the potential of the mercury should diminish in the same ratio. Mercury contained in a tube of uniform section would always have the same potential, for as it expanded and lengthened by heat, its specific density would diminish, and the product of density into height would remain constant. If contained in a tube of infinitely small diameter, compared with the diameter of the cup-like extensions, the height would remain constant, whilst the potential would diminish in the ratio of the expansion of mercury, but this is different from the ratio of the diminution of potential of the springs, and in order that these ratios may be accordant, or in other words that the equilibrium of the whole system may be the same at all temperatures, the peculiar form has been employed represented in the illustration, which is between the two forms already referred to.

The amount of the variation of gravitation with variation of depth is exceedingly small, and requires some method for indicating it. The method employed in the results hitherto tabulated and presented with the paper is by means of electrical contact, which is established whenever a sounding is to be taken, between the centre of the steel diaphragm and the end of a micrometer screw, which is at other times insulated from the body of the instrument. The screw is of such pitch, and the circular plate which turns with it has divisions so proportioned, that each division represents a depth of one fathom.

The readings of the instrument have been compared with soundings taken by means of Sir Wm. Thomson's steel wire sounding apparatus, and the accordance between the two is very satisfactory, especially as the bathometer, from the very nature of its action, gives a mean of the surrounding depths, whilst the sounding-line gives the actual depth below the ship. The reading of the instrument is also effected by means of a spiral glass tube, connecting by means of liquid, less dense than mercury, with the mercury in the upper cup; this arrangement has lately been tried and found to work successfully. The instrument is also available for the measurement of height; in mountain ascents, however, the elevated land will influence its readings, and allowance would have to be made for the effect of this local attraction.

The chief disturbing element in the use of this instrument is the effect of latitude, which will have to be ascertained approximately before its readings can be accepted as true indications of the depth. The difference between the total attraction of the earth at the pole and on the equator amounts to $\frac{1}{180}$ of its effect at the equator, the rate of increase in travelling from the equator to the pole being as the square of the sine of the latitude. The amount of this variation is easily calculable in fathoms of depth, to be tabulated for use with the instrument.

The principal value of the bathometer would be to serve the mariner as an additional means of determining his position when he was debarred from taking astronomical observation on account of the state of the weather. If the contour of the ocean bed were laid down on charts more perfectly than it is at present, and if these were in the hands of the mariner, he would be able to tell from his bathometer what was the depth of ocean below him, and whether that depth was increasing or decreasing in pursuing his course; he could also observe the rate of increase or decrease of depth, and in consulting his chart he would be enabled to determine his actual position with considerable accuracy, and thus be forewarned of the approach of danger.

## *PHOTOGRAPHY OF THE RED AND ULTRA-RED END OF THE SPECTRUM*

IN 1874 Dr. Vogel communicated to the scientific public that he had been able to photograph the least refrangible rays of the solar spectrum by using what are known as the Uranium Dry Plates prepared by the Uranium Dry Plate Company. At the same time he experimented with other bromide plates, using dyes to give them distinctive tints. He then enunciated that the sensitiveness of the plates for the hitherto unphotographed portion of the spectrum was due to the colours employed, and apparently all his efforts have been diverted in elaborating this idea. Last summer I commenced a series of similar experiments to see whether the discovery could be made of practical use in photography; and have arrived at the conclusion, that the colouring matter gives this extended sensitiveness owing to the compound of silver formed and not to the colour itself, in fact, that the tint given to the film necessitates a very prolonged exposure. The additions of resins, nitro-glucose, and other similar compounds containing carbon to the bromized and bromo-iodized collodion soon convinced me that it was the organic salts of silver to which we must look for sensitiveness in the yellow red and ultra-red rays of the spectrum. Nearly every resinous body seems to prolong the photographic spectrum towards the ultra-red, and one or two in particular, also when the film is least colourless when viewed by transmitted light, that then it is probably in the most impressionable condition. Another point which is worthy of notice is, that a film dried from moisture, taking, in fact, the form of a dry plate, is always most readily acted upon by the ultra-red end of the spectrum. Probably this is due to the absorptive qualities possessed by the silver nitrate solution, and not really from an increased sensitiveness of the compound salts when dry.

If ordinary pyroxylin be employed for the collodion it is generally less suitable than if it contain a certain quantity of nitro-glucose, or other similar body; and it frequently happens if this be absent entirely that the photographic spectrum will stop short near *b*.

Taking a collodion made with pyroxylorin prepared at high temperatures and using the ordinary solvents (in the alcohol of which suitable resin and bromides are dissolved), it will be found in general that when the silver salts formed through them by the sensitizing bath, or by emulsifying them by direct addition of silver nitrate to the collodion, are presented to the action of the spectrum, the whole of it will be impressed with a developable image. With three prisms of 60° and one of 45° twenty minutes is sufficient exposure to give when the slit is nearly closed, a lens of four feet focus being used as the objective.

When this is overcome it will be possible (and I hope shortly to do so) to present a complete photographic map of those lines which lie beyond A to a distance at least equal to D − A, a point beyond which I have not as yet been able to obtain an image. The great difficulty to be encountered is that of finding a sharp focus for the different points of the invisible spectrum, the change in length from one point to another being very rapid.

Uranium and iron salts have also furnished me with spectra which are well worthy of notice. With the latter salt more especially the action of the heat-rays is very decided, though at present it seems to me that the exposure must be very prolonged.

I propose at a later date to give details of all the most interesting of these experiments sufficient to enable anyone to repeat them who may desire to do so.

W. DE W. ABNEY

P.S.—It may be as well to state that the best results with resin plates have been obtained when a modification of alkaline development has been adopted.

## *RAOUL PICTET'S SULPHUROUS ACID ICE-MACHINE*

THE countries between the 40th degrees of N. and S. latitude have in general too temperate winters to admit of natural ice being obtained in any quantity; and yet these are the countries in which it is most required.

The high price at which it is sold prevents many people from buying it. It is for the purpose of rendering the supply of this useful and healthful article abundant and cheap that ice-making machines have been devised. These are of three classes, of which we shall give a brief account in order to show the advantages of the new invention, due to the ingenuity of a young Genevese physicist, M. Raoul Pictet.

The first class comprises the Ammoniacal Machines. These are based on the principle, applied by M. Carré, of the solution of ammonia in water. A saturated solution of ammonia is introduced into a boiler which is heated to 140° or 150° C. The ammonia is disengaged under strong pressure, and is liquefied in a condenser washed by a current of ordinary water. The liquid ammonia flows into the refrigerator, where it is evaporated and it returns into the liquid in a gaseous form. The evaporation is the source of the cold, which may be made very intense.

In order to work an apparatus of this kind, it is necessary that the first operation be effected, *i.e.*, the liquefaction of the ammonia in the condenser. For this purpose it is necessary that the pressure in the boiler correspond to the tension of ammonia vapour, at the temperature of the water of condensation, 30° C. at least in warm countries. This pressure is raised then to fifteen or eighteen atmospheres, an enormous pressure, liable to great danger.

Under so great tension the gas traverses cast-iron walls of two centimetres, the joints leak, not being air-tight, and the ammonia rapidly escapes from the apparatus. The alkaline solution must then be constantly renewed, which is very costly. There is another inconvenience. The fire under the boiler causes deposits, which, increasing day by day, give rise to the danger of an explosion. The fear of such a catastrophe demands constant watchfulness.

In countries less warm, with a water of condensation at 20°, the tension of the ammonia hardly exceeds eight atmospheres. In these circumstances the Carré machine works well and produces economical results. But in such countries natural ice is abundant, and the service rendered is consequently of less value.

The second class includes the Ether Machines. Sulphuric ether was first employed for the manufacture of ice in England. A large pneumatic pump draws up the vapours of ether, which are formed in a tubular refrigerator, and compresses these vapours in a condenser bathed in spring water. The evaporation may also freeze the water contained in the tanks, while the compression of the vapours and their condensation in the condenser transfer to the spring-water all the heat freed from the water in the tanks, transformed into ice. A pipe allows the condensed ether to return to the refrigerator, and be again subjected to volatilisation.

These machines, more simple than the ammonia ones, are, however, less workable. Ether is a liquid of small volatility, and gives only weak tensions. At $-4°$ or $-5°$ C., this tension varies from 4 to 8 centimetres of mercury according to the quality of the ether. The cylinder of the pneumatic machine must then be of considerable dimensions in order to draw up a small weight of ether and produce a limited amount of cold. The whole of the first half of the machine works with an almost complete vacuum, but if the joints, the walls of the tubes, and the caulking of the cylinder are not perfectly hermetic, atmospheric air will enter the apparatus; and should the manometer show that it is present to the extent of one or two centimetres, the evaporisation of the ether will be arrested. With the smallest amount of air present the machine becomes unworkable; a hole no larger than a pin-point is sufficient to paralyse the half of its normal product.

Another inconvenience arises from the fact that ether is not a body perfectly constant in its chemical characteristics. Under the action of frequent changes of condition, of frequent volatilisations and condensations, it becomes acidified and transformed into less volatile isomeric bodies. On this account it is necessary frequently to change the active liquid, which is very troublesome and expensive.

Lastly, the greases with which the piston of the cylinder is lubricated form a close mixture with the ether, a mixture which is carried into all the apparatus, and which also tends to trammel its regular working.

The third kind, Compressed Air Machine, is the least workable of all, and has invariably failed on trial. Its principle is as follows:—Air is compressed in a large cylinder to nearly three atmospheres. This compression raises the temperature of the air to about 150° C. A current of water cools this air, which enters cold into a second cylinder, where it expands from three atmospheres to the ordinary pressure. This work which it produces upon a second piston is equal to the deduction of the original work, for the two cylinders are joined *en suite*, and are worked by the same rod. The air which is expanded lowers the temperature, and gives the second cylinder about 60° of cold. This air may be utilised to manufacture ice, or to cool cellars, apartments, &c.

This machine, in order to work well, requires large cylinders and close-fitting pistons with very little friction, a perfectly regulated introduction into the expansion cylinder, and orifices, valves, and flaps without a flaw. But these conditions are almost impossible to realise in practice. A piston of large size, travelling in a cylinder under a temperature from $-50°$ to $-60°$ C., is an abundant source of friction, for it is only imperfectly lubricated by glycerine. A thick coating, produced by the solidification of the vapour of water in the expansion cylinder, is also a cause of accident and trouble in the working. Lastly, the smallest derangement in the aspirating or compressing valves of the first cylinder puts an entire stop to the production of cold. These machines, therefore, are absolutely unequal to the practical solution of the problem.

A machine capable of easily performing the work must comply with the following five essential conditions:—1. Too great pressure must not occur in any part of the apparatus. 2. The volatile liquid employed ought to be so volatile that there will be no danger of air entering; *i.e.*, the pressure must be at least one atmosphere in order to be in equilibrium with the external pressure. 3. It is necessary to have a system of compression which does not require the constant introduction of grease or of foreign materials into the machine. 4. The liquid must be stable, it must not decompose by the frequent changes of condition, and it must not exert chemical action on the metals of which the apparatus is constructed. 5. Lastly, it is necessary, as far as possible, to remove all danger of explosion and of fire, and for this reason the liquid must not be combustible.

If we examine the series of liquids investigated by M. Regnault, only one will be found to satisfy these essential desiderata; this liquid is sulphurous anhydride, $SO_2$.

In fact, this body is liquid under the atmospheric pressure at a temperature of $-10°$ C., and it does not give pressures higher than four atmospheres at a temperature of 35°. This liquid does not act on metals or fats; it is not combustible, and is the least expensive of all known volatile liquids. By the process of manufacture discovered by M. R. Pictet, it costs less than sulphuric ether.

Thus, by taking advantage of the general principle of the evaporation of a volatile liquid to produce cold, and utilising sulphurous acid, we can obtain a machine which gives results constant in every country, and which acts in a perfectly mechanical and normal manner in all latitudes. The following is a brief description of a typical machine, manufacturing 250 kilogrammes of ice per hour:—

A cylindrical tubular copper boiler has a length of 2 metres and a diameter of 35 centimetres; 150 tubes of 15 millimetres traverse its entire length, and are soldered by their extremities to the two ends. This first boiler is the refrigerator. It is placed horizontally in a large sheet-iron vat, which contains 100 tanks of 20 litres each. An incongealable liquid, salted water, is constantly circulating in the interior of the refrigerator by means of a helix. This liquid is re-cooled to about $-7°$ in a normal course, and it licks on its return the sides of the tanks which contain the water to be frozen.

In the space reserved between the tubes of the refrigerator, the sulphurous acid liquid is volatilised, its vapours are drawn up by an aspirating force-pump, which compresses them without the condenser. This condenser is a tubular boiler, the same as the refrigerator; only a current of ordinary water passes constantly into the interior of the tubes to carry off the heat produced by the change of the gaseous into the liquid state of the sulphurous acid, and by the work of compression. A tube furnished with a gauge tap, adjusted by the hand once for all, permits the liquefied sulphurous acid to return into the refrigerator to be subjected anew to volatilisation.

Sulphurous acid has the exceptionally advantageous property of being an excellent lubricant, so that the metallic piston which works in the cylinder of the compressing pump requires no greasing. Thus the introduction of foreign matter into the apparatus becomes entirely impossible.

The work necessary to manufacture 250 kilogrammes of ice per hour is at the most seven-horse power.

A cold of 7° in the bath is amply sufficient to obtain in the tanks a rapid and in every way economical congelation.

With these mechanical arrangements the following important advantages are realised:—1. The pressure never exceeds four atmospheres. 2. There is never any entry of air to fear, the pressures, as far as $-10°$ C., being always above that of the atmosphere. 3. The volatile liquid employed is perfectly stable, undecomposable, and without chemical action on metals. 4. All greasing in the machine is dispensed with. 5. The volatile liquid is obtained at a very low price, and it is accompanied by no danger of explosion or fire. 6. The cost of production of the ice approaches infinitely near to the theoretic minimum: it is about 10 francs per ton of ice.

By means of all these advantages the practical problem of the manufacture of ice may be considered as solved for all climates, and the process of M. Pictet will not fail to be speedily adopted in all warm countries as soon as it becomes known; it is in such countries that its happy results will be specially utilised and appreciated.

A small specimen of M. Pictet's machine will be shown at the forthcoming Loan Exhibition of Scientific Apparatus at South Kensington.

## *APPARATUS FOR DEMONSTRATING THE TRANSFORMATION OF FORCE*

In a recent number of the *Journal de Physique*, M. Crova describes a convenient apparatus for showing the relations between heat, electricity, and mechanical force. The arrangement is as follows:—

Two of Clamond's thermo-electric generators are connected in surface, and put in communication with a Gramme machine in such a way as to set this in action. In the circuit is inserted a sort of electric lamp, in which a platinum wire placed in the centre of a small globe (which protects it from agitation of the air) can be raised to incandescence. The only difficulty of the experiment consists in so regulating the length and diameter of the platinum wire as that it may be raised to a red heat, while the thermo-electric current retains sufficient intensity to drive the Gramme machine. A circuit entirely metallic then is obtained, with which the following transformations can be effected:—

1. The Gramme machine being excluded from the circuit, a portion of heat, transformed into electricity by the thermo-electric pile, reappears in the state of heat in the platinum wire.

2. The platinum wire being excluded from the circuit, and the Gramme machine introduced, a portion of heat, transformed into electricity in the pile, produces mechanical work in the machine, which acts as a motor.

3. The platinum wire and the machine being included in the circuit, a part of heat, transformed in the pile into electricity, produces heat in the wire and work in the motor. If we then stop the motion of the Gramme machine, we find the incandescence of the platinum wire increased. The machine being liberated, on the other hand, is set agoing again, and the incandescence of the platinum wire diminishes in proportion as the motion is accelerated. In this way is rendered sensible to the eye the expenditure of heat necessary to develop an increasing quantity of mechanical work.

4. Taking the handle of the machine, we turn it *in the direction* of the rotation the current produces, but with an increasing velocity. In this way a velocity is reached such that the incandescence of the wire *completely disappears.*

5. If the handle be turned in a direction opposite to that of the rotation the current communicates, there is considerable resistance, and the incandescence of the wire *increases* rapidly; on turning more quickly, the wire is fused. Thus, in the metallic circuit under consideration, the circulation of a given quantity of energy may appear exteriorly in the form of heat or of mechanical work, the one of these quantities being the complement of the other. If by an exterior force we introduce into the circuit an additional quantity of work, the increase of the quantity of energy put in circulation is rendered visible by the incandescence of the wire; any communication outwards from the circuit, of a certain quantity of energy which circulates in it, appears, on the other hand, in diminution, or even disappearance, of the incandescence.

## *NOTES*

Lord Salisbury, on Monday, named the following as Commissioners under the Oxford University Bill:—Lord Selborne (Chairman), Lord Redesdale, the Dean of Chichester, Mr. Mountague Bernard, Sir Henry Maine, Mr. Matthew White Ridley, and Mr. Justice Grove. The feeling among scientific men is one of intense disappointment, leading to the conclusion that it is useless any longer to consider whether Oxford will ever be in a position to do anything for the promotion of science.

The report of the Cambridge Board of Mathematical Studies to the Studies' Syndicate contrasts with the reports of most of the other boards in the paucity of its suggestions for improvement. They do not seem to think that very much is required in order to perfect the system of mathematical teaching. They believe in the probable stability and development of the system of inter-collegiate lectures, but say very little to assist its development, and they say nothing about the present vehement competition by means of private tuition, and the defective method of study that it induces. In answer to the question how University teaching may be organised so as to give the greatest encouragement to the advancement of knowledge, "the Board offer no suggestions under this head." Is this quite what might have been expected in a report bearing the signatures of Stokes, Cayley, Adams, Clerk-Maxwell, Sir W. Thomson, Tait, Lord