

## AN EXPERIMENT UPON COOLING THROUGH CHANGE OF STATE.

BY ROBERT A. MILLIKAN.

*Ryerson Physical Laboratory, University of Chicago.*

At the request of SCHOOL SCIENCE AND MATHEMATICS I submit to its readers the modification of the experiment upon "cooling through change of state," which has been introduced into the beginning physics work at the University of Chicago and at the University High School. This experiment in some form or other I regard as of quite as great importance as any which can be introduced into an elementary course; for to one who is not familiar with the facts and theories of physics there is nothing in the whole subject which is more strikingly interesting or more illuminating in its relation to the doctrine of conservation of energy than the direct, experimental proof in the laboratory, of the fact that freezing is a warming process.

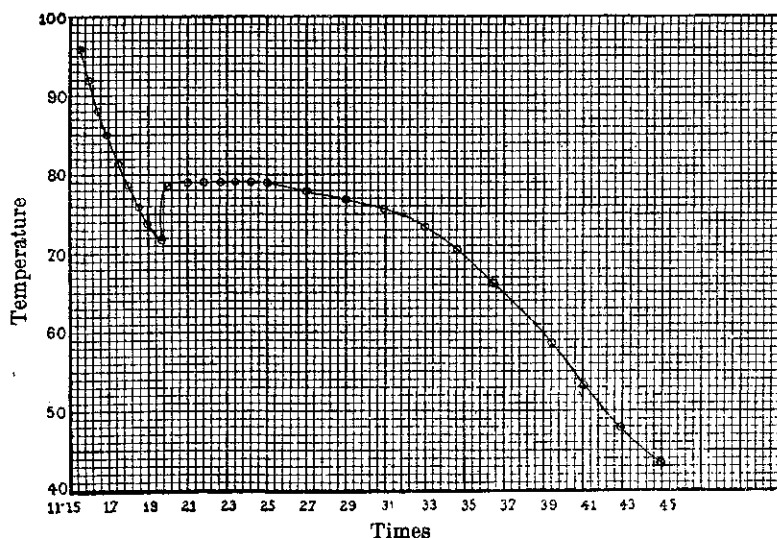
In order to bring out this fact as simply and directly as possible it is desirable to use some liquid which can be made to *undercool* so that the student can actually see his thermometer rise rapidly as solidification sets in. It was formerly my custom to use water for this purpose, a few cubic centimeters of distilled water being placed by each pupil in a test-tube containing a thermometer, and the whole being kept quietly immersed in a freezing mixture at say  $-10^{\circ}$  C, until the temperature of the distilled water fell to about  $-3^{\circ}$  C, when the test-tube was removed and the water stirred. The chief objection to this form of the experiment is that the freezing point of water is so low that it is impossible to follow the temperature of the solidifying substance completely through its change of state.

The hyposulphite of soda, which I believe is suggested in Gage's text-book for this experiment, is indeed admirably adapted to show undercooling and the consequent rise in temperature as solidification sets in, but unfortunately it is also well suited to upset completely the pupils' faith in the law that every crystalline substance has a fixed freezing point and that the temperature of such a substance remains constant while the change of state is going on. For like all the substances which contain water of crystallization the undercooled hyposulphite of soda rises upon solidifying to a temperature which depends largely upon the amount of water which is present, and it furthermore does not

maintain a temperature which is at all constant while the process of solidification is going on.

Acetanilid has been quite widely used for the experiment; but while it maintains a constant temperature during solidification it has these two serious disadvantages; first—it will not *undercool*, and, second, its solidifying point is so high, (about  $130^{\circ}\text{C}$ .) that the ordinary laboratory thermometer which reads to but  $100^{\circ}\text{C}$  or  $110^{\circ}\text{C}$ , cannot be used with it.

After a considerable amount of experimenting with different substances it was found that acetamide is a well nigh ideal sub-



stance for illustrating all the points which it is desirable to illustrate by an experiment upon "cooling through change of state." The experiment with it is as follows: A test tube is supported vertically in a burette holder or other clamp and enough loose crystals of acetamide are inserted to fill it about a third full. The tube is heated carefully with a Bunsen burner until all of the crystals are melted. A thermometer is then inserted and the temperature recorded every half minute for a period of fifteen or twenty minutes. When these temperatures are plotted as ordinates and times as abscissas a curve is obtained of the type shown in Fig. 1. It will be seen that in this particular experiment which is a fair sample of the results obtained by the average high school pupil, the temperature fell rapidly from  $100^{\circ}\text{C}$  to  $71.8^{\circ}\text{C}$ ,

that it then rose suddenly, as solidification set in, to  $79^{\circ}$  C, remained constant at this point for five minutes and then fell slowly during the next twenty minutes from  $79^{\circ}$  C to  $43.5^{\circ}$  C. The same test-tube of acetamide may be used an unlimited number of times and it will always show precisely the same behavior as above save that it will often fall as low as to  $60^{\circ}$  C or even  $55^{\circ}$  C before solidification begins.

Acetamide costs about 50 cents per ounce. Three or four ounces will provide for a class of from twenty to thirty pupils and one supply of test-tubes partially filled with acetamide can be used for an indefinite length of time. In winter no precautions whatever need be taken with the experiment. In summer the acetamide absorbs some moisture and should be boiled in its test-tube in order to drive off this water before the cooling curve is taken.

The experiment in this form has proved one of the most satisfactory which the writer has ever tried with an elementary class. Its advantages may be summarized thus:

(1) It furnished direct and striking proof that solidification is a heat evolving process.

(2) It shows that crystalline substances have a definite melting point which they maintain during the process of change of state.

(3) It is inexpensive.

(4) It can easily be completed, graph and all, in a laboratory period of the usual length.

(5) It is not troublesome for the teacher and requires none of his time outside of laboratory hours.

(6) Finally it shows the pupil the natural use of a graph in physics and teaches him how to interpret his graph. This I consider a point of the utmost importance; for I confess that I have had considerable difficulty in finding a sufficient number of what seemed to me sensible and natural applications of the graphical method which were suitable to introduce into elementary physics courses. I doubt if I am altogether alone in feeling that there is some danger of *dragging* graphs into such courses at points at which they add nothing to the pupils' grasp of the physical relations involved but serve rather to render the subject a little more complex and difficult than it would otherwise be. The case in hand is beyond question one in which the graph is needed in order to gain a clear picture of the physical relations

involved. In a word the graph is needed as the interpreter of the physics rather than the physics as the interpreter of the graph.

If it is desired to have the pupil take the curve of a substance which does not undercool as well as of one which does the writer recommends *naphthaline* in place of *acetanilid*, for the reason that it has a more convenient melting point (about  $79^{\circ}\text{C}$ ) and shows a much flatter curve during the time in which the process of solidification is going on.

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#### AN INTERESTING EARTHQUAKE FAULT.

Professor Fernando Sanford of the Stanford University sends us the accompanying photograph, which is a view of an earthquake fault made near Olema, north of San Francisco. The fence in the foreground was continuous with the line of posts back of the man on the downhill side. It has been moved up hill 16 feet along with all the foreground. It will be noticed that there has been no appreciable change of level on the level ground

