of no consequence, provided the distance is not altered; thus two candles one foot off give the same number of revolutions per second, whether they are side by side or opposite to each other. From this it follows that if the radiometer is brought into a uniformly lighted space it will continue to revolve. This is proved to be the case by experiment.

The speed with which a sensitive radiometer will revolve in full sunshine is almost incredible. Nothing is apparent but an undefined nebulous ring, which becomes at times almost invisible. The number of revolutions per second cannot be counted, but it must be several hundreds, for one candle will make the arms spin round forty times a second.

The action of dark heat (*i. e.* from boiling water) is to repel each surface equally, and the movement of the radiometer is therefore arrested if a flask of boiling water is brought near it. The same effect is produced by ice.

From some observations made by the author, it appears probable that heat of a still lower refrangibility repels the white more than it does the black surface. Many instances are given of the radiometer revolving the reverse way. Thus breathing gently on the instrument will generally cause this effect to be produced.

An experiment is described with a radiometer the moving parts of which are of aluminium, blacked on one side. When exposed to the radiation from a candle the arms revolve the normal way. On removing the candle they revolve the reverse way. Heated with a Bunsen burner the arms revolve the normal way as they are getting hot; but as soon as the source of heat is removed and cooling commences, rotation sets up in the reverse way, and continues with great energy till the whole is cold. The reverse movement during the cooling is apparently equal in energy to the normal movement as it is being heated.

It is easy to get rotation in a radiometer without having the surfaces of the disks differently coloured. An experiment is described with one having the pith disks blacked on both sides. On bringing a candle near it, and shading the light from one side, rapid rotation is produced, which is at once altered in direction by moving the shade to the other side.

The author describes many forms of radiometer, by means of which the movements can be exhibited to a large audience, or can be made to record themselves telegraphically on a self-recording instrument.

II. "On Repulsion resulting from Radiation."—Part IV. By William Crookes, F.R.S. &c. Received February 5, 1876.

(Abstract.)

In this paper the author describes experiments on the repulsion produced by the different rays of the solar spectrum. The apparatus employed is the horizontal beam suspended by a glass fibre and having

square pieces of pith at each end coated with lampblack. The whole is fitted up and hermetically sealed in glass, and connected with an improved mercury-pump. In front of the square of pith at one end a quartz window is cemented to the apparatus; and the movements of the beam, when radiation falls on the pith, are observed by a reflected ray of light on a millimetre-scale. The apparatus was fitted up in a room specially devoted to it, and was protected on all sides, except where the rays of light had to pass, with cotton-wool and large bottles of water. A heliostat reflected in a constant direction a beam of sunlight, which was received on an appropriate arrangement of slit, lenses, and prisms for projecting a pure spectrum. Results were obtained in the months of July, August, and September; and they are given in the paper graphically as a curve, the maximum being in the ultra-red, and the minimum in the ultra-violet. Taking the maximum at 100, the following are the mechanical values of the different colours of the spectrum:—

Ultra-red	100
Extreme red	85
Red	73
Orange	66
Yellow	57
Green	41
Blue	22
Indigo	$8\frac{1}{2}$
Violet	6
Ultra-violet	5

A comparison of these figures with those usually given in text-books to represent the distribution of heat in the spectrum is a sufficient proof that the mechanical action of radiation is as much a function of the luminous rays as it is of the dark heat-rays.

The author discusses the question, "Is the effect due to heat or to light?" There is no real difference between heat and light; all we can take account of is difference of wave-length; and a ray of a definite refrangibility cannot be split up into two rays, one being heat and one light. Take, for instance, a ray of definite refrangibility in the red. Falling on a thermometer it shows the action of heat, on a thermopile it produces an electric current, to the eye it appears as light and colour, on a photographic plate it causes chemical action, and on the suspended pith it causes motion. But all these actions are inseparable attributes of the ray of that particular wave-length, and are not evidence of separate identities.

The author enters into some theoretical explanations of the action of the different parts of the spectrum but these cannot well be given in abstract.

An experiment is described by which sunlight was filtered through alum,

glass, and water screens, so as to cut off the whole of the ultra-red or dark-heat rays. The ray of light which was thus freed from dark heat was allowed to fall on the pith surface of the torsion-apparatus, when it produced a deflection of 105°. On interposing a solution of iodine in disulphide of carbon the deflection fell to 2°, showing that the previous action was almost entirely due to *light*. With a candle tried under the same circumstances, the light filtered from dark heat produced a deflection of 37°, which was reduced to 5° by interposing the opaque solution of iodine.

In order to obtain comparative results among disks of pith coated with lampblack and with other substances, a torsion-apparatus was constructed in which two or more disks could be exposed one after the other to a standard light. One disk always being lampblacked pith, the other disks could be changed so as to get comparisons of action. If the action of radiation from a candle on the lampblacked disk be taken as 100, the following are the proportions obtained:—

On Lampblacked pith	100
Iodide of palladium	87·3
Precipitated silver	56
Amorphous phosphorus	40
Sulphate of baryta	37
Milk of sulphur	31
Red oxide of iron	28
Scarlet iodide of mercury and copper	22
Lampblacked silver	18
White pith	18
Carbonate of lead	13
Rock-salt	6·5
Glass	6·5

In consequence of some experiments tried by Profs. Tait and Dewar, and published in 'Nature,' July 15, 1875, the author fitted up a very sensitive apparatus for the purpose of carefully examining the action of radiation on alum, rock-salt, and glass. The source of radiation was a candle. Perfectly transparent and highly polished plates of the same size were used, and the deflection was made evident by an index ray of light. Taking the action on the alum at 100, that on the rock-salt in five successive experiments was 81, 77·3, 71, 62·5, 60·4. This increasing action on the alum was found to be caused by efflorescence, which took place rapidly in the vacuum, and rendered the crystal partially opaque. A fresh alum plate being taken, this and the rock-salt were coated with lampblack and replaced in the apparatus, the black side away from the source of radiation, so that the radiation would pass through the crystal before reaching the lampblack. The action of radiation was in the proportion of blacked alum 100 to blacked rock-salt 73.

Rock-salt and glass were next tested against each other *in vacuo* in a torsion-balance. Professors Dewar and Tait say that rock-salt is inactive when the beam from a candle is thrown on it, while a glass disk is active. The author has failed to corroborate these results; he found the mean of several concordant observations to be—rock-salt 39, glass 40.

The Measurement of the Force.

The author describes a torsion-balance in which he is enabled to weigh the force of radiation from a candle, and give it in decimals of a grain. The principle of the instrument is that of W. Ritchie's torsion-balance, described in the Philosophical Transactions for 1830. The construction is somewhat complicated, and cannot be well described without reference to the diagrams which accompany the original paper. A light beam, having two square inches of pith at one end, is balanced on a very fine fibre of glass stretched horizontally in a tube, one end of the fibre being connected with a torsion-handle passing through the tube, and indicating angular movements on a graduated circle. The beam is cemented to the torsion-fibre, and the whole is enclosed in glass and connected with the mercury-pump and exhausted as perfectly as possible. A weight of 0·01 grain is so arranged that it can be placed on the pith or removed from it at pleasure. A ray of light from a lamp reflected from a mirror in the centre of the beam to a millimetre-scale 4 feet off shows the slightest movement. When the reflected ray points to zero, a turn of the torsion-handle in one or the other direction will raise or depress the pith end of the beam, and thus cause the index ray to travel along the scale to the right or to the left. If a small weight is placed on one end so as to depress it, and the torsion-handle is then turned, the tendency of the glass fibre to untwist itself will ultimately balance the downward pressure of the weight, and will again bring the index ray to zero. It was found that when the weight of the $\frac{1}{100}$ of a grain was placed on the pith surface, the torsion-handle had to be turned 27 revolutions and 353°, or 10073° before the beam became horizontal. The downward pressure of the $\frac{1}{100}$ of a grain was therefore equivalent to the force of torsion of the glass thread when twisted through 10073°.

The author next ascertained what was the smallest amount of weight which the balance would indicate. He found that 1° of torsion gave a very decided movement of the index ray of light, a torsion of 10073° balancing the $\frac{1}{100}$ of a grain, while 10074° overbalanced it. The balance will therefore turn to the $\frac{99}{100,000,000}$ of a grain.

Divide a grain weight into a million parts, place one of them on the pan of the balance, and the beam will be instantly depressed.

Weighed in this balance the mechanical force of a candle 12 inches off was found to be 0·000444 grain; of a candle 6 inches off 0·001772 grain. At half the distance the weight of radiation should be four times, or 0·001776 grain; the difference between theory and experiment being

only four millionths of a grain is a sufficient proof that the indications of this instrument, like those of the apparatus previously described by the author, follow rigidly the law of inverse squares. An examination of the differences between the separate observations and the mean shows that the author's estimate of the sensitiveness of his balance is not excessive, and that in practice it will safely indicate the millionth of a grain.

One observation of the weight of sunlight is given; it was taken on December 13; but the sun was so obscured by thin clouds and haze that it was only equal to 10·2 candles 6 inches off. Calculating from this datum, it is seen that the pressure of sunshine is 2·3 tons per square mile.

The author promises further observations with this instrument, not only in photometry and in the repulsion caused by radiation, but in other branches of science in which the possession of a balance of such incredible delicacy is likely to furnish valuable results.

February 17, 1876.

Dr. J. DALTON HOOKER, C.B., President, in the Chair.

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

The following Papers were read :—

I. "Researches upon the Specific Volumes of Liquids." By T. E. THORPE, Ph.D., F.R.S.E., Professor of Chemistry in the Yorkshire College of Science, Leeds. Communicated by Prof. A. W. WILLIAMSON, For. Sec. R.S. Received January 14, 1876.

II. *On the Specific Volumes of certain similarly constituted Inorganic Chlorides.*

The results of the observations made by Pierre and Kopp upon the boiling-points, specific gravities, and thermal expansibilities of the trichlorides and tribromides of phosphorus, arsenic, and antimony have led Kopp to suppose that the specific volumes of phosphorus, arsenic, and antimony, in their liquid combinations, may be identical. The same conclusion has been drawn with respect to tin, titanium, and silicon from Pierre's observations upon the tetrachlorides of these elements*.

* Ann. der Chem. u. Pharm. xcvi. p. 319. In his original paper Kopp remarks that the specific volume of antimony, from his observations on the chloride, $SbCl_3$, and the bromide, $SbBr_3$, is decidedly larger than that of phosphorus and arsenic. But the larger value is in part due to the atomic weight of antimony being taken as 129. If the more