# PHYSICS EXPERIMENTS
## (HEAT)

***'In the matter of physics, the first lessons should contain nothing but what is experimental and interesting to see. A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds.' - Albert Einstein***

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# LEAVING CERTIFICATE PHYSICS

## LISTED EXPERIMENTS

### CONTENTS

## HEAT

Experiment at Higher Level only*

## NOTE

For examination purposes any valid method will be acceptable for describing a particular experiment unless the syllabus specifies a particular method in a given case.
Students will be expected to give details of equipment used, assembly of equipment, data collection, data manipulation including graphs where relevant. Students will also be expected to know the conclusion or result of an experiment and appropriate precautions.

## SAFETY

1. The Leaving Certificate Physics syllabus states on page three:

   'Standard laboratory safety precautions must be observed, and due care must be taken when carrying out all experiments.
   The hazards associated with electricity, EHT, lasers etc. should be identified where possible, and appropriate precautions taken. The careful use of sources of ionising radiation is essential. It is important that teachers follow guidelines issued by the Department of Education and Science.'

2. The guidelines referred to here consist of two books, which were published by the Department of Education in 1997. The books are

   'Safety in School Science'

   and

   'Safety in the School Laboratory (Disposal of chemicals)'

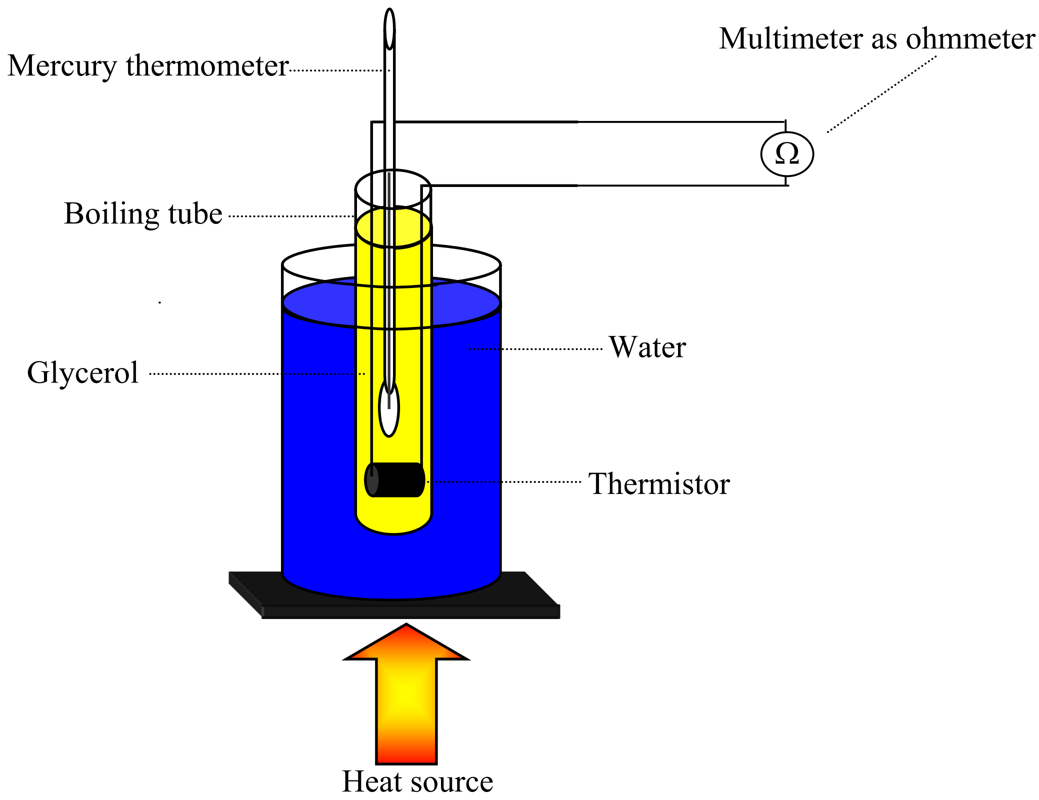
   When these books were published they were distributed to all schools. They have been revised and are available on the 'physical sciences initiative' web site at www.psi-net.org in the 'safety docs' link of the physics section.

3. Teachers should note that the provisions of the Safety, Health and Welfare at Work Act, 1989 apply to schools. Inspectors appointed under that act may visit schools to investigate compliance.

# CALIBRATION CURVE OF A THERMOMETER USING THE LABORATORY MERCURY THERMOMETER AS A STANDARD

## Apparatus

Mercury thermometer, thermistor or any other thermometer to be calibrated, boiling tube containing glycerol, heat source, beaker of water, ohmmeter/multimeter.




## Procedure

1. Set up apparatus as shown in the diagram.
2. Place the mercury thermometer and the thermistor in the boiling tube.
3. Record the temperature $\theta$, in °C, from the mercury thermometer and the corresponding thermistor resistance $R$, in ohms, from the ohmmeter.
4. Increase the temperature of the glycerol by about 5 °C.
5. Again record the temperature and the corresponding thermistor resistance.
6. Repeat the procedure until at least ten sets of readings have been recorded.
7. Plot a graph of resistance $R$ against temperature $\theta$ and join the points in a smooth, continuous curve.

## Results

| $\theta$ /°C | $R$/Ω |
|---|---|
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## Notes

The resistance of the leads has been ignored in the description above, since it is negligible.

There is very good thermal contact between the glycerol and the thermistor since the glycerol does not contain dissolved gases.

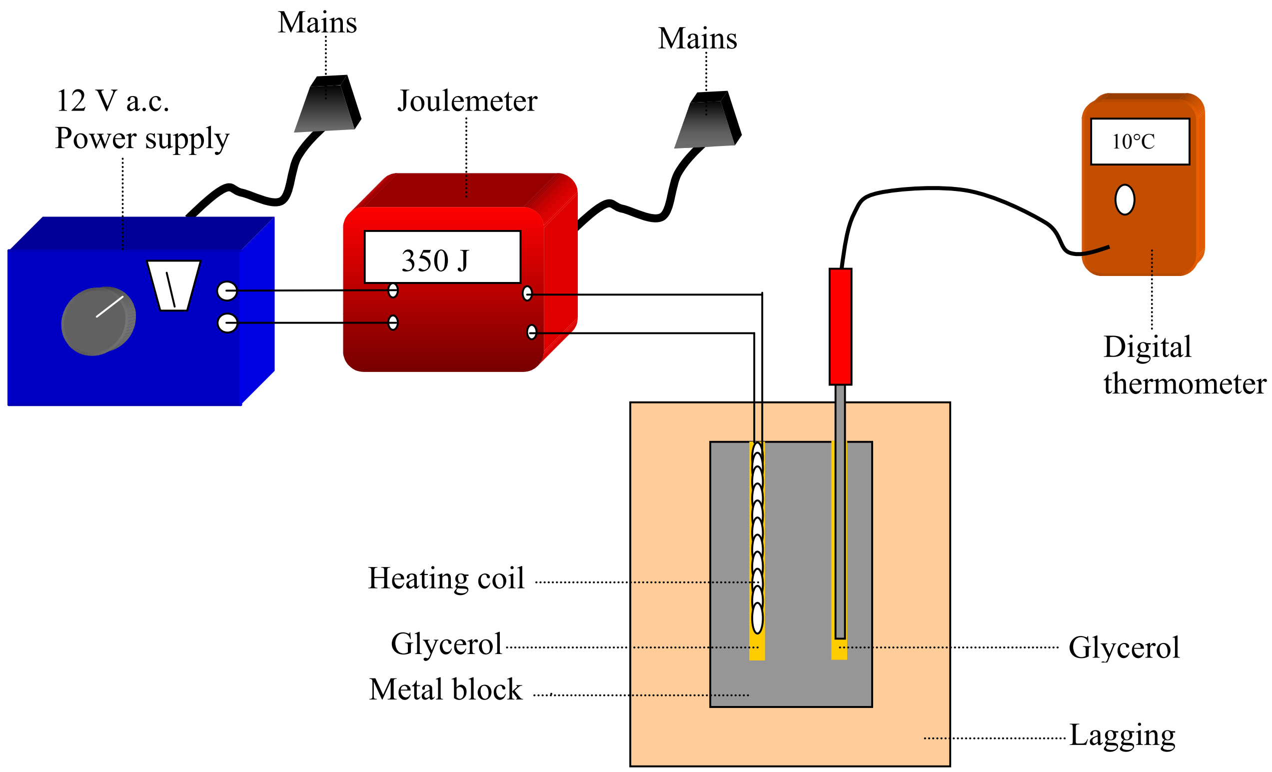
The boiling tube of glycerol is placed in a water bath to limit the maximum temperature reached to 100 °C.

The thermistor can now be used to measure temperatures within the range for which it has been calibrated.  Place the thermistor in thermal contact with the body whose temperature is to be found.  Measure the resistance and find the corresponding temperature from the calibration curve.

## MEASUREMENT OF THE SPECIFIC HEAT CAPACITY OF A METAL BY AN ELECTRICAL METHOD

## Apparatus

Joulemeter, block of metal, heating coil to match, beaker, lagging, thermometer accurate to 0.1 °C, glycerol, electronic balance and a low voltage a.c. supply.




## Procedure

1. Find the mass of the metal block *m*.
2. Set up the apparatus as shown in the diagram.
3. Record the initial temperature $\theta_1$ of the metal block.
4. Plug in the joulemeter and switch it on.
5. Zero the joulemeter and allow current to flow until there is a temperature rise of 10 °C.
6. Switch off the power supply, allow time for the heat energy to spread throughout the metal block and record the highest temperature $\theta_2$.
7. The rise in temperature $\Delta\theta$ is therefore $\theta_2 - \theta_1$.
8. Record the final joulemeter reading *Q*.

## Results

| | | |
|---|---|---|
| Mass of metal block | $m$ | = |
| Initial temperature of the block | $\theta_1$ | = |
| Final temperature of the block | $\theta_2$ | = |
| Rise in temperature | $\Delta\theta$ | = $\theta_2 - \theta_1$ = |
| Final joulemeter reading | $Q$ | = |

## Calculations

The specific heat capacity of the metal $c$ can be calculated from the following equation:

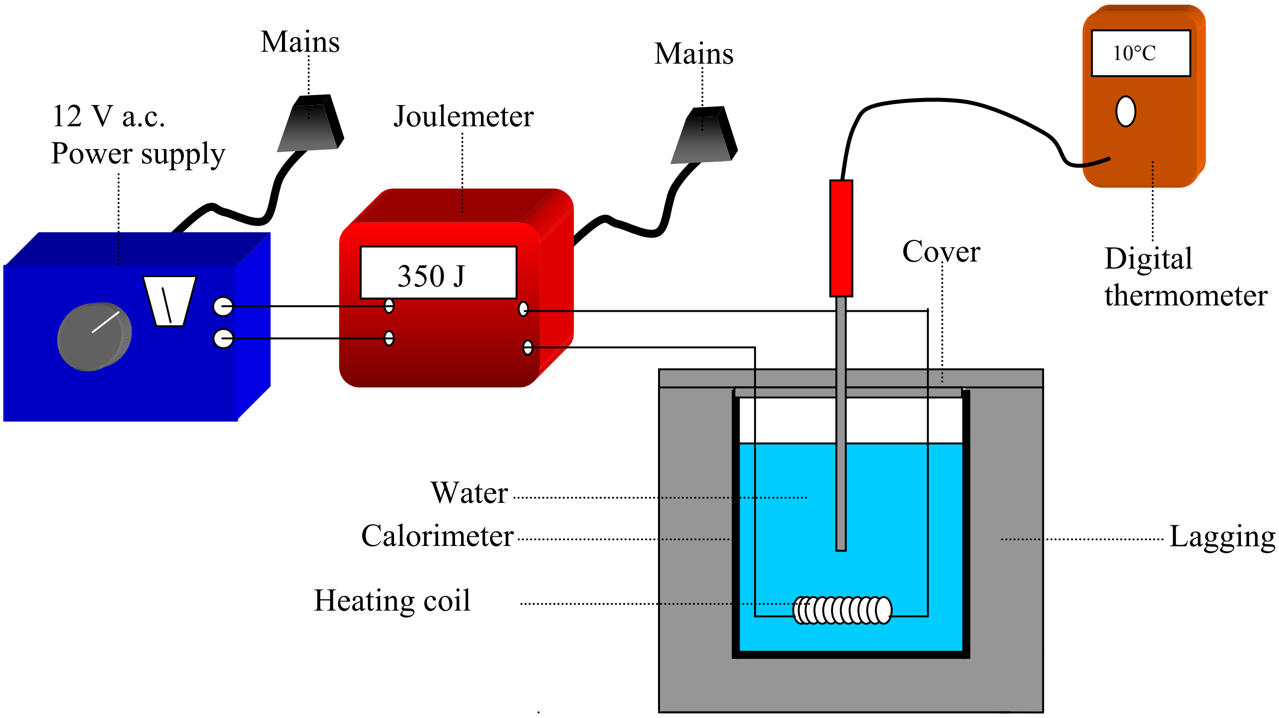
Energy supplied electrically = energy gained by the metal block

$$Q = mc\,\Delta\theta\ .$$

# MEASUREMENT OF SPECIFIC HEAT CAPACITY OF WATER BY AN ELECTRICAL METHOD

## Apparatus

Joulemeter, calorimeter, heating coil, beaker, lagging, thermometer reading to 0.1 °C, electronic balance and a low voltage a.c. supply.




## Procedure

1. Find the mass of the calorimeter $m_{\text{cal}}$.
2. Find the mass of the calorimeter plus the water $m_1$. Hence the mass of the water $m_w$ is $m_1 - m_{\text{cal}}$.
3. Set up the apparatus as shown. Record the initial temperature $\theta_1$.
4. Plug in the joulemeter , switch it on and zero it.
5. Switch on the power supply and allow current to flow until a temperature rise of 10 °C has been achieved.
6. Switch off the power supply, stir the water well and record the highest temperature $\theta_2$. Hence the rise in temperature $\Delta\theta$ is $\theta_2 - \theta_1$.
7. Record the final joulemeter reading $Q$.

## Results

| | | |
|---|---|---|
| Mass of the calorimeter | $m_{cal}$ | $=$ |
| Mass of the calorimeter plus the water | $m_1$ | $=$ |
| Mass of the water | $m_w$ | $= m_1 - m_{cal} =$ |
| Initial temperature of water | $\theta_1$ | $=$ |
| Final temperature | $\theta_2$ | $=$ |
| Rise in temperature | $\Delta\theta$ | $= \theta_2 - \theta_1 =$ |
| Final joulemeter reading | $Q$ | $=$ |

## Calculations

Given that the specific heat capacity of the calorimeter $c_{cal}$ is known, the specific heat capacity of water $c_w$ can be calculated from the following equation:

Electrical energy supplied = energy gained by water + energy gained by calorimeter

$$Q = m_w c_w \Delta\theta + m_{cal} c_{cal} \Delta\theta .$$

## Notes

If a polystyrene container is used in place of the copper calorimeter, then the energy gained by the water is equal to the electrical energy supplied since the heat capacity of the container is negligible.

The energy equation now reads: $Q = m_w c_w \Delta\theta$ .
If a joulemeter is unavailable, electrical energy can be supplied to the heating coil from a power supply unit connected in series to an ammeter and rheostat. A voltmeter must be placed in parallel with the heating coil to measure the potential difference and a stopwatch used to measure the time of current flow.
Switch on the current and the stopwatch simultaneously. Adjust the rheostat to maintain a constant current. Allow the current to flow until a temperature rise of 10 °C has been achieved. Record the steady current $I$ and voltage $V$ readings. Switch off the current and the stopwatch simultaneously. Record the time $t$ in seconds.

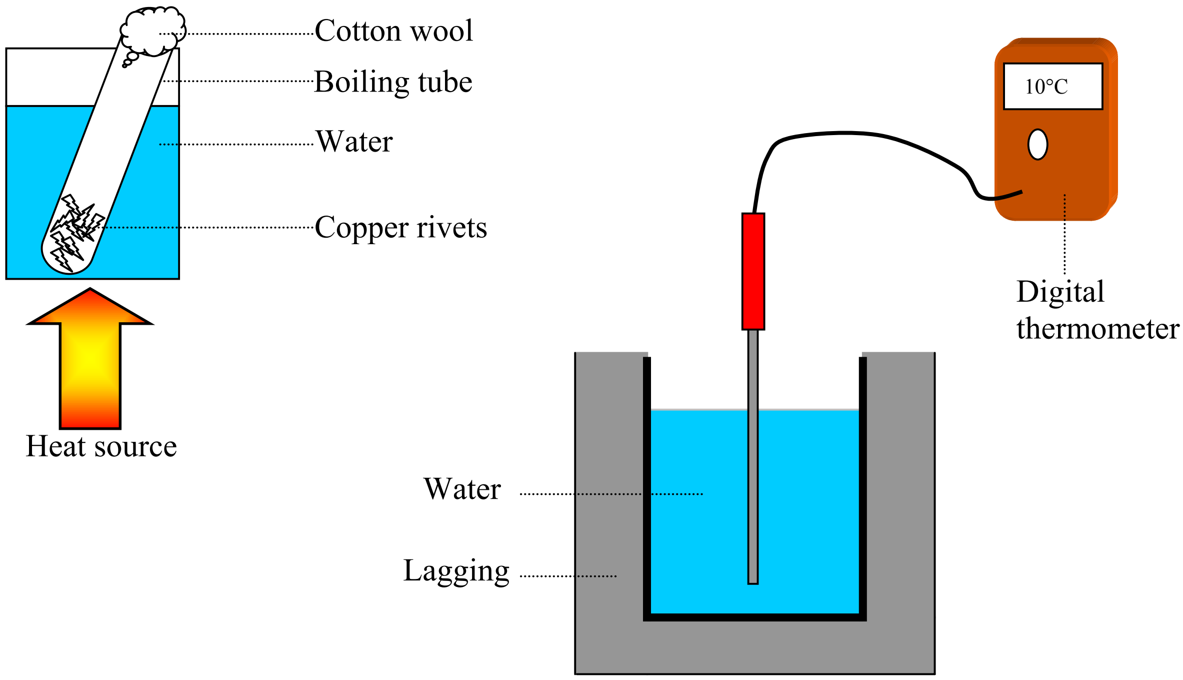
If a calorimeter is used the energy equation is: $VIt = m_w c_w \Delta\theta + m_{cal} c_{cal} \Delta\theta$ .

If a polystyrene container is used the energy equation is: $VIt = m_w c_w \Delta\theta$ .

## MEASUREMENT OF THE SPECIFIC HEAT CAPACITY OF A METAL OR WATER BY A MECHANICAL METHOD

### Apparatus

Copper calorimeter, copper rivets, beaker, boiling tube, lagging, thermometer accurate to 0.1 °C, heat source and electronic balance.




### Procedure

1. Place some copper rivets in a boiling tube. Fill a beaker with water and place the boiling tube in it.
2. Heat the beaker until the water boils. Allow boiling for a further five minutes to ensure that the copper pieces are 100° C.
3. Find the mass of the copper calorimeter $m_{cal}$.
4. Fill the calorimeter, one quarter full with cold water. Find the combined mass of the calorimeter and water $m_1$. Hence the mass of the water $m_w$ is $m_1 - m_{cal}$.
5. Record the initial temperature of the calorimeter plus water $\theta_1$.
6. Quickly add the hot copper rivets to the calorimeter, without splashing.
7. Stir the water and record the highest temperature $\theta_2$. The fall in temperature $\Delta\theta_1$ of the copper rivets is 100 °C – $\theta_2$. The rise in temperature $\Delta\theta_2$ of the calorimeter plus water is $\theta_2 - \theta_1$.
8. Find the mass of the calorimeter plus water plus copper rivets $m_2$ and hence find the mass of the rivets $m_{co}$.

## Results

| | | | | |
|---|---|---|---|---|
| Mass of the calorimeter | $m_{cal}$ | = | | |
| Mass of the calorimeter plus the water | $m_1$ | = | | |
| Mass of the water | $m_w$ | = | $m_1 - m_{cal}$ | = |
| Initial temperature of water | $\theta_1$ | = | | |
| Initial temperature of rivets | 100° C | | | |
| Initial temperature of calorimeter | $\theta_1$ | = | | |
| Final temperature of water | $\theta_2$ | = | | |
| Final temperature of rivets | $\theta_2$ | = | | |
| Rise in temperature of water | $\Delta\theta_2$ | = | $\theta_2 - \theta_1$ | = |
| Rise in temperature of calorimeter | $\Delta\theta_2$ | = | $\theta_2 - \theta_1$ | = |
| Fall in temperature of rivets | $\Delta\theta_1$ | = | 100° C - $\theta_2$ | |
| Mass of calorimeter plus water plus rivets | $m_2$ | = | | |
| Mass of rivets | $m_{co}$ | = | $m_2 - m_1$ | |

## Calculations

Assume that heat losses to the surroundings or heat gains from the surroundings are negligible.
Given that either the specific heat capacity of water $c_w$ or the specific heat capacity of copper $c_c$ is known, the other specific heat capacity can be calculated from the following equation:

Energy lost by copper rivets = energy gained by copper calorimeter + the energy gained by the water

$$m_{co}c_c\,\Delta\theta_1 = m_{cal}c_c\,\Delta\theta_2 + m_w c_w\,\Delta\theta_2\,.$$

If $c_w$ is known, then $c_c$ can be calculated or alternatively if $c_c$ is known, $c_w$ can be found.

## Notes

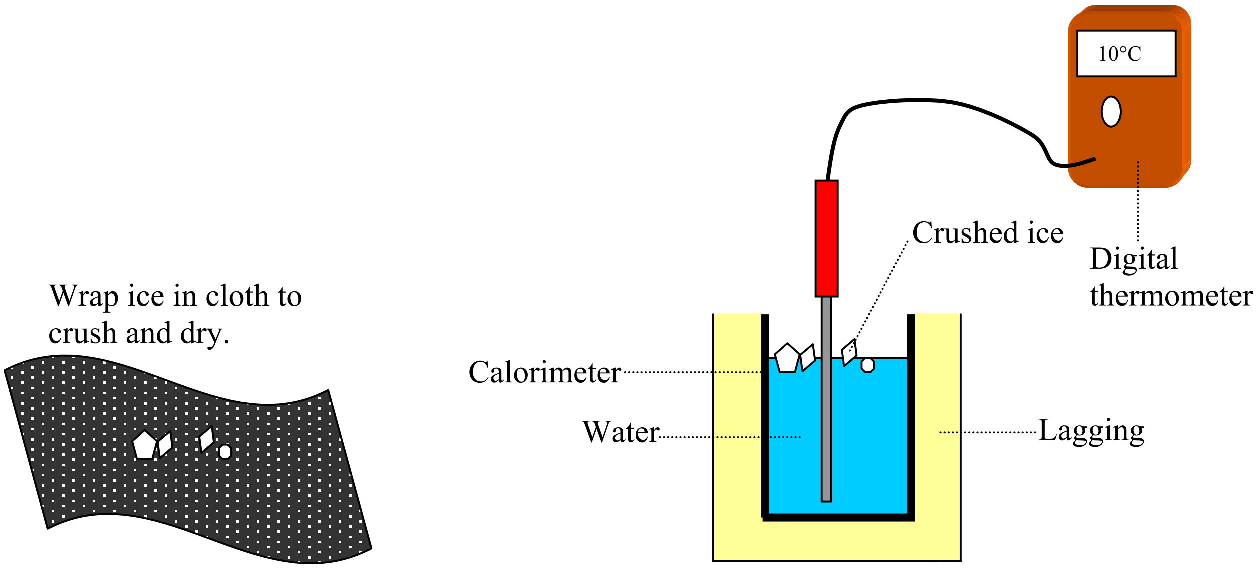
If a polystyrene container is used in place of the copper calorimeter, then the energy gained by the water is equal to the energy lost by the copper rivets. The energy equation now reads:

$$m_{co}c_c\,\Delta\theta_1 = m_w c_w\,\Delta\theta_2\,.$$

## MEASUREMENT OF THE SPECIFIC LATENT HEAT OF FUSION OF ICE

### Apparatus

Ice, water, calorimeter, lagging, beakers, kitchen paper, digital thermometer reading to 0.1 °C and electronic balance.




### Procedure

1. Place some ice cubes in a beaker of water and keep taking the temperature with the thermometer until the ice-water mixture reaches 0 °C.
2. Find the mass of the calorimeter $m_{cal}$.
3. Half fill the calorimeter with water warmed to approximately 10 °C above room temperature. Find the combined mass of the calorimeter and water $m_2$. The mass of the water $m_w$ is $m_2 - m_{cal}$.
4. Record the initial temperature $\theta_1$ of the calorimeter plus water.
5. Surround the ice cubes with kitchen paper or a cloth and crush them between wooden blocks – dry them with the kitchen paper.
6. Add the pieces of dry crushed ice, a little at a time, to the calorimeter. Do this until the temperature of the water has fallen by about 20 °C.
7. Record the lowest temperature $\theta_2$ of the calorimeter plus water plus melted ice. The rise in temperature of the ice $\Delta\theta_1$ is $\theta_2 - 0$ °C and the fall in temperature of the calorimeter plus water $\Delta\theta_2$ is $\theta_1 - \theta_2$.
8. Find the mass of the calorimeter plus water plus melted ice $m_3$. The mass of the melted ice $m_i$ is $m_3 - m_2$.

## Results

| | | | |
|---|---|---|---|
| Mass of the calorimeter | $m_{cal}$ | = | |
| Mass of the calorimeter plus water | $m_2$ | = | |
| Mass of the water | $m_w$ | = | $m_2 - m_{cal}$ = |
| Initial temperature of the calorimeter plus water | $\theta_1$ | = | |
| Final temperature of the calorimeter plus water plus melted ice | $\theta_2$ | = | |
| Rise in temperature of the ice | $\Delta\theta_1$ | = | $\theta_2 - 0$ °C = |
| Fall in temperature of the calorimeter plus water | $\Delta\theta_2$ | = | $\theta_1 - \theta_2$ = |
| Mass of the calorimeter plus water plus melted ice | $m_3$ | = | |
| Mass of the melted ice | $m_i$ | = | $m_3 - m_2$ = |

## Calculations

Assume heat losses cancel heat gains. Given that the specific heat capacity of water $c_w$ and the specific heat capacity of copper $c_c$ are already known, the latent heat of fusion of ice $l$ may be calculated from the following equation:

Energy gained by ice = energy lost by calorimeter + energy lost by the water.

$$m_i l + m_i c_w \Delta\theta_1 = m_{cal} c_c \Delta\theta_2 + m_w c_w \Delta\theta_2$$

## Notes

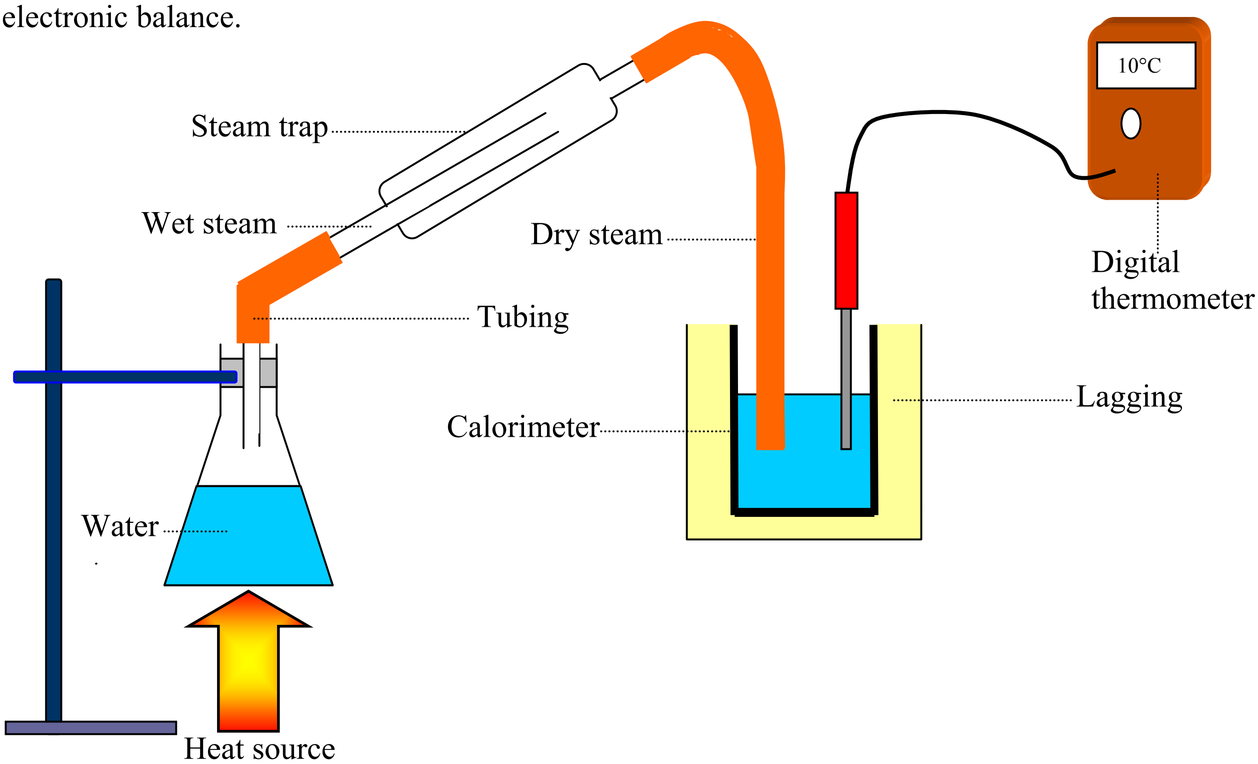
If a polystyrene container is used in place of the copper calorimeter, the energy gained by the ice is equal to the energy lost by the water.
The energy equation now reads: $m_i l + m_i c_w \Delta\theta_1 = m_w c_w \Delta\theta_2$.

To avoid melting the crushed ice, transfer it with a plastic spatula.

# MEASUREMENT OF THE SPECIFIC LATENT HEAT OF VAPORISATION OF WATER

## Apparatus

Calorimeter, lagging, beaker, conical flask fitted with stopper and delivery tube or steam generator, steam trap, retort stand, heat source, thermometer accurate to 0.1 °C and electronic balance.




## Procedure

1. Half fill the conical flask or steam generator with water and fit with the delivery tube.
2. Heat until steam issues freely.
3. Find the mass of the calorimeter $m_{cal}$.
4. Half fill the calorimeter with water cooled to approximately 10 °C below room temperature.
5. Find the mass $m_1$ of the water plus calorimeter.
6. The mass of the cooled water $m_w$ is $m_1 - m_{cal}$.
7. Record the temperature of the calorimeter plus water $\theta_1$.
8. Allow dry steam to pass into the water in the calorimeter until the temperature has risen by about 20 °C.
9. Remove the steam delivery tube from the water, taking care not to remove any water from the calorimeter in the process.
10. Record the final temperature $\theta_2$ of the calorimeter plus water plus condensed steam. The fall in temperature of the steam $\Delta\theta_1$ is 100 °C – $\theta_2$.
11. The rise in the temperature of the calorimeter plus water $\Delta\theta_2$ is $\theta_2 - \theta_1$.
12. Find the mass of the calorimeter plus water plus condensed steam $m_2$. Hence the mass of the condensed steam $m_s$ is $m_2 - m_1$.

## Results

| | | | |
|---|---|---|---|
| Mass of the calorimeter | $m_{cal}$ | = | |
| Mass of the water plus calorimeter | $m_1$ | = | |
| Mass of the cooled water | $m_w$ | = | $m_1 - m_{cal} =$ |
| Temperature of the calorimeter plus water | $\theta_1$ | = | |
| Final temperature of the calorimeter plus water plus condensed steam | $\theta_2$ | = | |
| Fall in temperature of the steam | $\Delta\theta_1$ | = | $100\ °C - \theta_2 =$ |
| Rise in the temperature of the calorimeter plus water | $\Delta\theta_2$ | = | $\theta_2 - \theta_1 =$ |
| Mass of the calorimeter plus water plus condensed steam | $m_2$ | = | |
| Mass of the condensed steam | $m_s$ | = | $m_2 - m_1 =$ |

## Calculations

Assume heat losses to the surroundings cancel heat gains from the surroundings. Given that the specific heat capacity of water $c_w$ and the specific heat capacity of copper $c_c$ are already known, the specific latent heat of vaporisation of water $l$ may be calculated from the following equation:

Energy lost by steam = energy gained by calorimeter + energy gained by the water

$$m_s l + m_s c_w \Delta\theta_1 = m_{cal} c_c \Delta\theta_2 + m_w c_w \Delta\theta_2 .$$

## Notes

If a polystyrene container is used in place of the copper calorimeter, then the energy lost by the steam is equal to the energy gained by the water.
The energy equation now reads: $m_s l + m_s c_w \Delta\theta_1 = m_w c_w \Delta\theta_2$.

Use a tilted insulated tube as an alternative delivery pipe for dry steam. This does away with the need to use a steam trap.

If the water in the calorimeter is initially cooled to10 °C below room temperature and then heated to 10 °C above room temperature the heat gains and heat losses approximately cancel each other out.