





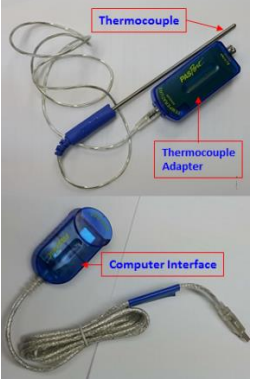




# Specific Heat

## Objectives

- To measure the specific heat capacity of water
- To measure the specific heat capacity of aluminium
- To measure the heat of fusion of ice (**Optional**)

## Apparatus Required

				
<b>Power Supply</b>	<b>Beaker</b>	<b>Beam Balance</b>	<b>Conecting wires</b>	<b>ice</b>
				
<b>Calorimeter Assembly</b>				
		<b>Thermometer Assembly</b>		
		<b>Accessories</b>		<b>Aluminium Shots</b>

## Introduction

In this experiment you will measure the specific heat capacity of water and aluminium. You will also measure the heat of fusion of ice if time permits. For detail theoretical introduction please look at the Appendix 1.

### Part 1: Measuring the specific heat of water ( $c_w$ )

In this exercise you will heat water through electric heater and find out the specific heat capacity of water by finding the time rate of change of temperature around room temperature.

When current  $I$  and voltage  $V$  are applied to the heater, which is immersed inside the water of mass  $m_w$ , its temperature rises by  $\Delta T$  in time  $\Delta t$ . Assuming that the system is perfectly isolated and the heat supplied by the electric heater is completely absorbed by the water. Also assuming that the heat absorbed by the water container is negligible the energy conservation equation can be written as,

$$IV\Delta t = m_w c_w \Delta T.$$

Here,  $c_w$  is the specific heat of water.

The above equation can be re-written as

$$\Delta T = \frac{VI}{m_w c_w} \Delta t. \quad (1)$$

According to equation (1) the temperature rises linearly with time and using the slope of  $T$  verses  $t$  curve we can calculate the specific heat of water.

#### Procedure

1. Take the aluminium calorimeter (smaller container) and measure its mass; fill about 50% of it with water.
2. Mix some ice to the water and stir it. Add ice until the temperature of the water falls at least 10 °C below the room temperature.
3. Make sure the final volume of the water shouldn't exceed 70% of the total volume of the calorimeter.
4. Find the mass of the water in the calorimeter ( $m_w$ ).
5. Put the plastic cover and the cap assembly on the calorimeter.
6. Insert the thermometer from the hole at the top of the cap. Make sure thermometer is not touching the electric heater.
7. Connect the thermocouple to computer through adapter and interface.
8. Make sure power supply is switched off and turn all the dials to lowest position by turning them counter-clockwise.
9. Connect the electric heater with the electric leads to the power supply. Make sure heating filament is well inside the water.
10. Open data studio, run the program and obtain Temperature-time graph.
11. Turn on the heater by turning on the power supply.
12. Raise value of current ( $I$ ) and voltage ( $V$ ) by turning nubs clockwise. Supply moderate power ( $P=I \times V$ ) so that the temperature will rise slowly. (Note: 5 to 7 Watt power is good)
13. You will get a **Temperature/time** curve.
14. Keep stirring the water almost contentiously to have equal distribution of heat. You have to stir non-stop especially 2 °C below room temperature to 2°C above room temperature.
15. Stop stirring when the temperature hits 2°C above the room temperature but don't turn off the heater as you have to continue heating water till 60°C for the second part of the experiment.
16. Find the slope of **temperature/time** graph very close to the room temperature.
17. Calculate specific heat capacity of the water using equation (1)

18. Compare it with the standard value 4190 J/Kg°C.

## Part 2: Finding Specific Heat of Aluminium (cal)

In this experiment you will continue heating water till the temperature hits more than 60°C. Then you will drop more than 50g of aluminium shots to find the specific heat of aluminium by conserving energy.

Let's say, when mass  $m$  of aluminium shots at room temperature  $T_R$  is added to the mass  $m_w$  of hot water at temperature  $T_h$  the mixture attains the final temperature  $T$ . Assuming that the system is perfectly isolated and the heat lost by the aluminium container is negligible, according to the conservation of energy, the heat gained by the aluminium shots equals to the heat lost by the water. The equation can be written as

$$m_w c_w (T_h - T) = m c (T - T_R).$$

Where  $c$  is the specific heat of aluminium.

Hence the equation can be written as

$$c = \frac{m_w c_w (T_h - T)}{m (T - T_R)}. \quad (2)$$

### Procedure

1. Continue heating water from the part 1 of the experiment.
2. Stir the water continuously for at least 1 to 2 min time to time.
3. Take some aluminium shots and measure their mass. (Choose the shots with mass between 50 to 100 g. Choose the quantity of aluminium shots such a way that it is not going to displace the water out of the calorimeter.
4. If you want to heat water faster you can raise the power up to about 20 Watts. **The maximum voltage you can use for the heater is 6 V. Do not exceed 6 V!**
5. Once the temperature is around 60°C bring back the slow heating rate to around 10 Watts and stir it nicely.
6. Once the temperature is around 65°C turn off the power supply and take off the connecting cables from the cap assembly of the calorimeter.
7. Take off the calorimeter cap assembly. Add the aluminium shots gently so that no aluminium piece goes out of the water and no water splash out of the container. **(To minimize error you may not take off the cap assembly out completely. You may raise the cap assembly slightly up holding the thermometer in its place and tilt the assembly so as to make one side open. Slide the aluminium shots.)**
8. Put the cap assembly back immediately and stir the water.
9. Find the temperature of the water just before adding aluminium shots ( $T_h$ ) and temperature of the mixture ( $T$ ) from the graph.

10. Take the mass of the container and its contents and find the mass of the water ( $m_w$ ). (The mass of the water now may be slightly different than the mass of the water in the beginning due to evaporation and other effects).
11. Calculate the value of “ $c$ ” from the equation (2).
12. Compare it with the given value of specific heat of aluminium (910 J/kg°C) at room temperature.
13. We assumed that the heat lost by the aluminium container is negligible compare to the heat lost by the water. For more accurate result you can include the heat lost by aluminium container and rewrite the equation (2). Write down in your report if you got any improvement on the result?

Note: following the same technique you can find specific heat capacity of any other material.

### Part 3: Finding Heat of Fusion of Ice ( $L_f$ ) (Optional)

In this exercise you will be finding the latent heat of fusion of ice by using conservation of energy. You will add melting ice to tap water and find the heat of fusion by conserving the heat energy of the system.

If you add  $m_i$  amount of melting ice into  $m_w$  amount of water at temperature  $T_w$  °C (which is higher than 0°C) in an isolated system the ice will gain energy and water will lose energy. If all ice melts and the final temperature of the mixture is  $T$  °C, according to conservation of energy,

$$m_i L_f + m_i c_w (T - 0) + m_w c_w (T - T_w) = 0.$$

Where  $L_f$  is the latent heat of fusion.

$$L_f = \frac{m_w c_w (T_w - T)}{m_i} - c_w T \quad (3)$$

To find the latent heat of fusion of ice follow the following steps.

1. Fill 2/3 of the foam calorimeter with room temperature water and measure the mass of the water ( $m_w$ ).
2. Keep electric heater cables disconnected from the power supply. In this experiment you are not going to heat the water.
3. Connect the thermocouple to the computer as in exercise 1.
4. Start Data studio and run the temperature-time graph. Since the water is at room temperature ( $T_w$ ) you will see a straight line in *temperature/time* graph
5. After few minutes slowly open the top-cup and add some melting ice into the water and stir it until it gets melted. (It is very important that the temperature of the ice should be at 0°C)
6. The temperature graph in the data studio will go down. Keep stirring until the temperature gets stabilized (it should be a straight line for about 2 minutes)
7. Once all the ice gets melted the temperature will stabilized ( $T$ ).
8. Measure the mass of the calorimeter and its contents.
9. Measure the mass of the ice ( $m_i$ ) by subtracting mass of the room temperature water from the final mass of the calorimeter and its contents.

10. Plug in all the measured values in equation (3) and calculate latent heat of fusion of ice.
11. Compare it with the standard value

# Appendix 1

## *Specific heat capacity $c$*

Specific heat is the amount of heat required to change a unit mass of a substance by one degree in temperature.

If  $Q$  is the amount of heat required to raise the temperature by  $\Delta T$  of an object with mass  $m$  then the specific heat capacity  $c$  is given by

$$c = \frac{Q}{m\Delta T}. \quad (\text{a-1})$$

For example: the specific heat capacity of water is 4190 J/kg °C which means that you need to supply 4190 J of heat to raise the temperature of 1 kg of water by 1°C.

## *Heat of fusion $L_f$*

Heat of fusion is amount of heat required to convert unit mass of solid into liquid without a change in temperature.

If  $Q$  amount of heat melts  $m$  mass of a solid its heat of fusion is

$$L_f = \frac{Q}{m}. \quad (\text{a-2})$$

The process of fusion takes place at a constant temperature. For example ice melts to water at 0 °C. Like specific heat the heat of fusion is fixed for a particular material. The heat of fusion of ice is 333 kJ/kg. It means when 333 kJ heat is supplied to 1 kg of ice at 0°C it turns to 1 kg of water at same temperature. On the other hand if 333 kJ of heat is removed from 1 kg of water at 0°C it converts back to ice at same temperature and the heat is called heat of transformation. Therefore the heat of fusion and transformation are always equal.

## **Law of Conservation of Energy:**

The law of conservation of energy states that the total energy of an isolated system always remains constant. In other words energy cannot be created or destroyed; it can only be transferred from one body to another body or one form to another form.

## **Electric Power:**

If we pass a current through a resistor it gets heat up and we call it an electric heater. The power ( $P$ ) through the resistor (electric heater) can be calculated by:

$$P = IV$$

Where,  $I$  is the current and  $V$  is the voltage across the heater.

Therefore the heat energy ( $Q$ ) generated by the electric power in time  $t$  is:

$$Q = IV\Delta t \quad (\text{a-3})$$

### **Thermocouple:**

Thermocouple is a device used to measure the temperature. It is an electrical thermometer.

## Appendix 2:

**It is very important to take the slope very close to the room temperature.** The reason is no matter how much precaution we take to insulate the system there will always be some heat exchange between the environment and the system. Therefore when the temperature of system (water) is less than the room temperature it will gain some extra heat from atmosphere and hence the rate of temperature raise will be faster than normal. In such a situation we are underestimating the specific heat. On the other hand when the temperature of the system (water) is more than the room temperature there will be leakage of heat to the atmosphere and hence the rate of temperature raise will be slower. In this case we are overestimating the specific heat. Right around room temperature the rate of rise of temperature will completely due to the electric heater because there will be negligible heat exchange between surrounding and the system. Therefore it is appropriate to consider the slope around the room temperature only.

## Appendix 3

Things that you can include in the report.

1. Find the heat supplied by the heater for a specific temperature interval (for example: from 15 to 20°C; the segment of the  $T$  v/s  $t$  curve must be a straight line for this interval i.e. must have been continuously stirred).
2. Find the heat gained by the water for the interval.
3. Find the heat gained by the aluminium container for this interval.
4. Find the rate of heat exchange between the system and surrounding for this interval.
5. Compare the rate of heat exchange with  $T_R \pm 1^\circ\text{C}$ .
6. Repeat Step 1 to 4 for another interval of higher temperature (for example: from 55 to 60°C)
7. Compare the rate of heat exchange for this interval with other two previous intervals.
8. What can you conclude from this?