SOME PHYSICAL PROPERTIES OF CURRENT-BEARING MATTER. — III. BOILING POINT.

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THIS article contains a description of some experiments on the effect of a current on the boiling point of mercury and of two electrolytes, copper sulphate solution and dilute acetic acid. The results are all negative. The boiling point of mercury is not altered by 0.04° by a current density of over 100 amperes per square centimeter, and the electrolytes showed no change as great as 0.001° for current densities of 0.05 with the copper sulphate and 0.001 with the acetic acid.

MERCURY.

The general plan of the experiments on mercury was to boil the substance in two vessels, in one of which a current could be turned on at will, and to measure the difference of temperatures by a differential thermocouple. To form the latter a piece of platinum wire about thirty centimeters long was soldered at its ends, by means of zinc, to long pieces of copper wire. Zinc was chosen as the solder because its melting point is above the boiling point of mercury. The two junctions were protected by pieces of drawn out glass tubing and immersed in the vessels of boiling mercury, while the ends of the copper wires were connected to a galvanometer with a key in the circuit. The thermoelectric power of a copper-platinum junction at the temperature of boiling mercury is about ten microvolts per degree, according to Tait's diagram, and the galvanometer (of the Rowland wall pattern) gave a deflection of half a scale division per microvolt, consequently each scale division represented a difference of temperature of one fifth of a degree.

The only difficulty in the carrying out of this plan was to bring about the introduction of a rather heavy current into the boiling mercury without the formation of an arc. This was finally done by introducing the current into portions of the mercury which never rose to the boiling point. Fig. 1 shows the arrangement of the apparatus. A glass *Z*-tube about one centimeter in diameter had one arm drawn out and connected by rubber tubing to a small glass funnel. The horizontal arm of the *Z*-tube was closed by a small cork through which passed an iron wire *C* and a small glass tube *D*. Mercury was poured into the funnel until it half filled the horizontal arm and an iron wire *B* was inserted into the

mercury in the funnel. By the wires *B* and *C* connections were made through a switch, a rheostat and an ammeter to a dynamo. In the vertical arm of the *T*-tube was placed one of the copper-platinum junctions in its protecting tube, the end reaching down into the narrow part *A*. The joint at *E* was open. The mercury was boiled at *A* by applying a very small Bunsen flame, the vapor of mercury being drawn off through the tube *D* by an aspirator, air entering freely at *E* to prevent reduction of pressure. In addition, the tube *D* was made to fit loosely in its cork that air might enter there also if necessary. The cross section

Fig. 1.

of the mercury at *A* was about 0.1 square centimeter, which of course was somewhat reduced by bubbles on boiling. The current was 10 amperes, making a current density of over 100 amperes per square centimeter at the point where the boiling took place. Higher than this one could not go without danger of forming an arc at *A*.

The second copper platinum junction dipped into boiling mercury in a vessel which presented no features of interest. As in Fig. 1 mercury vapor was removed by an aspirator and a constant level was maintained by a funnel-shaped reservoir.

The mercury in both vessels being brought to boiling (with no current flowing) the galvanometer circuit was closed. It proved impossible to keep the instrument at zero, the reading varying slowly and irregularly several scale divisions on either side of the zero point. However, there were times when the reading remained stationary at or very near the zero point for several seconds, and by taking advantage of these periods it was possible to make a number of conclusive tests, throwing the current on, maintaining it for several seconds, and interrupting it without altering the reading. A change of one fifth of a scale division would have been easy to recognize, and this would have meant a change in the boiling point of 0.04°.

ELECTROLYTES.

On account of the relatively high resistance of electrolytes one must be content with lower values of the current density and make up for this by more delicate measurements of change of temperature.

The first solution used was copper sulphate, of density 1.12. It is impossible to boil this in glass without some slight bumping, but in copper vessels it boils freely and steadily, and the boiling point may be taken by a Beckmann thermometer to 0.001° .

The first plan was to use a copper beaker as one electrode, dipping another electrode of copper rod into the center of the solution. The thermometer was dipped into the solution half way between the central electrode and the wall of the beaker. On applying to the boiling liquid a current whose average density was one fifth of an ampere per square centimeter there was a decided change in the reading of the thermometer which seemed to depend on the direction of the current. When the current was passed so that copper (and hydrogen) appeared at the inner surface of the beaker the thermometer rose at once, sometimes by as much as two or three tenths of a degree. With the current reversed the effect was usually a much smaller rise, sometimes preceded and sometimes followed by a slight fall. Bearing in mind the effect produced on the boiling point of a liquid by the nature of the surface of the containing vessel it seemed possible that the rapid deposition or removal of copper at the surface from which the steam bubbles took their rise might have been causing the irregular effect noticed. This suspicion was intensified when the thermometer showed no change as great as 0.001° on applying an alternating current of a frequency of 1,800 per minute and a density of 0.07 to the boiling solution.

Five different forms of apparatus were devised in the hope of eliminating the supposed effect of the changing surface before it was discovered that the trouble was due to something entirely different, namely the torrent of gas bubbles that arose from the electrodes. The electrodes, surrounded by a sheath of gas, were undoubtedly warmer than the solution, as in the water pail electric forge, and the bubbles, coming off in torrents, did not cool off completely before striking the bulb of the thermometer.

Fig. 2.

In Fig. 2 is shown a form of apparatus which can be used both to demonstrate the source of trouble and to eliminate its effects. The containing vessel is of copper varnished within with shellac. The Beckmann thermometer dips into the center of the liquid, and the current enters and leaves by two heavy copper rods, surrounded by wide glass tubes open at both ends. To reinforce the insulation of the copper beaker its walls were protected by sheets of mica, held in place between the walls of the beaker and the wide glass tubes. All the gas generated passes up the

glass chimneys without striking the thermometer, and it is possible to throw on and off the current in the boiling liquid without altering the reading of the thermometer by 0.001° . Of course there were times when the reading fluctuated slightly when there was no current flowing, and the boiling point rose very slowly in the long run on account of the increasing concentration of the solution. As in the experiments with mercury, advantage had to be taken of those times when the thermometer was quiescent.

To test still further the correctness of this diagnosis of the trouble a thermometer was inserted in one of the wide glass tubes. On applying a current to the boiling liquid this thermometer rose promptly about three quarters of a degree and fell again when the current was stopped, while the Beckmann thermometer outside was unaffected. In addition the wide glass tubes were removed and the Beckmann thermometer raised to the level of the electrodes. On turning on the current the thermometer rose at once.

The current density employed in these experiments was about 0.05 ampere per square centimeter in the neighborhood of the thermometer bulb.

Experiments were also made on a five per cent. solution of acetic acid, using carbon electrodes with a form of apparatus otherwise the same as that shown in Fig. 2. On account of the high resistance of this solution the greatest current density that could be attained was 0.001 ampere per square centimeter, and no change as great as 0.001° could be detected in the boiling point.