

3. That the penetration of the hyphæ of the *Saprolegnia* into the derma renders it at least possible that the disease may break out in a fresh-run salmon without re-infection.

4. That the cause of the disease, the *Saprolegnia*, may flourish in any fresh water; in the absence of salmon, as a saprophyte upon dead insects and other animals.

5. That the chances of infection for a healthy fish entering a river, are prodigiously increased by the existence of diseased fish in that river, inasmuch as the bulk of *Saprolegnia* on a few diseased fish vastly exceeds that which would exist without them.

6. That, as in the case of the potato disease, the careful extirpation of every diseased individual is the treatment theoretically indicated; though, in practice, it may not be worth while to adopt that treatment.

## II. "On the Conservation of Solar Energy." By C. WILLIAM SIEMENS, D.C.L., LL.D., F.R.S., Mem. Inst. C.E. Received February 20, 1881.

The question of the maintenance of Solar Energy is one that has been looked upon with deep interest by astronomers and physicists from the time of La Place downward.

The amount of heat radiated from the sun has been approximately computed, by the aid of the pyrhelimeter of Pouillet and by the actinometers of Herschel and others, at 18,000,000 of heat units from every square foot of his surface per hour, or, put popularly, as equal to the heat that would be produced by the perfect combustion every thirty-six hours of a mass of coal of specific gravity=1.5 as great as that of our earth.

If the sun were surrounded by a solid sphere of a radius equal to the mean distance of the sun from the earth (95,000,000 of miles), the whole of this prodigious amount of heat would be intercepted; but considering that the earth's apparent diameter as seen from the sun is only seventeen seconds, the earth can intercept only the 2,250-millionth part. Assuming that the other planetary bodies swell the intercepted heat by ten times this amount, there remains the important fact that  $\frac{224999999}{2250000000}$  of the solar energy is radiated into space, and apparently lost to the solar system, and only  $\frac{1}{225000000}$  utilised.

Notwithstanding this enormous loss of heat, solar temperature has not diminished sensibly for centuries, if we neglect the periodic changes—apparently connected with the appearance of sun-spots—that have been observed by Lockyer and others, and the question forces itself

upon us how this great loss can be sustained without producing an observable diminution of solar temperature even within a human lifetime.

Amongst the ingenious hypotheses intended to account for a continuance of solar heat is that of shrinkage, or gradual reduction of the sun's volume suggested by Helmholtz. It may, however, be urged against this theory that the heat so produced would be liberated throughout his mass, and would have to be brought to the surface by conduction, aided perhaps by convection; but we know of no material of sufficient conductivity to transmit anything approaching the amount of heat lost by radiation.

Chemical action between the constituent parts of the sun has also been suggested; but here again we are met by the difficulty that the products of such combination would ere this have accumulated on the surface, and would have formed a barrier against further action.

These difficulties led Sir William Thomson to the suggestion that the cause of maintenance of solar temperature might be found in the circumstance of meteorolites falling upon the sun, not from great distances in space, as had been suggested by Mayer and Waterston, but from narrow orbits which slowly contracted by resistance until at last the meteorolites became entangled in the sun's atmosphere and fell in; and he shows that each pound of matter so imparted would represent a large number of heat units without disturbing the planetary equilibrium. But in considering more fully the enormous amount of planetary matter that would be required for the maintenance of the solar temperature, Sir William Thomson soon abandoned this hypothesis for that of simple transfer of heat from the interior of a fluid sun to the surface by means of convection currents, which latter hypothesis appears at the present time to be also supported by Professor Stokes and other leading physicists.

But if either of these hypotheses could be proved, we should only have the satisfaction of knowing that the solar waste of energy by dissipation into space was not dependent entirely upon loss of his sensible heat, but that his existence as a luminary would be prolonged by calling into requisition a limited, though may be large, store of energy in the form of separated matter. The true solution of the problem will be furnished by a theory, according to which radiant energy which is now supposed to be dissipated into space and irrecoverably lost to our solar system, could be arrested, wholly or partly, and brought back in another form to the sun himself, there to continue the work of solar radiation.

Some years ago it occurred to me that such a solution of the solar problem might not lie beyond the bounds of possibility, and although I cannot claim intimate acquaintance with the intricacies of solar physics, I have watched its progress, and have engaged also in some

physical experiments bearing upon the question, all of which have served to strengthen my confidence and ripened in me the determination to submit my views, not without some misgiving, to the touchstone of scientific criticism.

For the purposes of my theory, stellar space is supposed to be filled with highly rarefied gaseous matter, including probably hydrogen, oxygen, nitrogen, carbon, and their compounds, besides solid materials in the form of dust. This being the case, each planetary body would attract to itself an atmosphere depending for its density upon its relative attractive importance, and it would not seem unreasonable to suppose that the heavier and less diffusible gases would form the staple of these atmospheres; that, in fact, they would consist mostly of nitrogen, oxygen, and carbonic anhydride, whilst hydrogen and its compounds would predominate in space.

But the planetary system, as a whole, would exercise an attractive influence upon the gaseous matter diffused through space, and would therefore be enveloped in an atmosphere, holding an intermediate position between the individual planetary atmospheres and the extremely rarefied atmosphere of the stellar space.

In support of this view it may be urged, that in following out the molecular theory of gases as laid down by Clausius, Clerk Maxwell, and Thomson, it would be difficult to assign a limit to a gaseous atmosphere in space and, further, that some writers, among whom I will here mention only Grove, Humboldt, Zoellner, and Mattieu Williams, have boldly asserted the existence of a space filled with matter, and that Newton himself, as Dr. Sterry Hunt tells us in an interesting paper which has only just reached me, has expressed views in favour of such an assumption. Further than this, we have the facts that meteorolites whose flight through stellar, or at all events through interplanetary space, is suddenly arrested by being brought into collision with our earth, are known to contain as much as six times their own volume of gases taken at atmospheric pressure; and Dr. Flight has only very recently communicated to the Royal Society the analysis of the occluded gases of one of these meteorolites taken immediately after the descent to be as follows:—

CO <sub>2</sub> .....	0·12
CO .....	31·88
H .....	45·79
CH <sub>4</sub> .....	4·55
N.....	17·66
	<hr/>
	100·00

It appears surprising that there was no aqueous vapour, considering there was much hydrogen and oxygen in combination with carbon, but

perhaps the vapour escaped observation, or was expelled to a greater extent than the other gases by external heat when the meteorolite passed through our atmosphere. Opinions concur that the gases found occluded in meteorolites cannot be supposed to have entered into their composition during the very short period of traversing our atmosphere, but if any doubt should exist on this head, it ought to be set at rest by the fact that the gas principally occluded is hydrogen, which is not contained in our atmosphere in any appreciable quantity.

Further proof of the fact that stellar space is filled with gaseous matter is furnished by spectrum analysis, and it appears from recent investigation, by Dr. Huggins and others, that the nucleus of a comet contains very much the same gases found occluded in meteorolites, including "carbon, hydrogen, nitrogen, and probably oxygen," whilst, according to the views set forth by Dewar and Liveing, it also contains nitrogenous compounds such as cyanogen.

Adversely to the assumption that interplanetary space is filled with gases, it is urged that the presence of ordinary matter would cause sensible retardation of planetary motion, such as must have made itself felt before this; but assuming that the matter filling space is an almost perfect fluid not limited by border surfaces, it can be shown on purely mechanical grounds, that the retardation by friction through such an attenuated medium would be very slight indeed, even at planetary velocities.

But it may be contended that, if the views here advocated regarding the distribution of gases were true, the sun should draw to himself the bulk of the least diffusible, and therefore the heaviest gases, such as carbonic anhydride, carbonic oxide, oxygen and nitrogen, whereas spectrum analysis has proved on the contrary a prevalence of hydrogen.

In explanation of this seeming anomaly, it can be shown in the first place, that the temperature of the sun is so high, that such compound gases as carbonic anhydride and carbonic oxide, could not exist within him; it has been contended, indeed, by Mr. Lockyer, that none of the metalloids have any existence at these temperatures, although as regards oxygen, Dr. Draper asserts its existence in the solar photosphere. There must be regions, however, outside that thermal limit, where their existence would not be jeopardised by heat, and here great accumulation of those comparatively heavy gases that constitute our atmosphere would probably take place, were it not for a certain counterbalancing action.

I here approach a point of principal importance in my argument, upon the proof of which my further conclusions must depend.

The sun completes one revolution on its axis in 25 days, and its diameter being taken at 882,000 miles, it follows that the tangential velocity amounts to 1.25 miles per second, or to 4.41 times the

tangential velocity of our earth. This high rotative velocity of the sun must cause an equatorial rise of the solar atmosphere to which Mairan, in 1731, attributed the appearance of the zodiacal light. La Place rejected this explanation on the ground that the zodiacal light extended to a distance from the sun exceeding our own distance, whereas the equatorial rise of the solar atmosphere due to its rotation could not exceed  $\frac{9}{20}$ ths of the distance of Mercury. But it must be remembered that La Place based his calculation upon the hypothesis of an empty stellar space (filled only with an imaginary ether), and that the result of solar rotation would be widely different, if it was supposed to take place within a medium of unbounded extension. In this case pressures would be balanced all round, and the sun would act mechanically upon the floating matter surrounding it in the manner of a fan, drawing it towards itself upon the polar surfaces, and projecting it outward in a continuous disk-like stream.

By this fan action, hydrogen, hydrocarbons, and oxygen, are supposed to be drawn in enormous quantities toward the polar surfaces of the sun; during their gradual approach, they will pass from their condition of extreme attenuation and extreme cold, to that of compression; accompanied with rise of temperature, until on approaching the photosphere, they burst into flame, giving rise to a great development of heat, and a temperature commensurate with their point of dissociation at the solar density. The result of their combustion will be aqueous vapour and carbonic anhydride or oxide, according to the sufficiency or the insufficiency of oxygen present to complete the combustion, and these products of combustion in yielding to the influence of centrifugal force will flow toward the solar equator, and be thence projected into space.

The next question for consideration is: What would become of these products of combustion when thus rendered back into space? Apparently they would gradually change the condition of stellar material, rendering it more and more neutral, but I venture to suggest the possibility, nay, the probability, that solar radiation would, under these circumstances, step in to bring back the combined materials to a condition of separation by a process of dissociation carried into effect at the expense of that solar energy which is now supposed to be lost to our planetary system.

According to the law of dissociation as developed by Bunsen and Sainte-Claire Deville, the point of dissociation of different compounds depends upon the temperature on the one hand, and upon the pressure on the other. According to Sainte-Claire Deville, the dissociation tension of aqueous vapour of atmospheric pressure and at  $2800^{\circ}$  C. is 0.5, or only half of the vapour can exist as such, its remaining half being found as a mechanical mixture of hydrogen and oxygen, but that with the pressure, the temperature of dissociation rises and falls,

as the temperature of saturated steam rises and falls with its pressure. It is therefore conceivable that the temperature of the solar photosphere may be raised by combustion to a temperature exceeding  $2800^{\circ}$  C., whereas dissociation may be effected in space at comparatively low temperatures.

These investigations had reference only to heats measured by means of pyrometers, but do not extend to the effects of radiant heat. Dr. Tyndall has shown by his exhaustive researches that vapour of water and other gaseous compounds intercept radiant heat in a most remarkable degree, and there is other evidence to show that radiant energy from a source of high intensity possesses a dissociating power far surpassing the measurable temperature to which the compound substance under its influence is raised. Thus carbonic anhydride and water are dissociated in the leaf cells of plants, under the influence of the direct solar ray at ordinary summer temperature, and experiments in which I have been engaged for nearly three years\* go to prove that this dissociating action is obtained also under the radiant influence of the electric arc, although it is scarcely perceptible if the source of radiant energy is such as can be produced by the combustion of oil or gas.

The point of dissociation of aqueous vapour and carbonic anhydride admits, however, of being determined by direct experiment. It engaged my attention some years ago, but I have hesitated to publish the qualitative results I then obtained, in the hope of attaining to quantitative proofs.

These experiments consisted in the employment of glass tubes, furnished with platinum electrodes, and filled with aqueous vapour or with carbonic anhydride in the usual manner, the latter being furnished with caustic soda to regulate the vapour pressure by heating. Upon immersing one end of the tube charged with aqueous vapour in a refrigerating mixture of ice and chloride of calcium, its temperature at that end was reduced to  $-32^{\circ}$  C., corresponding to a vapour pressure, according to Regnault, of  $\frac{1}{1800}$  of an atmosphere. When so cooled no slow electric discharge took place on connecting the two electrodes with a small induction coil. I then exposed the end of the tube projecting out of the freezing mixture, backed by white paper, to solar radiation (on a clear summer's day) for several hours, when upon again connecting up to the inductorium, a discharge, apparently that of a hydrogen vacuum, was obtained. This experiment being repeated furnished unmistakable evidence, I thought, that aqueous vapour had been dissociated by exposure to solar radiation. The  $\text{CO}_2$  tubes gave, however, less reliable results. Not satisfied with these qualitative results, I made arrangements to collect the permanent

\* See "Proc. Roy. Soc.," vol. 30, p. 208, and paper read before Section A, British Association, and printed in full in the Report for 1881, Part I, p. 474.

gases so produced by means of a Sprengel pump, but was prevented by lack of time from pursuing the inquiry, which I purpose, however, to resume shortly, being of opinion that, independently of my present speculation, the experiments may prove useful in extending our knowledge regarding the laws of dissociation.

It should here be observed that, according to Professor Stokes, the ultra-violet rays are in a large measure absorbed in passing through clear glass, and it follows from this discovery that only a small portion of the chemical rays found their way through the tubes to accomplish the work of dissociation. This circumstance, being adverse to the experiment, only serves to increase the value of the result observed.

Assuming, for my present purpose, that dissociation of aqueous vapour was really effected in the experiment just described, and assuming, further, that stellar space is filled with aqueous and other vapour of a density not exceeding the  $\frac{1}{10000}$ th part of our atmosphere, it seems reasonable to suppose that its dissociation would be effected by solar radiation, and that solar energy would thus be utilised. The presence of carbonic anhydride and carbonic oxide would only serve to facilitate the decomposition of the aqueous vapour by furnishing substances to combine with nascent oxygen and hydrogen. It is not necessary to suppose that all the energy radiated from the sun into space should be intercepted, inasmuch as even a partial return of heat in the manner described would serve to supplement solar radiation, the balance being made up by absolute loss. To this loss of energy must be added that involved in keeping up the circulating movement of the gas, which, however, would probably not be relatively greater than that concerned in the tidal retardation of the earth's rotation. By means of the fan-like action resulting from the rotation of the sun, the vapours dissociated in space would be drawn towards the polar surfaces of the sun, be heated by increase in density, and would burst into flame at a point where both their density and temperature had reached the necessary elevation to induce combustion, each complete cycle taking, however, years to be accomplished. The resulting aqueous vapour, carbonic anhydride and carbonic oxide, would be drawn towards the equatorial regions, and be then again projected into space by centrifugal force.

Space would, according to these views, be filled with gaseous compounds in process of decomposition by solar radiant energy, and the existence of these gases would furnish an explanation of the solar absorption spectrum, in which the lines of some of the substances may be entirely neutralised and lost to observation. As regards the heavy metallic vapours revealed in the sun by the spectroscope, it is assumed that these form a lower and denser solar atmosphere, not participating in the fan-like action which is supposed to affect the light outer atmosphere only, in which hydrogen is the principal factor.

Such a dense metallic atmosphere could not participate in the fan action affecting the lighter photosphere, because this is only feasible on the supposition that the density of the in-flowing current is, at equal distances from the gravitating centre, equal or nearly equal to the outflowing current. It is true that the products of combustion of hydrogen and carbonic oxide are denser than their constituents, but this difference may be balanced by their superior temperature on leaving the sun, whereas the metallic vapours would be unbalanced, and would therefore obey the laws of gravitation, recalling them to the sun. On the surface of contact between the two solar atmospheres intermixture, induced by friction, must take place, however, giving rise perhaps to those vortices and explosive effects which are revealed to us by the telescope in the intermediate or stormy region of the sun, and which have been commented on by Sir John Herschel and other astronomers. Some of the denser vapours would probably get intermixed and carried away mechanically by the lighter gases, and give rise to that cosmic dust which is observed to fall upon our earth in not inappreciable quantities. Excessive intermixture would be prevented by the intermediary neutral atmosphere, the penumbra.

As the whole solar system moves through space at a pace estimated at 150,000,000 of miles annually (being about one-fourth of the velocity of the earth in its orbit), it appears possible that the condition of the gaseous fuel supplying the sun may vary according to its state of previous decomposition, in which other heavenly bodies may have taken part. May it not be owing to such differences in the quality of the fuel supplied that the observed variations of the solar heat may depend? and may it not be in consequence of such changes in the thermal condition of the photosphere that sun-spots are formed?

The views here advocated could not be thought acceptable unless they furnished at any rate a consistent explanation of the still somewhat mysterious phenomena of the zodiacal light and of comets. Regarding the former, we should be able to return to Mairan's views, the objection by La Place being met by a continuous outward flow from the solar equator. Luminosity would be attributable to particles of dust emitting light reflected from the sun, or by phosphorescence. But there is another cause for luminosity of these particles, which may deserve a passing consideration. Each particle would be electrified by gaseous friction in its acceleration, and its electric tension would be vastly increased in its forcible removal, in the same way as the fine dust of the desert has been observed by Werner Siemens to be in a state of high electrification on the apex of the Cheops Pyramid. Would not the zodiacal light also find explanation by slow electric discharge backward from the dust towards the sun? and would the same cause not account for a great difference of potential between the sun and earth, which latter may be supposed to be washed by the solar



radial current? May not the presence of the current also furnish us with an explanation of the fact that hydrogen, while abounding apparently in space, is practically absent in our atmosphere, where aqueous vapour, which may be partly derived from the sun, takes its place? An action analogous to this, though on a much smaller scale, may be set up also by terrestrial rotation giving rise to an electrical discharge from the outgoing equatorial stream to the polar regions, where the atmosphere to be pierced by the return flood is of least resistance.

It is also important to show how the phenomena of comets could be harmonised with the views here advocated, and I venture to hope that these occasional visitors will serve to furnish us with positive evidence in my favour. Astronomical physicists tell us that the nucleus of a comet consists of an aggregation of stones similar to meteoric stones. Adopting this view, and assuming that the stones have absorbed in stellar space gases to the amount of six times their volume, taken at atmospheric pressure, what it may be asked, will be the effect of such a mass of stone advancing towards the sun at a velocity reaching in perihelion the prodigious rate of 366 miles per second (as observed in the comet of 1845), being twenty-three times our orbital rate of motion. It appears evident that the entry of such a divided mass into a comparatively dense atmosphere must be accompanied by a rise of temperature by frictional resistance, aided by attractive condensation. At a certain point the increase of temperature must cause ignition, and the heat thus produced must drive out the occluded gases, which in an atmosphere 3000 times less dense than that of our earth would produce  $6 \times 3000 = 18,000$  times the volume of the stones themselves. These gases would issue forth in all directions, but would remain unobserved except in that of motion, in which they would meet the interplanetary atmosphere with the compound velocity, and form a zone of intense combustion, such as Dr. Huggins has lately observed to surround the one side of the nucleus, evidently the side of forward motion. The nucleus would thus emit original light, whereas the tail may be supposed to consist of stellar dust rendered luminous by reflex action produced by the light of the sun and comet combined, as foreshadowed already by Tyndall, Tate, and others, starting each from different assumptions.

These are in brief the outlines of my reflections regarding this most fascinating question, which I venture to put before the Royal Society. Although I cannot pretend to an intimate acquaintance with the more intricate phenomena of solar physics, I have long had a conviction, derived principally from familiarity with some of the terrestrial effects of heat, that the prodigious and seemingly wanton dissipation of solar heat is unnecessary to satisfy accepted principles regarding the conservation of energy, but that it may be arrested and returned over and over again to the sun, in a manner somewhat analogous

to the action of the heat recuperator in the regenerative gas furnace. The fundamental conditions are :—

1. That aqueous vapour and carbon compounds are present in stellar or interplanetary space.

2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That these dissociated vapours are capable of being compressed into the solar photosphere by a process of interchange with an equal amount of reassociated vapours, this interchange being effected by the centrifugal action of the sun itself.

If these conditions could be substantiated, we should gain the satisfaction that our solar system would no longer impress us with the idea of prodigious waste through dissipation of energy into space, but rather with that of well-ordered self-sustaining action, capable of perpetuating solar radiation to the remotest future.

*March 9, 1882.*

#### THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The Right Hon. Anthony John Mundella, whose certificate had been suspended as required by the Statutes, was balloted for and elected a Fellow of the Society.

The following Papers were read :—

- I. Experiments to Determine the Value of the British Association Unit of Resistance in Absolute Measure." By LORD RAYLEIGH, F.R.S., Professor of Experimental Physics in the University of Cambridge. Received February 15, 1882.

(Abstract.)

This paper contains an account of a repetition by Dr. Schuster, Mrs. Sidgwick, and myself, of the British Association experiment on the unit of resistance with an improved apparatus. Three distinct series of observations were taken, of which the two first were more or less imperfect. In the third series an extraordinary concordance in the results obtained on different occasions at the same speed of rotation was arrived at, but the numbers corresponding to the four speeds