must be remembered that if a thermometer or a pyrometer, as the case may be, is plunged into a mass of water or of molten metal, the temperature will fall continuously until the water or the metal begins to become solid; the temperature will then remain constant until the whole mass is solid, when the downward course of the temperature is resumed. This little thermo-junction is plunged into a mass of gold; an electric current is, in popular language, generated, and the strength of the current is proportional to the temperature to which the thermo-junction is raised; so that the spot of light from a galvanometer to which the thermo-junction is attached enables us to measure the temperature, or, by the aid of photography, to record any thermal changes that may occur in a heated mass of metal or alloy.

It is only necessary for our purpose to use a portion of the long scale, and to make that portion of the scale movable. Let me try to trace before you the curve of the freezing of pure gold. It will be necessary to mark the position occupied by the movable spot of light at regular intervals of time during which the gold is near 1045°, that is, while the metal is becoming solid. Every time a metronome beats a second, the white screen A (Fig. 3), a sheet of paper will be raised a definite number of inches by the gearing and handle, B, and the position successively occupied by the spot of light, C, will be marked by hand.

You see that the time-temperature curve, x, y, so traced is not continuous. The freezing point of the metal is very clearly marked by the horizontal portion. If the gold is very pure the angles are sharp, if it is impure they are rounded. If the metal had fallen below its freezing point without actually becoming solid, that is, if superfusion or surfusion had occurred, then there would be, as is often the case, a dip where the freezing begins, and then the temperature curve rises suddenly.

If the metal is alloyed with large quantities of other metals, then there may be several of these freezing points, as successive groups of alloys fall out of solution. The rough diagrammatic method is not sufficiently delicate to enable me to trace the subordinate points, but they are of vital importance to the strength of the metal or alloy, and photography enables us to detect them readily.

Take the case of the tin-copper series; you will see that as a mass of tin-copper alloy cools, there are at least two distinct freezing points. At the upper one the main mass of the fluid alloy became solid: at the lower, some definite group of tin and copper atoms fall out, the position of the lower point depending upon the composition of the mass.

(*To be continued.*)

THE INSTITUTION OF MECHANICAL ENGINEERS.

THE ordinary spring meeting of the Institution of Mechanical Engineers was held on Wednesday and Friday evening of last week, April 24 and 26, the President, Prof. Alexander B. W. Kennedy, F.R.S., occupying the chair both evenings. The following was down on the agenda of the meeting: Adjourned discussion on Captain H. Riall Sankey's paper on "Governing of Steam Engines by Throttling and by Variable Expansion"; the "Third Report to the Alloys Research Committee," by Prof. W. C. Roberts-Austen, C.B., F.R.S., "Appendix on the Elimination of Impurities during the Process of making 'Best Selected' Copper," by Mr. Allan Gibb; "Appendix on the Pyrometric Examination of the Alloys of Copper and Tin," by Mr. Alfred Stansfield.

In the discussion on Captain Sankey's paper a number of members spoke. As a general result it may be stated that the position taken by the author in his paper was supported, viz.: that for certain purposes, governing by means of the throttle valve was to be preferred; whilst under other conditions variable expansion governors would have advantages over the other method. Captain Sankey in his contribution impartially discussed both systems, and his paper may be taken as a good model of what a memoir of the kind should be, no undue bias being shown on either side.

The report of Prof. Roberts-Austen was perhaps of even greater interest than those which have preceded it; whilst the two appendices of Messrs. Gibb and Stansfield discussed important practical details. A request had been made that the investigations of Warburg and Tegetmeier on molecular porosity, and their observations on the "Electrolysis of Glass"[1] should be repeated. It will be remembered that atoms of sodium were made to pass through glass at a temperature of 200° C. under the influence of the electric current. Lithium atoms were then made to follow along the tracks or molecular galleries left by the sodium, the lithium having a lower atomic volume and weight than the sodium. When potassium, having a higher atomic weight and volume, was substituted, it was not found possible to trace out the sodium. We are thus, the author said confronted with a molecular porosity which can in a sense be gauged, and the mechanical influence of the volume of the atom is thus made evident. It will also be evident that there is a direct connection between the properties of a mass and the volume of its atoms. The results previously obtained were entirely confirmed and somewhat extended in the experiments the author had undertaken. The septa, or dividing partitions, in these fresh experiments, were made mostly of soda glass, of which thick bulbs were blown from barometer tube. In most of the experiments the glass was electrolysed, using mercury and an amalgam of some metal as cathode and anode respectively. The temperature was from 250° to 350° C. The electromotive force employed was 100 volts, and the current in the case of the sodium experiments averaged about one-thousandth of an ampere, and was sometimes as high as one-fiftieth of an ampere. When the glass bulbs were employed they soon became cracked, and the free passage of the current fused the glass, forming a well-rounded hole. In each experiment a safety fuse was placed in series, to stop the current in case of breakage. In experiments in which sodium amalgam had been placed in the bulb and pure mercury outside, sodium passed into the mercury to the extent of 0·03 gramme or 0·46 grain. In one experiment, which lasted eighteen hours, the amount of sodium found in the mercury was 0·0131 gramme, or 0·2022 grain. The quantity of electricity which passed through the glass was measured by the aid of an electrolytic cell placed in series, in which copper was deposited to the amount of 0·0206 gramme, or 0·3179 grain. Calculating the number of coulombs of electricity passed by means of the electrolysis of glass, the number 55 is found, and by the electrolysis of copper sulphate, 62; thus showing, as well as a rough approximate experiment could, that the passage of sodium into the mercury follows the ordinary law of electrolysis. It is doubtful whether the sodium from the amalgam actually penetrated right through the glass; but there can be no question that it replaced a considerable proportion of the sodium which the glass contained. An attempt to pass potassium through the same glass failed. Gold was then used, both in the form of amalgam and dissolved in metallic lead, but in the latter case the temperature employed was, of course, higher. No gold was found to have been transmitted through the glass; but the glass employed became coloured by gold, and minute spangles of the metal were found embedded in it. The same result was obtained when copper was used as an amalgam; and in this case minute nodules of copper were deposited below the surface of the glass, an effect which is highly suggestive in connection with the formation of mineral veins by earth currents. Sodium amalgam placed in a bulb and surrounded with mercury, but with no current, gave negative results, showing that simple diffusion did not play any important part in the results obtained. The fact that a current passes at all through glass is a proof that electrolytic action has taken place; so that, even if a metal be not actually transmitted through glass, the passage of a current indicates that sodium, potassium, or other metallic constituent of the glass, must be leaving it, and is probably replaced by one or more of the metals in the metallic bath which constitutes the anode.

The author next referred to an addition made to the recording pyrometer by means of which increased sensitiveness was obtained. The galvanometer, which affords the means of measuring the temperatures of the masses of metal or alloy under examination, may occupy one of two positions: it may either be nearer to the slit through which the ray of light falls upon the photographic plate, or it may be further away from it. It will be evident that two galvanometers may be used simultaneously, with the light from their respective mirrors playing

[1] E. Warburg, "Ueber die Elektrolyse des festen Glases," *Wiedemann's Annalen*, vol. xxi. 1884, p. 622. E. Warburg and F. Tegetmeier, "Ueber die elektrolytische Leitung des Bergkrystalls," *Wiedemann's Annalen*, vol. xli., 1890, page 18. E. Warburg, "Ueber eine Methode Natrium Metall in geisslersche Röhren einzuführen," *Wiedemann's Annalen*, vol. xl. 1890, page 1.

through the same slit upon the photographic plate. The further galvanometer can have a much lower resistance, and consequently greater delicacy, than the nearer one, so that, while the line photographed on the moving sensitised plate from the nearer galvanometer might represent a range of temperature of, say, 1500 degrees, the line traced by the mirror of the further galvanometer should represent only one-tenth of this. The angular deflection of the nearer mirror would not exceed the limits of the sensitised plate, while the mirror of the delicate galvanometer might traverse a far larger range. Both galvanometers would be connected "in parallel" with the same thermo-junction; and obviously any portion of the extended range which it was desirable to reflect on the sensitised plate could easily be caught by a suitable adjustment of the mirror on the further galvanometer. If, therefore, the thermo-junction is plunged into a mass of metal cooling from say an initial temperature of 1500 degrees, the whole of the cooling curve could be traced by the mirror of the less delicate galvanometer, while only the portion greatly magnified would be recorded by the mirror of the more delicate galvanometer. The first curve derived from the less delicate galvanometer would serve as a "calibration curve" for that afforded by the other galvanometer.

By means of diagrams exhibited on the walls of the theatre, a large number of cooling curves for electro-iron were shown, care being taken that the iron was exceedingly pure. The points of recalescence were well shown on these curves, which may be studied with interest in the *Transactions* of the Institution, as bearing on the question of allotropy of iron, which has already been fully discussed in a former report. The cooling-curve of an aluminium-copper alloy was also given. This was the alloy containing 6 per cent. of copper, used by Mr. Yarrow in the construction of torpedo boats for the French Government. Two freezing points were shown, one due to the main mass, and the other at a lower point due to the copper associated with the aluminium. The pyrometric examination of iron-aluminium alloys was also treated at some length, but it would be difficult to give results without reproducing the curves and the diagram shown.

One feature that may be noticed, however, was that the freezing point of iron alloyed with, say, one per cent. of aluminium, is but little lower than that of iron itself; that is to say, the melting point of nearly pure iron is only slightly lowered by a small addition of aluminium. Osmond had already shown that aluminium does not produce any considerable lowering of the freezing point of cast-iron; and the usually accepted idea that cast-iron or steel containing aluminium is very fusible, must be due to the fluidity of the metal when it is melted.

Another interesting point was that the samples of alloys used in these experiments were kept for some months before being analysed, and it was found that during this time those which contained from 40 to 60 per cent. of aluminium had spontaneously disintegrated, and had fallen to powder. The powder was not oxidised, but consisted of clean metallic grains, probably resulting from chemical changes which had gradually taken place in the solid alloy. Whether the iron and aluminium were in a state of solution or were chemically combined when molten, there can be little doubt that they are so combined in the metallic powder, as attempts to re-melt this powder have proved unsuccessful, which points to the formation of an infusible compound.

Some experiments made by Mr. Thomas Wrightson to ascertain whether the welding of iron is attended with a fall of temperature, as is the case in the regelation of ice, were next described. The welding was done by means of electricity and observations were taken by means of the pyrometer formerly described. The results have been communicated to the Royal Society, and tend to show that the welding of iron and the regelation of ice are analogous phenomena, a point of no small theoretical importance.

In his last report the author had called attention to the fact that M. André Le Chatélier had suggested that the prejudicial action of an element is due to its forming a fusible compound with the metallic mass in which it is hidden; while, on the other hand, the presence of an element which forms an infusible compound with the mass, promotes the formation of a fine grain and imparts strength. The author did not wish it to be supposed, however, that the action of the added element is due solely to its infusibility, or to its power of forming a fusible compound with a portion of the mass which contains it; for cases are numerous in which such an explanation does not apply. In this connection a suggestion made long ago by Raoult Pictet (*Comptes rendus*, vol. lxxxviii. 1879, pp. 855 and 1315), well deserved consideration. He urged that there must be a connection between the melting-points of metals and the periodic law of Mendeléeff; for he showed that for all metals there is a simple relation between their atomic weight, the amplitude of the movement of their molecules under the influence of heat, and their melting-point. Pure metals with high melting-points—such as platinum, iron, copper, and gold—are comparatively strong; and, conversely, metals with low melting-points—zinc, lead, cadmium, bismuth, and tin—are relatively weak. Metals with high melting-points must necessarily be coherent and tenacious, because much heat is required to drive their molecules apart in reducing them to the liquid mobile state in which the molecules have very small coherence; and therefore at ordinary temperatures much force must be applied to overcome the cohesion of the molecules and break the mass. Conversely, in metals with low melting-points a small elevation of temperature will overcome the molecular cohesion, and render them liquid—that is, will melt them. Such metals will be weak, the author continued, because if little heat is required to melt the metal, less force will be needed to tear it apart. Hence melting-point and tenacity are clearly connected. The absolute temperature of the melting-point of a metal must be closely connected with its atomic volume, because the former is inversely proportional to the rate at which the amplitude of the oscillations of the molecules increases with temperature; and the rate of increase of amplitude at any given temperature is obtained by multiplying the ordinary thermal coefficient of linear expansion by the cube root of the atomic volume.

Prof. Roberts-Austen here pointed out that the recent work of Dewar and Fleming (*Philosophical Magazine*, vol. xxxiv. 1892, p. 326) bears directly on this question. They employed very low temperatures, and show that at the absolute zero of temperature pure metals would probably offer no resistance to the passage of an electric current, but that the electrical resistance of alloys does not diminish so rapidly with the lowering of temperature as in the case of pure metals. Prof. Dewar (*Proceedings* of the Royal Institution, vol. xiv. part 2, 1895, p. 1) has shown, moreover, that the tenacity of pure metals and alloys is greatly increased by extreme cold—that is, by the closer approximation of their molecules; and this affords additional evidence that metals become stronger at temperatures which are further and further removed from their melting-points.

The discussion on this paper was of a somewhat brief nature, the reading of the report and the appendices, together with the carrying out of certain experiments and illustrations, taking a considerable time. Mr. Wrightson also explained at some length his welding experiments, which, as stated, have been placed before the Royal Society.

Prof. Goodman, of Leeds, gave some interesting particulars of the work upon which he has been engaged during the last two years in connection with anti-friction alloys. He had discovered that these substances must always contain a metal of high atomic volume, and there seemed to be a direct connection between the efficiency of the anti-friction of alloy and the atomic volume of one of its constituents. If the atomic volume of the alloy were small, then the friction was enormously increased, but with high atomic volume it was reduced. He had produced an anti-friction metal which would withstand a pressure of two tons to the square inch when running at 550 revolutions per minute, the temperature being 140°; that was a very remarkable result for a white metal. The alloy used had a higher atomic volume than bismuth, but he was not at liberty then to state the nature of the substance. He wished, however, to impress the necessity of absolute purity, or that if there were any impurities, they should be of high atomic volume.

Mr. Blount, in referring to the author's remarks on the electrolysis of glass, and the fact that potassium would not follow sodium and lithium, said he would be glad of an explanation why gold, which had a lower atomic volume than sodium, should not have traversed the "galleries" left in the glass by the sodium.

The summer meeting of the Institution will be held in Glasgow, commencing Tuesday, July 30.

THE ROYAL COMMISSION ON TUBERCULOSIS.

In July 1890, a Royal Commission was appointed to inquire and report "what is the effect, if any, of food derived from tuberculous animals on human health, and if prejudicial, what are the circumstances and conditions with regard to the tuber-