dowment of research laboratories. I have tried to make it clear that the physicist must avail himself of the powers and energies set in play in the larger industrial enterprises, and finally that the field of possible exploration in physics by experimental methods has its natural boundaries, outside of which our advances in knowledge must be derived from a study of celestial bodies.

The riddle of gravitation is yet to be solved. This all-permeating force must be connected with other forcec and other properties of matter. It will be a delicate task, indeed, for the total attraction between very large masses closely adjacent, aside from the earth's attraction, is very small.

Scientific facts are of little value in themselves. Their significance is their bearing upon other facts, enabling us to generalize and so to discover principles, just as the accurate measurement of the position of a star may be without value in itself, but in relation to other similar measurements of other stars may become the means of discovering their proper motions. We refine our instruments ; we render more trustworthy our means of observation ; we extend our range of experimental inquiry, and thus lay the foundation for the future work, with the full knowledge that, although our researches cannot extend beyond certain limits, the field itself is, even within those limits, inexhaustible.

ELIHU THOMSON.

PHOSPHORESCENT SUBSTANCES AT LIQUID-AIR TEMPERATURES.

A RECENT number of the *Philosophical Magazine** contains a paper 'On Phosphorescence,' by Herbert Jackson, which was delivered before the meeting of the British Association at Bristol, September 12, 1898, a portion of the paper being devoted to a review of the results obtained in researches relating to phosphorescent phenomena. It is evident from the paper that considerable investigation has been undertaken to ascertain the effects of high temperatures on phosphorescent substances, but that comparatively little has been done towards learning the behavior of the latter at very low temperatures, such as are obtained by the use of liquefied air. It is stated, however, in the paper referred to, that, "Professor Dewar has shown that great reduction of the temperature will cause phosphorescence to linger for a considerable time in many substances which had hitherto been considered as practically non-phosphorescent." This in particular refers to the phosphorescence produced in certain substances when exposed to light while at a temperature near that of liquefied air. Ivory, paper, and various other materials show phosphorescence under such conditions, but little or none at normal temperatures (20° C.).

Professor Dewar has found also that when a phosphorescent substance is excited by light at a normal temperature and then immersed in liquefied air the phosphorescent discharge is practically suspended, and continues so while the substance remains at the low temperature. August and Louis Lumiere have recently published a note in the *Comptes rendus*, CXXVIII., No. 9, 1899, p. 549, 'Influence des températures très basses sur la phosphorescence,' to which reference will be made presently.

The results obtained in some experiments made by the writer on the effect of liquid-air temperatures on phosphorescent substances are given below. These experiments were already completed when it was learned that the above-mentioned note in the *Comptes rendus* had been published. They were as follows :

Balmain's luminous paint, which is strongly phosphorescent at normal temperatures, was subjected to a very low temperature by the use of liquefied air, boiling

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* *Phil. Mag.*, Lon. 46, 281, p. 402, Sept., 1898.

under atmospheric pressure. The sun and the electric arc were both used to excite phosphorescence in this substance. The temperature of the liquefied air employed, from experiments made with a platinum resistance thermometer, was determined to be approximately —188° C. It varied several degrees during the experiments, on account of changes in the composition of the liquefied air, due to ebullition.

Balmain's paint is a polysulphide of calcium mixed with varnish. The former is prepared by a secret process, but probably produced by mixing the powdered shells of certain shellfish with sulphur, and calcining these together at a high temperature in a closed crucible.

A number of experiments were performed with Balmain's paint at about 20 C. in order to ascertain the properties of this particular substance at ordinary temperatures.

Test cards of the phosphorescent material were prepared for the experiments in the following manner:

A sheet of cardboard was covered with dead black paper and a portion of it coated as evenly as possible with the luminous paint; it was then cut into cards, each having a surface approximately 4 x 5 centimeters coated with paint. Test plates of thin sheet iron were also coated with the same substance.

The preliminary experiments, at normal temperatures (20° C.), showed: (1) that Balmain's paint, exposed for a few seconds to the sun or the electric arc, gave bright violet phosphorescence when removed immediately away from strong light, and that after being in the dark for three hours its luminosity was so faint as to be hardly visible; (2) that a very slight elevation of temperature, a few degrees, caused a perceptible brightening of the phosphorescent surface, and that when the temperature of the substance was lowered, its luminosity was lessened in a corresponding manner; (3) that the brightening of the phosphorescent surface caused by the application of heat was merely a rapid discharge of the phosphorescent energy; (4) that a test card of luminous paint exposed to sunlight and then placed in darkness for three weeks showed phosphorescence when heated to about 300 degrees C.; (5) that the part of the solar spectrum producing phosphorescence in the substance employed was practically entirely that towards the violet end; (6) that the infra-red rays of the solar spectrum falling on a phosphorescent surface rapidly discharged the phosphorescence.

Those who have investigated this subject are no doubt familiar with these facts, but they are mentioned here for the purpose of comparison with the observations made at low temperatures.

1. When a card covered with Balmain's paint was exposed to strong sunlight, taken into a dark room, and then immersed in liquified air (about 188° below zero C.) its phosphorescence was so reduced as to appear perfectly destroyed. When, however, this card was allowed to warm up gradually to the temperature of the room (20° C.) the phosphorescence again became active, being almost as bright as before immersion in liquefied air.

2. A phosphorescent card treated in the manner just described, except rapidly warmed to the temperature of the room (from—188° C.) by immersion in water at 20° C., was then compared with a card having had the same exposure to sunlight but not placed in liquid air. It was observed that the two cards presented little difference in luminosity, showing that the temporary reduction of the temperature of the one placed in liquid air had not resulted in an appreciable change in its phosphorescent energy. The card which had been in the liquid air was slightly the brighter of the two. This was to be expected, because the

discharge of its phosphorescence had been temporarily checked by the cold liquid bath, while the phosphorescence of the other card, which was at 20° C. throughout the experiment, was being discharged continuously; the latter, therefore, was slightly more exhausted.

3. Two cards similarly coated with Balmain's paint and which had been placed away from light for several days were exposed to the sun; one ('A') in the ordinary manner, and the other ('B') exposed while immersed in liquid air.

The cards were brought to the dark-room, and the one ('A'), that had not been subjected to the low temperatare, was immediately immersed in liquid air.

Both cards were then taken out of the cold bath and allowed to warm up gradually to the temperature of the dark room. Almost immediately card 'B', which had been exposed to sunlight while in liquid air, showed phosphorescence, appearing comparatively bright by the time the other card ('A') became luminous; the latter, however, getting rapidly brighter soon phosphoresced more strongly than the card 'B', which was exposed to the sun while immersed in liquid air.

This experiment was repeated many times with always the same result.

Several times the test card which had been exposed to the sun while in liquid air showed faint phosphorescence when still in the cold bath. On employing an electric arc, however, the Balmain's paint was made to phosphoresce much more strongly while at the temperature of liquid air than when using sunlight.

On repeating the experiment with two stop-watches it was found that the card 'B', exposed to the sun while in liquid air, required not more than 5 to 10 seconds to show phosphorescence distinctly, when allowed to warm up gradually to 20° C. in the dark room. The card 'A', simply exposed to the sun and immersed in liquid air in the dark, required 40 seconds as the average time to show luminosity.

In order to obtain an approximate value for the temperature corresponding to this time of 40 seconds, small sticks of wood, weighted with lead, were frozen to the test card with alcohol and afterwards with mercury. The cards were placed in liquid air and then allowed to warm up to the room temperature exactly as in the experiments on phosphorescence. The sticks frozen with alcohol fell from the test cards in 17 seconds, a value found by ten determinations, showing little variation from the mean. The sticks frozen with mercury fell from the card in 90 seconds. From this it was obvious that the 40 seconds required for the phosphorescence to become visible in the experiment mentioned above with card 'A' corresponded to a temperature between the melting point of alcohol and that of mercury, or a temperature of from 75° to 100° below zero C. Only this rough approximation of temperature was made because a more accurate determination would have had no general significance. This is evident when it is remembered that the phosphorescing power of different samples of the same material, the intensity of the light employed to excite a phosphorescent substance, and the sensitiveness of the eyes of different observers, all of which determine temperature values like that under consideration, are factors which are subject to considerable variation.

The results obtained in the foregoing experiments are in agreement with those published in the *Comptes rendus* by A. and L. Lumiere, already referred to. In the experiments of these investigators the electric arc was employed to excite phosphorescence in sulphides of calcium and zinc at normal temperatures; the phosphorescence produced was found to become invisible when these substances were cooled down from normal temperatures to from —45° to — 55° C.

When magnesium light was used as the exciting agent, the resulting phosphorescence did not become invisible until the substances were cooled to between —70° and —90° C. These temperature values might have been considerably different if other samples of the same phosphorescent materials had been used.

Other experiments by the undersigned were as follows:

4. A test card coated with phosphorescent paint was placed under a color screen, composed of strips of red, yellow, green and blue, transparent celluloid. The paint was then exposed to sunlight, both at 20° C. and at the temperature of liquefied air (—188° C.). The phosphorescence produced at 20° C. was more intense than at —188° C., but in the two cases the relative effects of the colored light appeared to be the same, blue light giving strong phosphorescence, while red light produced very little.

5. A test card ('A') of phosphorescent paint was exposed to sunlight for two minutes, the first at 20° C., the second at —188° C. (in liquid air). The card was then taken into a dark room, where it became visibly phosphorescent when it had risen in temperature a few degrees above —188° C. When this card was warmed to 20° C. it appeared equal in luminosity to a card 'B' that had been exposed one minute to the sun while in liquid air and then warmed to 20° C. Thus it appeared that the previous additional exposure to the sun of the paint on card 'A' of one minute at 20° C. did not appreciably increase the intensity of its phosphorescence.

The results of these experiments, as well as the observations of other writers mentioned above, indicate that the principal effects of very low temperatures on phorphorescence are as follows:

A. That the reduction of the temperature of a phosphorescing substance is accompanied by a corresponding decrease in the phosphorescent discharge.

B. That very low temperatures cause phosphorescence to linger long enough to be readily observed in a number of substances that are not visibly phosphorescent at normal and high temperatures.

C. That the production of phosphorescence in a phosphorescent substance is less when excitation occurs at low temperatures than when it takes place at high temperatures, other conditions being the same.

Furthermore, it appears as if, for a certain phosphorescent substance, different rates of phosphorescent discharge correspond to definite degrees of temperature, other conditions being the same, and that when an excited phosphorescent substance has been reduced to a very low temperature (even to —200° C.), so as to show no phosphorescence, there is still some phosphorescent activity present. In such a case, however, the eye is not sensitive enough to detect the existing feeble luminosity.

A number of common substances show marked phosphorescence when reduced to the temperature of liquid air and then exposed to strong light; besides ivory and paper, already mentioned, are gum arabic, cotton wool, starch, white glue, celluloid and kid-skin.

The colors produced in the phosphorescence of these substances were observed to be as follows:

Gum arabic; decided light blue.
Ivory; bluish white. (Some pieces greenish.)
Cotton wool ; bluish green,
Starch ; yellowish green.
Paper ; yellowish green.
White glue ; greenish yellow.
Celluloid ; greenish yellow.
Kid-skin (glove) ; decided green.

All of these substances were placed in filtered liquid air, exposed to an arc light, and then examined in the dark. They remained bright at least half a minute, when kept at a low temperature after excitation.

Calcium tungstate was found to give phosphorescence decidedly green in color, after being exposed to an arc light, while at the temperature of liquid air, and then examined in the dark. When this substance is subjected to the influence of Röntgen rays the fluorescence produced appears white.

Experiments on the present subject will be continued when more liquefied air is procured.

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SCIENTIFIC BOOKS.

Synopsis of the Recent and Tertiary Leptonacea of North America and the West Indies. [Proceedings U. S. National Museum, Vol. XXI., Pages 873–897 (with Plates LXXXVII., LXXXVIII.) 1899.] By WILLIAM H. DALL.

The Mollusca of Funafuti. Part I., *Gastropoda.* [Memoirs of Australian Museum III., Part 7, March 6, 1899.] By CHARLES HEDLEY.

In the first of these two very interesting and valuable additions to the literature of Malacology, Dr. Dall gives descriptions and figures of eighteen (18) new species and conveniently arranges all the known forms in the three lists —East Coast, West Coast, and Tertiary—showing that of the thirty-five east coast species enumerated, there are but two (*Kellia suborbicularis* and *Turtonia minuta*) which are found also on the west coast, the *Lasæa rubra* from Bermuda proving to be a distinct species. But four (*Kellia suborbicularis, Mysella planulata, Turtonia minuta* and *Aligena elevata*) are also found among the fossils. Many interesting changes are made in the synonymy, especially in the species from northeastern waters, some alteration in the name being made in every instance. They require the careful consideration of students interested in these small forms.

The combining of the recent genus *Kelliopsis* Verrill and Bush (1898) with the fossil genus *Aligena* H. C. Lea (1846) is unquestionably correct, but it is not made clear why *Abra æquata* Conrad (1843) (p. 877) is given as the type, and the two species (*A. striata* and *A. lævis*) described and figured by Lea fail to be mentioned even in the list of Tertiary species.

It is very doubtful if the combining of the genus *Mysella* Angas (1877) with *Montacuta* Verrill and Bush (1898) (the universally accepted interpretation of this genus), and the new interpretation of *Montacuta* Turton (1822), should remain unquestioned (p. 881).

In *Mysella* the hinge, the most important character, is described by Angas as consisting, in one valve, of a small, diverging, triangular cartilage-pit, close to which is a single, small, diverging, subcircular, flattened cardinal tooth; and, in the opposite valve, of two, thin, short, horizontal, lateral processes (P. Z. S. London, p. 176, 1877). The figures given of the only species (*M. anomala*) are entirely too small for accurate study and apparently resemble those of *M. substriata* as much as those of *M. bidentata.* It would seem improbable, however, that Angas could have failed to recognize the relationship of the Australian form to either or both of these well-known species. Probably with a more critical study of the specimen itself and with more material new points would be brought out, especially as it was placed by Angas between *Ervilia* and *Cytherea,* well separated from *Kellia.* In the species which Dr. Dall refers to *Montacuta* Turton, he describes and figures the hinge as having a prominent cardinal in each valve; the lamellæ obsolete; sockets for the resilium thickened and raised above the inner surface of the valve (*M. floridanum,* p. 893). The other species are similar to this, but he places the *Tellimya ferruginosa* Verrill (*non* Montagu) = *percompressa* Dall (p. 894) with them.

In an interior view of *percompressa,* the valves united, the dark brown resilium is somewhat triangular in form and lies underneath the beaks, fastened by its thin, inner edge to the sunken sockets which lie underneath the thickened posterior hinge-margin; its outer or upper edge is thick and broad, and bears an inconspicuous, thin, white ossicle. In one valve the anterior hinge-margin is thicker than in the