this means some 500 or 600 lines have been mapped.

The first problem of the spectrum is to identify the effects of atmospheric absorption, especially oxygen, carbonic acid and water vapour; this is done generally by comparing the spectra of the sun at great and small zenith-distances, or by reducing the atmo­spheric effect by observing from a great elevation, as did P. J. C. Janssen from the summit of Mont Blanc, but the only unquestion­able test is to find those lines which are not touched by Doppler effect when the receding and advancing limbs of the sun are com­pared (Cornu); by this method H. F. Newall has verified the presence of cyanogen in the photosphere, and it had previously served to disprove the solar origin of certain oxygen lines. In fact, doubt long surrounded the presence of oxygen in the sun, and was not set at rest until K. D. T. Runge and F. Paschen in 1896 identified an unmistakable oxygen triplet in the infra-red, which is shown terres­trially only in the vacuum tube, where the spectrum is very different from that of atmospheric absorptions. The absence of lines of the spectrum of any element from the solar spectrum is no proof that the element is absent from the sun; apart from the possibility that the high temperature and other circumstances may show it trans­formed into some unknown mode,,which is perhaps the explanation of the absence of nitrogen, chlorine and other non-metals; if the element is of high atomic weight we should expect it to be found only in the lowest strata of the sun’s atmosphere, where its tempera­ture was nearly equal to that of the central globe, and so any absorp­tion line which it showed would be weak. This is undoubtedly the case with lead and silver, and probably with mercury also. In Rowland’s table lines from the arc-spectra of the following are identified. , The order is approximately that of, the numbers of identified lines. Excepting strontium, those which are low upon the list are represented also by lines of small intensity. The chromo­sphere adds the three, last of the list. The strongest lines are those due to calcium, iron, hydrogen, sodium, nickel, in the order named.