To Study the Relationship Between the Temperature of a Hot Body and Time by Plotting a Cooling Curve

Aim

To study the relationship between the temperature of a hot body and time by plotting a cooling curve.

Apparatus

Newton's law of cooling apparatus (a thin-walled copper calorimeter suspended in a double walled enclosure), two thermometers, clamp and stand, stop clock/watch.

Theory

Newton's law of cooling, states that the rate of cooling (or rate of loss of heat) of a body is directly proportional to the temperature difference between the body and its surroundings, provided the temperature difference is small.

$$\frac{dQ}{dt} \propto (T - T_0)$$

For a body of mass m, specific heat s, temperature T kept in surrounding of temperature T_0.

Then $$Q = msT$$

Rate of cooling, $$\frac{dQ}{dt} = ms\frac{dT}{dt}$$

Hence, $$ms\frac{dT}{dt} \propto (T - T_0)$$

or $$\frac{dT}{dt} \propto (T - T_0) \qquad (\because \quad ms = \text{constant})$$

As time increase, T decreases, $(T - T_0)$ decreases, hence rate of fall of temperature $\left(\frac{dT}{dt}\right)$ must also decrease.

Diagram

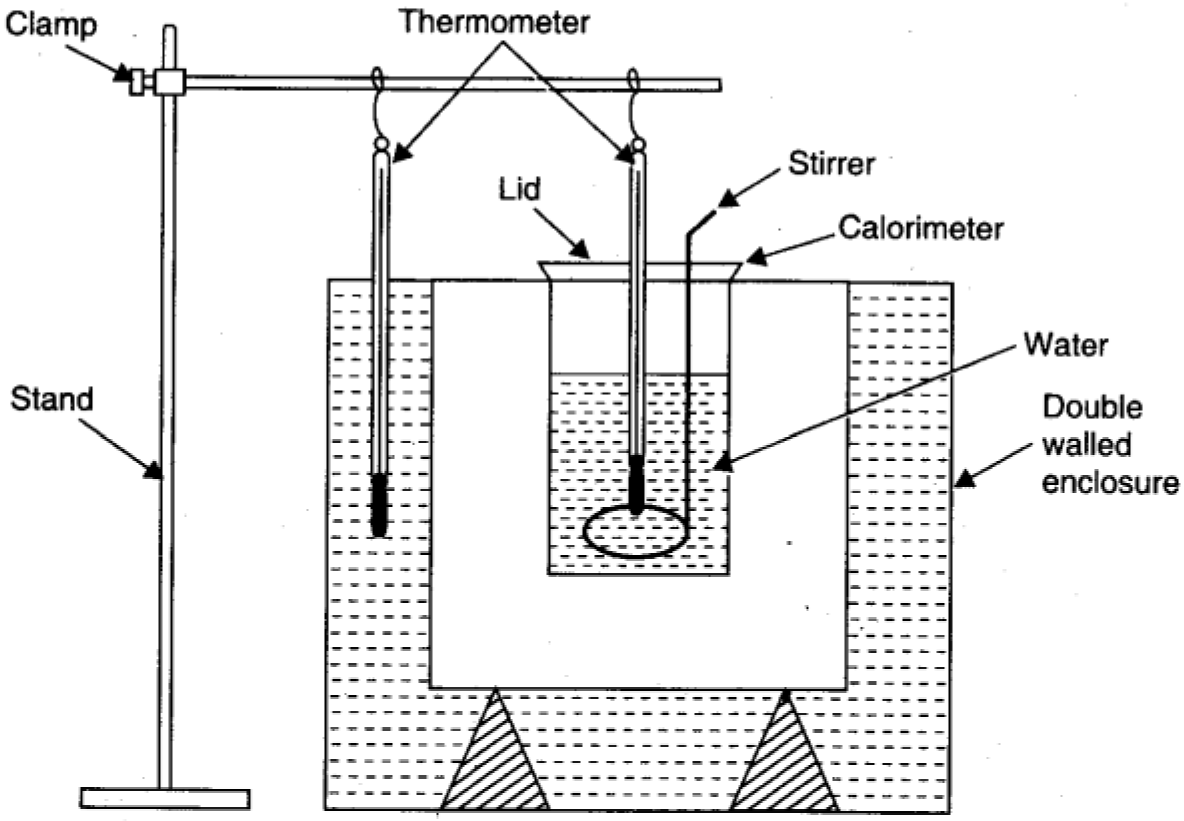


Fig. Newton's law of cooling apparatus.

Procedure

1. Fill the space between double wall of the enclosure with water and put the enclosure on a laboratory table.
2. Fill the calorimeter two-third with water heated to about 80°C.
3. Suspend the calorimeter inside the enclosure along with a stirrer in it. Cover it with a wooden lid having a hole in its middle.
4. Suspend from clamp and stand, one thermometer in enclosure water and the other in calorimeter water.
5. Note least count of the thermometers.
6. Set the stop clock/watch at zero and note its least count.
7. Note temperature (T_0) of water in enclosure.
8. Start stirring the water in calorimeter to make it cool uniformly.
9. Just when calorimeter water has some convenient temperature reading (say 70°C), note it and start the stop clock/watch.
10. Continue stirring and note temperature after every one minute. The temperature falls quickly in the beginning.
11. Note enclosure water temperature after every five minutes.

12. When fall of temperature becomes slow note temperature at interval of two minutes for 10 minutes and then at interval of 5 minutes.
13. Stop when fall of temperature becomes very slow.
14. Record your observations as given ahead.

Observations

Least count of enclosure water thermometer = ……………….°C
Least count of calorimeter water thermometer = ………..°C
Least count of stop clock/watch = …………….s.
Table for time and temperature

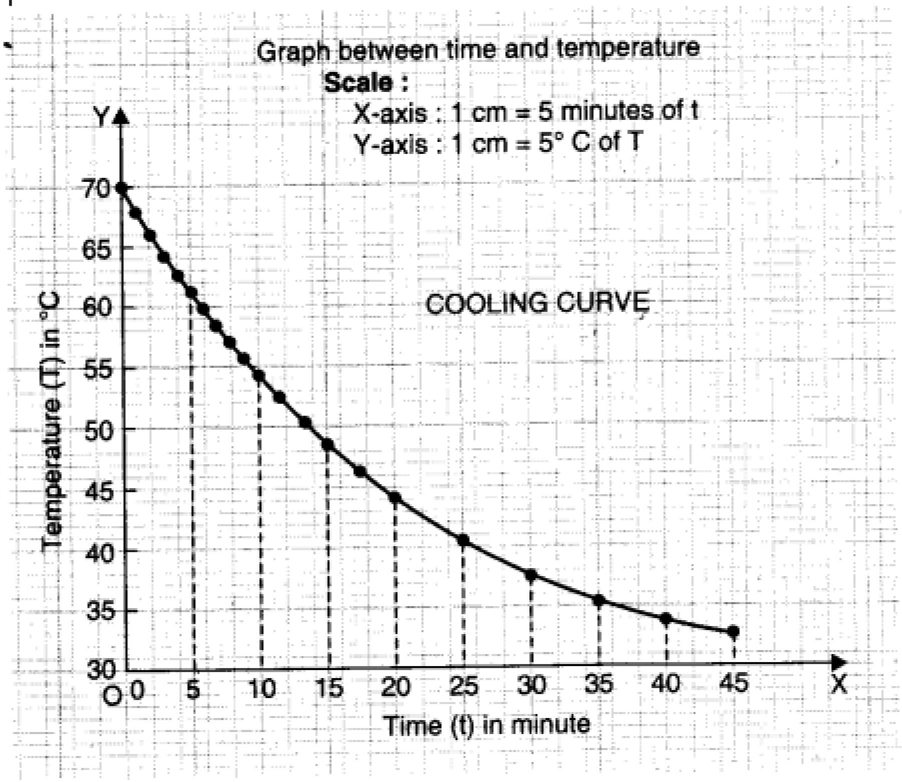
Serial No. of Obs.	Time for cooling t(mt)	Temperature of water in calorimeter T (°C)	Temperature of water in enclosure T_0 (°C)	Difference of temperature $T - T_0$ (°C)
1.	0	70	30	40
2.	1	68		38
3.	2	66		36
4.	3	64		34
5.	4	62		32
6.	5	61	30	31
7.	6	60		30
8.	7	59		29
9.	8	58		28
10.	9	56		26
11.	10	54	30	24
12.	12	53		23
13.	14	51		21
14.	16	49		19
15.	18	46		16
16.	20	44	30	14
17.	25	42	30	12
18.	30	38	30	8
19.	35	36	30	6
20.	40	35	30	5
21.	45	34	30	4

(Note. The ideal observations given above are as sample.)

Calculations

1. Temperature of water in enclosure will be found to remain same. If not then take its

mean as T_0.
2. Find temperature difference ($T - T_0$).
3. Plot a graph between time t and temperature T, taking t along X-axis and T along Y-axis. The graph comes to be as shown in below. It is called Cooling curve O of the liquid.



Graph between time (t) and temperature (θ)—cooling curve.

Result

The temperature falls quickly in the beginning and then slowly as difference of temperature goes on decreasing.
This is an agreement with Newton's law of cooling.

Precautions

1. Double-walled enclosure should be used to maintain surrounding at a constant temperature.
2. Stirring should remain continuous for uniform cooling.

Sources of error

1. Surrounding temperature may change.