What factors affect the temperature change of water when heated by an electric he...

Background Knowledge

The aim of this experiment is to investigate the factors that affect the temperature change of water when heated by an electric heater.

Planning Experimental Procedures

Factors:

There are many different factors that affect the temperature change of water when heated electrically:

* Mass of Water

* Time

* Type of Heater

* Purity of Water

* Amount of Current

* Environment Temperature

* Surface Area of Heater

* Electric Power

These eight factors listed above all affect the heating of water electrically in many ways. The Environmental Temperature would make a difference because if you were carrying out the experiment next to a heater, the heat being given off from the heater would make the temperature rise at a faster rate. If the experiment were to be carried out at room temperature the temperature rise would not be affected. The mass of water is a significant factor because the larger the mass of water means a stronger current is needed to heat the water. Some heaters are different to others so using the same heater throughout the experiment would mean that the same current is needed constantly. If the water were impure then it would take a greater current for the temperature to change. The greater the surface area of the heater the greater a temperature change would occur as the heater has a smaller area to work over. Time limits how long it would take for the water to change temperature, so generally by allowing more time, a greater change in temperature would occur.

Power

To work out the power of an electrical circuit (P), you need the voltage (V) and the current (I). To find this you can use the formula:

P = V * I

This will give us the power because:

Volt * Amps = Joules/Coulombs * Coulombs/Second – Joules/Second

Power can be measured in either joules per second (J/s) or watts (W)

Specific Heat Capacity

Heat is a form of energy and like any other form of energy it is measured in Joules. The Specific Heat Capacity of a substance is the amount of energy that is needed to raise the temperature of 1kg of the substance by 1ï¿½C. To work out the Specific Heat Capacity of substance when heated electrically you need the voltage (V), current (A) and the time (t) to work out the energy supplied.

Energy Supplied = V * A * t (power*time)

Then you need the mass of the substance (m) and the temperature change (? T).

Q = m * c * ? T

J = kg * Jkgï¿½ï¿½ ï¿½C * ï¿½C

Energy Supplied = mass * specific heat capacity * temperature change

c = Q (Energy Supplied)

mass * temperature change

Preliminary Experiment

Apparatus

The apparatus used for the preliminary experiment is as follows:

* Polystyrene Cup

* Measuring Cylinder

* Stopwatch

* Electrical Wires

* Immersion Heater

* Thermometer

* Ammeter

* Voltmeter

* Water

* Power Pack

Safety

Before we can carry out the test we must make sure that it is safe because if water and electricity combine they could have hazardous effects. All the wires must be checked for any loose covering, to reduce the chance of an electric shock. All connections must be done properly to make the experiment safe. The water must be kept in the cup, which, in turn was placed in the beaker to stop any spillage on the electrical circuit.

Method

Before I started the experiment I had to decide which two variables would be best to use for the actual experiment. I decided on the following:

* Mass of Water

* Current

I then decided to set up the experiment. I put two electrical wires into the power pack and then placed them on the ammeter and the voltmeter. I then wired the heater with the voltmeter to measure how much current I was going to use. I then measured each quantity of water by using the measuring cylinder. I then poured the water into the polystyrene cup and then placed the thermometer into the cup as well, and I recorded the starting temperature. After every minute I would check the temperature on the thermometer and record it and later on I would calculate the temperature change from the starting temperature till the end of the experiment, which I decided would be six minutes.

I decided to use a minimum of 0. 02kg of water because otherwise the heater would not be fully be submerged into the water, and therefore the water would not be heated sufficiently, creating an unfair test. I also decided to use 0. 08kg of water as the maximum because if I were to use any more water, the temperature change would be insignificant, because after 0. 08kg the graph begins to level off, showing that only a few ï¿½C change in the temperature, which would not have affected the results and it would be difficult to see any kind of relationship, due to the greater mass of water in the cup.

I then decided to make 2V the minimum voltage because if the voltage was any lower then the temperature would change as much, and it would be difficult to record the results because the temperature would only rise by a few ï¿½C because at this point the graph begins to level off. I then thought it would be best if I made 6V the maximum voltage because the voltmeter only allowed it reach 6V, and also we had to limit the power of the voltage as it might be dangerous. I decided to use a polystyrene cup rather than a glass beaker because the heat being given off would be transferred to the glass beaker quicker than the polystyrene cup and less heat would escape form the polystyrene cup.

When the Mass of water was the variable I decided to use the 5V because the lower voltages would give a low temperature change, by only a few ï¿½C and if I were to use any voltage greater than 5V then there would be a risk of overheating the heater, which would make the results inaccurate and no temperature change would occur. Therefore the power of the experiment would be 5 * 1. 5 = 7. 5W. When the Power was the variable I decided to use 0. 04kg of water because if the mass were lower than 0. 04kg then the heater would not be fully submerged into the water therefore the water would not be heated and the heater would overheat, and no temperature change would occur. Also if the mass was greater then 0. 04kg the temperature change would only rise by a few ï¿½C, therefore the results would be inaccurate and by using 0. 04kg I found that it was the best alternative, because I required a mass that would show temperature change clearly as well as the heater being fully submerged in the water.

Results of Preliminary Experiment

Mass of water is used as the variable.

Mass of water (kg)

(1s. f.)

Time (seconds)

Voltage (V)

Current (A)

Power (W)

Starting Temperature (ï¿½C)

Final Temperature (ï¿½C)

Temperature Change

(ï¿½C)

0. 02

360

5. 0

1. 5

7. 5

19. 0

46. 8

27. 8

0. 04

360

5. 0

1. 5

7. 5

19. 0

33. 0

14. 0

0. 06

360

5. 0

1. 5

7. 5

21. 0

29. 5

8. 0

0. 08

360

5. 0

1. 5

7. 5

21. 0

27. 0

6. 0

Predictions

As we increase the mass of water, the temperature change will decrease. This will work only if the time and the power of the experiment remain constant.

Quantitative Formula

Temperature Change is inversely proportional to the Mass of Water

Justifying my prediction

As we increase the amount of water when the time and power are constant the temperature change will decrease. This is because there is more water to heat, which means that it will take longer to heat the water. The particles will have more collisions and will need to work harder and longer if there is more water, therefore more kinetic energy is needed, which can only be converted from the heat energy. Whereas if there is less water the particles will not need to work was hard to heat the water therefore less kinetic energy is needed because there is a smaller mass needed to be heated. This means that as we increase the mass of water and keep the time and power constant, then the temperature change will decrease, thus justifying my prediction. This means that if I were to double the mass of the water then the temperature change would be halved.

This justifies my prediction:

Energy needed (E) = mass (m) * specific heat capacity (c) * change in temperature (? T)

If I substitute the formula with numbers, I should be able to prove that my Quantitative Formula is correct.

Mass = 0. 02kg

Specific Heat Capacity = 4200J

Time = 360 seconds

Power = 7. 5W

Mass = 0. 02kg

E = P*T

7. 5*360 = 2700J

? T = E/m*c

2700/(0. 02*4200) = 32. 14ï¿½C (2d. p)

Mass = 0. 04kg

E = P*T 0. 2kg * 2 = 0. 4kg

7. 5*360 = 2700J 32. 14ï¿½C / 2 = 16. 07ï¿½C

? T = E/m*c Thus proving my quantitative formula

2700/(0. 04*4200) = 16. 07ï¿½C (2d. p)

If you double the mass of water, this causes the change in temperature to be halved, shown above.

Power is used as a variable

Power (W)

Voltage (V)

Current (A)

Time (seconds)

Mass of water (kg)

(1s. f.)

Starting Temperature (ï¿½C)

Final Temperature (ï¿½C)

Temperature Change

(ï¿½C)

1. 2

2. 0

0. 6

360

0. 04

19. 0

23. 4

4. 4

2. 7

3. 0

0. 9

360

0. 04

19. 0

29. 0

10. 0

4. 8

4. 0

1. 2

360

0. 04

19. 0

36. 8

17. 8

7. 5

5. 0

1. 5

360

0. 04

19. 0

46. 8

27. 8

10. 8

6. 0

1. 8

360

0. 04

19. 0

59. 0

40. 0

As we increase the Power, the temperature change will rise as long as the mass of the water and the time of the experiment remain constant.

Quantitative Formula

Electrical Power is directly proportional to the Temperature Change

Justifying my prediction

I have stated that as we increase the Power, the temperature change will rise as long as the mass of water and the time remain constant. If we increase the power we will be increasing the amount of energy input. Heat energy from the heating element is converted to kinetic energy of the particle in the water. This means that if there is more heat there is more kinetic energy. This means that if I double the power of the circuit the temperature change will double as well.

This justifies my prediction:

Energy Supplied = V * A * t (power*time)

Q = m * c * ? T

J = kg * Jkgï¿½ï¿½ï¿½C * ï¿½C

Energy Supplied (E) = mass (m) * specific heat capacity (c) * change in temperature (? T)

If I substitute the formula with numbers, I should be able to prove that my Quantitative Formula is correct.

Mass = 0. 04kg

Specific Heat Capacity = 4200J

Time = 360 seconds

Power = 2. 7W & 10. 8W

Power = 2. 7W

E = P*T

2. 7*360 = 972J

? T = E/m*c

972/(0. 04*4200) = 5. 785ï¿½C (3d. p)

Power = 10. 8W

E = PT 2. 7W * 4 = 10. 8W

10. 8*360 = 3888J 5. 785ï¿½C * 4 = 23. 14ï¿½C

? T = E/m*c Thus proving my quantitative formula.

3888/(0. 04*4200) = 23. 14ï¿½C (2d. p)

Method for Mass of Water

Firstly I had to set up the circuit correctly. I had to measure the mass of water required and then poured it into the polystyrene cup. I then fully submerged the electric heater into the cup and then placed the thermometer as well. I recorded the starting temperature of the experiment. I then made sure that the Power supplied remained constantly at 7. 5W and then the timed the experiment for 6 minutes. After 6 minutes I would record the temperature and then calculate the change in the temperature. The temperature change was found by subtracting the final temperatures from the starting temperature.

Results

Mass of water (kg)

(1s. f.)

Time (seconds)

Voltage (V)

Current (A)

Power (W)

Starting Temperature (ï¿½C)

Final Temperature (ï¿½C)

Temperature Change

(ï¿½C)

0. 02

360

5. 0

1. 5

7. 5

23. 0

57. 0

34. 0

0. 04

360

5. 0

1. 5

7. 5

23. 0

49. 0

17. 0

0. 06

360

5. 0

1. 5

7. 5

23. 0

33. 0

10. 0

0. 08

360

5. 0

1. 5

7. 5

23. 0

31. 0

8. 0

Method for Power Supplied

Firstly I had to set up the circuit correctly. I then measured 0. 04kg by using a measuring cylinder, and then poured the water into the polystyrene cup. I then fully submerged the electric heater as well as the thermometer into the water, and I then recorded the starting temperature of the experiment. I then varied the power supplied several times for each experiment, during which I would time the experiment for 6 minutes. The temperature change was found by subtracting the final temperature from the starting temperature.

Results

Power (W)

Voltage (V)

Current (A)

Time (minutes)

Mass of water (kg)

(1s. f.)

Starting Temperature (ï¿½C)

Final Temperature (ï¿½C)

Temperature Change

(ï¿½C)

1. 2

2. 0

0. 6

360

0. 04

22. 0

26. 0

4. 0

2. 7

3. 0

0. 9

360

0. 04

22. 0

31. 0

9. 0

4. 8

4. 0

1. 2

360

0. 04

22. 0

38. 0

16. 0

7. 5

5. 0

1. 5

360

0. 04

22. 0

47. 0

25. 0

10. 8

6. 0

1. 8

360

0. 04

22. 0

55. 5

33. 5

Analysis of Results

In the first graph where the mass of water was varied and the time and the power were kept constant, I found no anomalous results but the relationship saying that the change in temperature is inversely proportional to the mass of water was correct. Graph 1 shows that temperature change is inversely proportional to the mass, because the gradient on the graph shows that y = 1/x, which in mathematical terms means that the y-axis i. e. temperature change is inversely proportional to the x-axis, i. e. mass of water, but in this case the y-axis and the x-axis can be replaced by either the temperature change or the mass of water. As shown on the graph, by doubling the mass of the water from 0. 02kg to 0. 04kg the temperature change is halved from

34ï¿½C to 17ï¿½C, so by doubling the mass, the temperature change is halved, thus proving the quantitative formula. Also during the experiment I had to switch electric heaters, as I could not find the one I was using before, which could have affected the outcome of the results.

In the second graph where the mass of water and the time remained constant but the power of the circuit was varied I had found out that I had no anomalous results. The statement made earlier that temperature change was directly proportional to the power was true, as shown in the graph because there is straight line that goes through all the points as well as the origin (0, 0), therefore the equation for this particular graph is y = mx + c.

After I had fully studied my results I have found out that the temperature change is directly proportional to the power as shown on the graph, because the line goes through the origin and follows the equation y = mx + c. The prediction made that temperature made is inversely proportional to the mass of water, is correct because the graph clearly shows that a curve line is shown which can be simplified to y = 1/x.

Quantitative Formula

Heat Energy Supplied is Directly Proportional to the Temperature Change

Heat Energy Supplied = mass * specific heat capacity * temperature change

Joules = kg * Joules/kgï¿½ï¿½ ï¿½C * ï¿½C

Evaluation

As seen in the first graph Temperature Vs Mass of Water it can be seen that in most cases there is a negative gradient, which remains constant. Hence my prediction that Temperature Change is inversely proportional to the Mass of Water stands true (? T? 1/Mass). There were no anomalies and the lines were perfect and showed that the temperature change is inversely proportional to the mass of water.

In the second graph Temperature Vs Power it can be seen that the formula y = mx + c remains true because there is a constant gradient, that goes through the origin. Therefore Temperature Change is directly proportional to the Power Supplied (? T ? Power). The lines were perfect and there were no anomalies so I can say that temperature change is directly proportional to the power.

Temperature change (? C) is directly proportional to the:

* Power Supplied

And inversely proportional to the:

* Mass of Water

Formulating

? T (? C) ? Power

? 1/Mass

There were four main factors that caused some anomalous results in my investigation:

? Surface Area of the Heating Element due to the non-availability of the same heater

? Human Error

? Loose or faulty Circuit Connections

? Lag time for the electric heater to go from cold to hot

? Environment Temperature

Improvements

All investigations must be carried out fairly. When measuring the mass of the water you must make sure that you do not spill any of the water and that the mass is measured properly. Using the same electric heater is vital because different heater have a difference in resistance, which in turn would heat the water at different rates. Also the starting temperature of the water should remain constant at all times to enable accurate results, as well as the surface area of the heating element remaining the same throughout the experiment. I can say that using 0. 08kg, as the maximum mass was a crucial decision because after 0. 08g the graph began to level off, so any further results would have no affect on the temperature change, because an increase in the mass of water would show no affect to the temperature change, defeating the purpose of this investigation.

The heater only heated the water right next to it to a higher temperature. If I were to do the experiment again I would stir the water occasionally during the experiment, so that the heat can be transferred all round the water, and not just stay in the immediate vicinity of the heater otherwise the results would be inaccurate because the heat would not be transferred to all the water particles therefore making the temperature change would only occur in the area where the heater was, and not in the entire cup of water. I could have also used a pipette to measure the exact mass of water instead of just running the tap and checking that the level of water was equal to the required mass. The pipette would allow the water to be transferred drop by drop, which would enable me achieving an accurate mass.

To make the investigation better I could have collected several more results and calculated an average, which would enable less human errors to occur. Also I could have used the same electric heater throughout the investigation, which would make the lag time equal for all the experiments, and also keep the resistance equal through out the experiment to achieve accurate results. I could have also used different variables. The aim of this investigation was to investigate " What factors affect the temperature change of water when heated by an electric heater?" therefore; I could have tried changing the time of heating. I can say that time is directly proportional to the change in temperature, because as time increases the temperature change will also increase.

Energy Supplied = V * A * t (power*time)

Q = m * c * ? T

J = kg * Jkgï¿½ï¿½ ï¿½C * ï¿½C

Energy Supplied (E) = mass (m) * specific heat capacity (c) * change in temperature (? T)

Both power and time are in conjunction with each other, so by varying the power, the time must remain constant, but by varying the time, the power must remain constant. If power is directly proportional to temperature change then time must be as well, as they occur in the same formula. Time and Power are identical to each other as they are both directly proportional to temperature change. Therefore I can say:

Specific Heat Capacity = Power * Time

Mass * ? T

But by investigating all three variables I would achieve an overall and firm conclusion to the experiment, as I have investigated the three main factors that affect the temperature change, when heated electrically.