the various positions of t.. N. American continent were greatly changed; and this co..sideration will aid in accounting, he thinks, for the curious fact that the ice in the eastern seaboard stretched unbroken past the fortieth parallel, while under the same latitude in the Cordilleras no glaciers formed below 9,000 feet.

THE third part of the second series of the magnificent work of Mr. William H. Edwards upon the Butterflies of North America has been published by Messrs. Hurd and Houghton, of Cambridge, Massachusetts, and embraces five plates, executed by Miss Mary Peart. The plates represent species of *Papilio*, *Argynnis*, *Apatura*, *Chionobas*, and *Lycæna*; all of them being rare and, for the most part, unfigured species, and also many but recently described.

WE have received the *Journal* of the Anthropological Society for April and July, containing in full the papers which have appeared in abstract in our reports of the meetings of the Society. Many of the papers are of great value, and the illustrations, especially those of the Andamanese, are very interesting.

IT is rumoured that, on the retirement of Sir Henry James from the directorship of the Ordnance Survey, a post which he has filled during a lengthened period with so much distinction, he will be succeeded by Col. A. Ross Clarke. We congratulate the Government on this selection, just at once to a most meritorious officer and to Science and the State. Col. Clarke's eminence as a mathematician and a geodesist are too highly appreciated wherever those sciences are cultivated, both at home and abroad, to need any comment from us.

THE additions to the Zoological Society's Gardens during the past week include a Manatee (*Manatus americanus*) from Demerara, a Ground Hornbill (*Bucorvus abyssinicus*), a White-thighed Colobus (*Colobus bicolor*) from West Africa, a Rose-crested Cockatoo (*Cacatua moluccensis*) from Moluccas, deposited; two Jaguars (*Felis onça*) from America, a Squirrel Monkey (*Saimaris sciurea*) from Brazil, purchased; four Amherst Pheasants (*Thaumalea amherstiæ*), a Siamese Pheasant (*Euplocamus prœlatus*), and two Vinaceous Doves (*Turtur vinaceus*) bred in the Gardens.

PHYSICAL PROPERTIES OF MATTER IN THE LIQUID AND GASEOUS STATES*

THE investigation to which this note refers has occupied me, with little intermission, since my former communication in 1869 to the Society, "On the Continuity of the Liquid and Gaseous States of Matter." It was undertaken chiefly to ascertain the modifications which the three great laws discovered respectively by Boyle, Gay-Lussac, and Dalton undergo when matter in the gaseous state is placed under physical conditions differing greatly from any hitherto within the reach of observation. It embraces a large number of experiments of precision, performed at different temperatures and at pressures ranging from twelve to nearly three hundred atmospheres. The apparatus employed is, in all its essential parts, similar to that described in the paper referred to; and so perfectly did it act that the readings of the cathetometer, at the highest pressures and temperatures employed, were made with the same ease and accuracy as if the object of the experiment had been merely to determine the tension of aqueous vapour in a barometer-tube. In using it the chief improvement I have made is in the method of ascertaining the original volumes of the gases before compression, which can now be know with much less labour and greater accuracy than by the method I formerly described. The lower ends of the glass tubes containing the gases dip into small mercurial reservoirs formed of thin glass tubes, which rest on ledges within the apparatus. This arrangement has prevented many failures in screwing up the apparatus, and has given more precision to the measurements. A great improvement has also been made in the method of preparing the leather-washers used in the packing for the fine screws, by means of which the pressure is obtained. It consists in saturating the leather with grease by heating it *in vacuo* under melted lard. In this way the air enclosed within the pores of the leather is removed without the use of water, and a packing is obtained so perfect that it appears, as far as my experience goes, never to fail, provided it is used in a vessel filled with water. It is remarkable, however, that the same packing, when an apparatus specially constructed for the purpose of forged iron was filled with mercury, always yielded, even at a pressure of forty atmospheres, in the course of a few days.

It is with regret that I am still obliged to give the pressures in atmospheres, as indicated by an air- or hydrogen manometer, without attempting for the present to apply the corrections required to reduce them to true pressures. The only satisfactory method of obtaining these corrections would be to compare the indications of the manometer with those of a column of mercury of the requisite length; and this method, as is known, was employed by Arago and Dulong, and afterwards in his classical researches by Regnault, for pressures reaching nearly to thirty atmospheres. For this moderate pressure a column of mercury about 23 metres, or 75 feet, in length had to be employed. For pressures corresponding to 500 atmospheres, at which I have no difficulty in working with my apparatus, a mercurial column of the enormous height of 380 metres, or 1,250 feet, would be required. Although the mechanical difficulties in the construction of a long tube for this purpose are perhaps not insuperable, it could only be mounted in front of some rare mountain escarpment, where it would be practically impossible to conduct a long series of delicate experiments. About three years ago I had the honour of submitting to the Council of the Society a proposal for constructing an apparatus which would have enabled any pressure to be measured by the successive additions of the pressure of a column of mercury of a fixed length; and working drawings of the apparatus were prepared by Mr. J. Cumine, whose services I am glad to have again this opportunity of acknowledging. An unexpected difficulty, however, arose in consequence of the packing of the screws (as I have already stated) not holding when the leather was in contact with mercury instead of water, and the apparatus was not constructed. For two years the problem appeared, if not theoretically, to be practically impossible of solution; but I am glad now to be able to announce to the Society that another method, simpler in principle and free from the objections to which I have referred, has lately suggested itself to me, by means of which it will, I fully expect, be possible to determine the rate of compressibility of hydrogen or other gas by direct reference to the weight of a liquid column, or rather of a number of liquid columns, up to pressures of 500 or even 1,000 atmospheres. For the present it must be understood that, in stating the following results, the pressures in atmospheres are deduced from the apparent compressibility, in some cases of air, in others of hydrogen gas, contained in capillary glass tubes.

In this notice I will only refer to the results of experiments upon carbonic acid gas when alone or when mixed with nitrogen. It is with carbonic acid, indeed, that I have hitherto chiefly worked, as it is singularly well adapted for experiment; and the properties it exhibits will doubtless, in their main features, be found to represent those of other gaseous bodies at corresponding temperatures below and above their critical points.

Liquefaction of Carbonic Acid Gas.—The following results have been obtained from a number of very careful experiments, and give, it is believed, the pressures, as measured by an air-manometer, at which carbonic acid liquefies for the temperatures stated:—

Temperatures in Centigrade degrees.	Pressure in atmospheres.
0	35·04
5·45	40·44
11·45	47·04
16·92	53·77
22·22	61·13
25·39	65·78
28·30	70·39

I have been gratified to find that the two results (for 13°·09 and 21°·46) recorded in my former paper are in close agreement with these later experiments. On the other hand, the pressures I have found are lower than those given by Regnault as the result of his elaborate investigation (*Mémoires de l'Academie des Sciences*, vol. xxvi. p. 618). The method employed by that distinguished physicist was not, however, fitted to give accurately

* "Preliminary Notice of further Researches on the Physical Properties of Matter in the Liquid and Gaseous States under varied conditions of Pressure and Temperature." Paper read before the Royal Society by Dr. Andrews, F.R.S., Vice-President of Queen's College, Belfast.

the pressures at which carbonic acid gas liquefies. It gave, indeed, the pressures exercised by the liquid when contained in large quantity in a Thilorier's reservoir; but these pressures are always considerably in excess of the true pressures in consequence of the unavoidable presence of a small quantity of compressed air, although the greatest precautions may have been taken in filling the apparatus. Even $\frac{1}{500}$ part of air will exercise a serious disturbing influence when the reservoir contains a notable quantity of liquid.

Law of Boyle.—The large deviations in the case of carbonic acid at high pressures from this law appeared distinctly from several of the results given in my former paper. I have now finished a long series of experiments on its compressibility at the respective temperatures of 6°·7, 63°·7, and 100° Centigrade. The two latter temperatures were obtained by passing the vapours of pyroxylic spirit (methyl alcohol) and of water into the rectangular case with plate-glass sides, in which the tube containing the carbonic acid is placed. The temperature of the vapour of the pyroxylic spirit was observed by an accurate thermometer, whose indications were corrected for the unequal expansion of the mercury; while that of the vapour of water was deduced from the pressure as given by the height of the barometer and a water-gauge attached to the apparatus. At the lower temperature (6°·7) the range of pressure which could be applied was limited by the occurrence of liquefaction; but at the higher temperatures, which were considerably above the critical point of carbonic acid, there was no limit of this kind, and the pressures were carried as far as 223 atmospheres. I have only given a few of the results; but they will be sufficient to show the general effects of the pressure. In the following Tables p designates the pressure in atmospheres as given by the air-manometer, t' the temperature of the carbonic acid, ϵ the ratio of the volume of the carbonic acid under one atmosphere and at the temperature t' to its volume under the pressure p' and at the same temperature, and θ the volume to which one volume of carbonic acid gas measured at 0° and 760 millimetres is reduced at the pressure p and temperature t':—

Carbonic Acid at 6°·7.

p. at.	t'. °	ϵ.	θ.
13·22	6·90	$\frac{1}{14·36}$	0·07143
20·10	6·79	$\frac{1}{23·01}$	0·04456
24·81	6·73	$\frac{1}{29·60}$	0·03462
31·06	6·62	$\frac{1}{39·57}$	0·02589
40·11	6·59	$\frac{1}{58·40}$	0·01754

Carbonic Acid at 63°·7.

p. at.	t'. °	ϵ.	θ.
16·96	63·97	$\frac{1}{17·85}$	0·06931
54·33	63·57	$\frac{1}{66·06}$	0·01871
106·88	63·75	$\frac{1}{185·9}$	0·00665
145·54	63·70	$\frac{1}{327·3}$	0·00378
222·92	63·82	$\frac{1}{446·9}$	0·00277

Carbonic Acid at 100°.

p. at.	t'. °	ϵ.	θ.
16·80	100·38	$\frac{1}{17·33}$	0·07914
53·81	100·33	$\frac{1}{60·22}$	0·02278
105·69	100·37	$\frac{1}{137·1}$	0·01001
145·44	99·46	$\frac{1}{218·9}$	0·00625
223·57	99·44	$\frac{1}{380·9}$	0·00359

These results fully confirm the conclusions which I formerly deduced from the behaviour of carbonic acid at 48°, viz. that while the curve representing its volume under different pressures approximates more nearly to that of a perfect gas as the temperature is higher, the contraction is nevertheless greater than it would be if the law of Boyle held good, at least for any temperature at which experiments have yet been made. From the foregoing experiments it appears that at 63°·7 carbonic acid gas, under a pressure of 223 atmospheres, is reduced to $\frac{1}{447}$ of its volume under one atmosphere, or to less than one half the volume it ought to occupy if it were a perfect gas and contracted in conformity with Boyle's law. Even at 100° the contraction under the same pressure amounts to $\frac{1}{381}$ part of the whole. From these observations we may infer by analogy that the critical points of the greater number of the gases not hitherto liquefied are probably far below the lowest temperatures hitherto attained, and that they are not likely to be seen, either as liquids or solids, till much lower temperatures even than those produced by liquid nitrous oxide are reached.

(To be continued.)

NEW METHOD OF OBTAINING ISOTHERMALS ON THE SOLAR DISC*

On June 5, 1875, I devised a method for obtaining the isothermals on the solar disc. As this process may create an entirely new branch of solar physics, I deem it proper that I should give a short account of it in order to establish my claim as its discoverer.

In the American Journal, July 1872, I first showed how one can, with great precision, trace the progress and determine the boundary of a wave of conducted heat in crystals, by coating sections of these bodies with Meusel's double iodide of copper and mercury, and observing the blackening of the iodide where the wave of conducted heat reaches 70° C. If we cause the image of the sun to fall upon the smoked surface of thin paper, while the other side of the paper is coated with a film of the iodide, we may work on the solar disc as we formerly did on the crystal sections.

The method of proceeding is as follows: beginning with an aperture of object-glass which does not give sufficient heat in any part of the solar image to blacken the iodide, I gradually increase the aperture until I have obtained that area of blackened iodide which is the smallest that can be produced with a well-defined contour. This surface of blackened iodide I call the *area* of blackened temperature. On exposing more aperture of object-glass, the surface of blackened iodide extends and a new area is formed bounded by a well-defined isothermal line. On again increasing the aperture another increase of blackened surface is produced with another isothermal contour; and on continuing this process I have obtained maps of the isothermals of the solar image. By exposing for about twenty minutes the surface of iodide to the action of the heat inclosed in an isothermal, I have obtained thermographs of the above areas; which are sufficiently permanent to allow one to trace accurately their isothermal contours. There are other substances, however, which are more suitable than the iodide for the production of permanent thermographs.

The contours of the successively blackened areas on the iodide are *isothermals*, whose successive thermometric values are inversely as the successively increasing areas of aperture of object glass which respectively produced them.

As far as the few observations have any weight, the following appear to be the discoveries already made of this new method. (1) There exists on the solar image an area of sensibly uniform temperature and of maximum intensity. (2) This area of maximum temperature is of variable size. (3) This area of maximum temperature has a motion on the solar image. (4) The area of maximum temperature is surrounded by well-defined isothermals marking successive gradations of temperature. (5) The general motions of translation and of rotation of these isothermals appear to follow the motions of the area of maximum temperature which they inclose; but both central area and isothermals have independent motions of their own.

On projecting the enlarged image of a sun-spot on the blackened surface and then bringing a hot-water box, coated with lamp-black, near the other side of the paper, one may

* The discovery of a method of obtaining Thermographs of the Isothermal Lines of the Solar Disc, by Alfred M. Mayer in Silliman's *American Journal* for July.