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Scientific Investigations – Insulation

Aims:

The aim of the investigation is to discover which variable prevents the least amount of heat loss through convection, conduction, radiation and possibly evaporation. Another aim of the experiment is to fi nd the best insulator out of the materials given.

Background Information:

In this investigation I will be using copper beakers to hold a volume of 100cm3. I will measure the temperature loss of each different beakers, I will test them with 3 different insulators. I could use many different insulators such as: cotton wool, tin foil, polystyrene, plastic, bubble wrap, paper and rubber. However I have chosen three to use, these are: cotton wool, tin foil, bubble wrap. I will also have to do one experiment with nothing; this is because I will need to compare my results.

The factors which will effect the rate of heat transfer are:

The temperature of the room,
The amount of water in beaker,
The size of beaker,
The type of insulator,
The time left between readings.

The factor I will change will be the type of insulator the beaker of water will be covered with, this will be known as the independent variable. I will keep one beaker without any insulation (control), of the other three, one will be covered with foil, one with a cotton wool and one beaker will have bubble wrap. Below is a description of the variables I will test:

Cotton Wool: The more wool around the container the better the insulator it would be; the amount of wool can make a difference in how much the temperature would fall in every one or two minutes, because if you have a bit of wool the heat could slightly go through but when you have enough wool to cover the container the air between the pockets would make it a good insulator.

Tin Foil: A bright shiny surface that is a poor absorber of radiation and reflects it away. This is a good material because it will not lose much energy. Different surfaces give out and take in different amounts of energy.

Bubble wrap: This can be a good insulator because air is a good insulator, so the air in the bubbles would stop the heat from leaving the container. It is very much like a double-glazed window.

The four main types of heat transfer are the following:

- Convection involves the movement of molecules and so it can only occur in fluids (liquids and gases), where the molecules can move within the body of the fluid. Convection currents are examples of floating and sinking. When part of a liquid or gas is made warmer than its surroundings it expands and rises because it is less dense. The air next to the icebox in a fridge is cooled and so it contracts. The cold air sinks because it is denser than the warm air below it. This movement of air is called a convection current. A dye in the form of a crystal or an ice cube can be used to see convection currents in water.

- Conduction is the main way in which energy transfers take place in solids, but it also applies to liquids and gases. Good conductors are needed to transfer the energy of the hot water in a radiator to the air outside and the energy from the heating element of a kettle into the water.

When one part of a material is hotter then another, the molecules in the hotter part have more energy than the surrounding ones. Heating a substance causes increased motion of the atoms and molecules. In a gas this means that the average speed of the atoms and molecules increases, but in a solid or a liquid it leads to increased vibration. Atoms and molecules do not exist in isolation, and they are continually interacting and swapping energy with their neighbours. The transfer of energy from energetic molecules to those with less energy is responsible for conduction.

Gases are poor at transferring energy in this way because the molecules are relatively far apart, compared to a solid or liquid. The more energetic molecules in part of a gas that has been heated travel large distances, in molecular terms, between collisions and so it takes them longer to transfer energy to other molecules.

- Radiation is when the warm water particles vibrate the water particles next to them. This will give them more energy and will make the water there warmer. The water particles at the top of the can will radiate the heat energy into the surrounding air. For heat to radiate it does not need to be in contact with matter. Heat can radiate for some thing to another body through a complete vacuum, this is how the sun heats up the earth. This process can also be called the Wave Motion.

-Evaporation is the process by which particles from a liquid form a vapour. Perfumes are designed to evaporate over a time period of several hours. The appetising smell of cooking food is due to evaporation. Evaporation is important to us when we are in a hot climate. This is because liquids need

energy to evaporate, and they take this energy from their surroundings. You can feel the coding effect if you put a drop of a liquid on your skin that evaporates easily.

Fair Test:

I must make sure that the tests are fair by being very accurate when measuring the temperatures of the beakers with boiling water in them, so that I end up with results that will indicate which material is the best insulator.

In this investigation it is important that I use containers made of the same size, and same shape, with the same volume of water, at the same temperature. This is called 'controlling the variables', which will help me carry out the investigation as accurate as possible.

Prediction:

I predict that the cotton wool will prevent the most amount of heat loss from the beaker because, due to the composition of the cotton wool i.e.: several layers, air is trapped between the layers and so provides the best insulation. This is good because although the air warms up, if it is unable to move easily and so cannot carry the heat away by convection currents. Efficient insulators tend to be substances that have lots of holes or gaps in them. Sometimes in fibrous insulators, they work by trapping air inside – because air is a bad conductor of thermal energy. Heat spreads through air slowly, and so this is why insulators tend to be fluffy substances like wool and fibreglass matting. These substances trap air between their filaments.

A material will be a good insulator if neither heat nor electricity can pass through it easily. Although the bubble wrap, in my experiment, is a good insulator, metals such as aluminium are good conductors. I think that the cotton wool will be the best material when preventing heat loss because it will slow down radiation (the main way that heat will travel from the hot liquid in the beaker through the walls and base of the beaker and then to the outside world). However, I do think that the foil will prevent heat loss successfully. Foil reflects better than all the other materials in my experiment. This is because it is fairly light in colour and shiny. This enables the foil to reflect the radiation from the hot object back the way it came. Although, the cotton wool will not stop convection through the top of the beaker, I think it will be the most successful way of insulating the beaker of hot water. The cotton wool will not cover the top of the beaker, and so this will increase the amount of heat lost. I think the beaker will lose heat because above the liquid, the air will take heat from the liquid and rise (convection current). In addition, after prolonged periods, some of the liquid will evaporate, losing energy and causing its temperature to fall.

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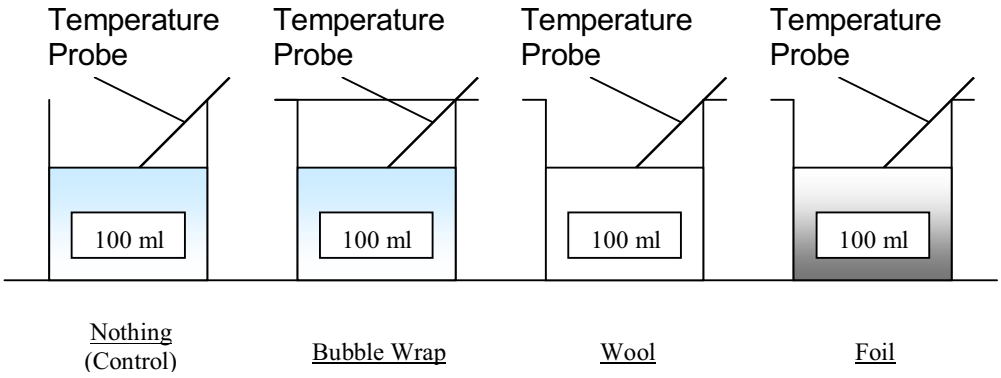
Method

1. Collect all the equipment that is needed as shown in the apparatus list above.
2. Wrap all the containers with the chosen materials.
3. Boil kettle.
4. Pour 100ml of boiled water into measuring cylinder.
5. Pour 100ml of the boiled water into each contai ner.
6. Put a temperature probe in each container.
7. Wait until the water cools down to 80°C
8. Start stop watch
9. Record the temperature every thirty seconds for five minutes.
10. Repeat the whole experiment two more times.

Diagram of experiment:



Safety and Skill:

To insure that my experiment will be safe I will be careful when handling the kettle/beakers due to the very hot water inside them.

When I take my readings I will look at the thermomete rs at eye level, this will mean that the readings are more accurate, than if were to read them at an angle.

What apparatus will I need?

Wool
Bubble wrap
Foil
4 copper beakers (same size)
Kettle
Water
2 temperature probes
Stopwatch
Data Logger
200ml measuring cylinder

Factors to Measure:

Temperature: For every couple of minutes I am going to measure the temperature to see the difference in temperature loss of the water.

Time: I am going to measure the time of how long it takes for the temperature to decrease, to see which material takes the longest to lose its heat energy in around ten minutes.

Trial Data (Preliminary Investigation):

To achieve a good range of results, I am going to measure the temperature of hot water in a copper container without it being covered by any materials, to see how much the temperature of the water would fall every 30 seconds starting from 80°C. I will do the experiment three times, for all three attempts I will use a volume of water accurate to 100cm3. Here are my resul ts:

Time (sec)	*Temp (°C) 100m Average*
Starting Temp	80.0
30	78.6
60	77.0
90	75.3
120	73.9
150	72.7
180	71.7
210	70.7
240	69.5
270	68.4
300	67.3

I will be timing for five minutes, every thirty seconds because this provides a good range of results in the first couple of minutes in which the greatest and quickest heat loss occurs. I used these results to plan for my practical. This meant I knew the correct temperature and volume for my proper experiment.

Collecting Data

Here are my result averages:

The temperatures are recorded in Degrees Celsius.

Time (Sec)	Nothing - (Control)	Tin Foil	Cotton Wool	Bubble Wrap
0	80	80	80	80
30	78.6	79.45	79	78.4
60	77	77.95	78.1	76.7
90	75.3	76.7	76.9	75.2
120	73.9	74.95	75.9	74
150	72.7	73.5	74.5	72.9
180	71.7	72.15	73.3	71.4
210	70.5	70.7	72.4	70.4
240	69.2	69.5	71.4	69.3
270	67.9	68.2	70.6	68.1
300	66.6	67.4	69.8	67.2

On the next two pages I have created five different graphs. The first large graph shows all the results on one page, this is us eful to compare each separate insulator. On the next page after this, there is a separate graph of each insulator. I have done this because I will put a separate best line of fit on each graph. I have also used these smaller graphs to circle any anomalies.

Analysis:

During my experiment, I decided to measure the temperature of each beaker and then to find how much heat was lost. I followed the simple sum below:

Original temperature of water – water temperature of last reading = heat lost to surroundings

All the experiments started at a temperature of 80 degrees Celsius, so all I had to do was takeaway the final ending temperature away from 80, here are my findings:

Nothing (Control) = 80 – 66.6 = 13.4

Tin Foil = 80 – 67.4 = 12.6

Cotton Wool = 80 – 69.8 = 10.2

Bubble Wrap = 80 – 67.2 = 12.8

This shows that if you put them in the order of best insulator, it would be as shown,

1. Cotton Wool
2. Tin Foil
3. Bubble Wrap
4. Nothing

Conclusion:

The four curves for each beaker on my graph show negative correlation, as the temperature decreased due to h eat loss. The line for the control, is suitable, as it shows a steeper gradient compared to the other three beakers. The line of best fit for each beaker gives a visual representation of the underlying trend. All of the insulators have a reasonable line, this is because I did the experiment three times for each of them. I have found out that the cotton wool was the best insulator and prevented the most heat loss and the worst insulator in my experiment was the beaker with no insulation. (Control). The results of the experiment do give reasonably clear plots, but there are some anomalies. One of these anomalies occurred for the foil beaker after thirty seconds. The problem was that in the first 30 seconds the temperature hardly decreased, it did not follow the pattern like all the other decreases. However, I have noticed that the water in the beaker, insulated with the cotton wool, was the second hottest after 30 seconds. After about 2 minutes, it was the hottest and so had kept the most heat in. In concl usion, I have proved that the beaker insulated with the cotton wool was the best at preventing heat loss. The cotton wool was the most successful insulator because it was the

only material containing many layers of material that could trap air and therefore heat. The trapped air could not move easily and so could not carry the heat away in convection currents. The main reason why the cotton wool was the best insulator is because the heat could not radiate through it. The cotton wool was also the most successful because of the layers, which trapped the hot air given off by the hot water in the beaker. However I have discovered that as Foil reflects better than all the other materials in my experiment (it is fairly light in colour and shiny), it enables the foil to reflect the radiation from the hot object back the way it came. That's why foil came second over all. In addition, after prolonged periods, some of the liquid evaporated, losing energy and caused its temperature to fall. This is the reason you have cotton wool like cushions around your boiler and in your loft.

My results supported my original prediction, as the cotton wool has been proved to be the most successful at preventing heat loss from the hot water in the beaker. However, the results for the beaker with the foil, and also the beaker with bubble wrap, have a difference of only about 0.1°C. I would not expect this because I predicted that the beaker with bubble wrap would of shown a slightly larger heat loss.

Evaluation:

I think that although I successfully proved that my results supported my prediction, I think that I could have made the experiment more of a fair test. The starting temperature was not always exactly 80*C. This is because we did the experiment on two different days we used two different kettles. They would have boiled the water at different speeds, and the kettle was in constant use, it also took time to measure the water every time. This made my experiment less accurate.

The results of the experiment do give reasonably clear plots, but there are some anomalies. One of these anomalies occurred for the foil beaker after thirty seconds. The problem was that in the first 30 seconds the temperature hardly decreased, it did not follow the pattern like all the other decreases during the experiment. However, I have noticed that the water in the beaker, insulated with the cotton wool, was the second hottest after 30 seconds. After about 2 minutes, it was the hottest and so had kept the most heat in.

I took my readings very accurately because I used a temperature probe. However I should have ensured that the readings were taken exactly every thirty seconds. Sometimes, results were recorded that did not fit into the pattern. This may have been because I wrote the results in the wrong time sections. Although I was very accurate, one person in the group may have been less accurate at taking readings than another – this could of affected some of the results or made them less accurate. Also, there may have been faults in the equipment and this could of affected the readings.

When I carried out my experiment, conditions were not perfect to carry out a fair test. For example, the room temperature could have changed due to the weather. Also, I found many problems (mainly invo lving the timing). I was under pressure to take the readings on each temperature every thirty seconds. If I were to carry out the experiment again, I would have worked as 1 group of four instead of two groups of two. This would mean that when every thirty seconds had passed, each reading would be taken simultaneously. Thereby, three readings would be taken for each beaker every minute. From these readings, I could find the average (this would have made the results more accurate by finding the mean).

Using my results table, I can see that one or two results did not fit in. This was due to mistakes made when recording the temperature readings. However, this did not alter the results greatly (if at all). The beaker covered in foil showed an anomaly in the results for the first thirty seconds. This was probably due to inaccuracy when taking the readings. However, I believe I have enough evidence to support my conclusion, that the best insulator was the cotton wool in my experiment.

To improve the experiment, and add to my conclusion, I could conduct the experiment for a longer period of time. For example, I would record the temperature of the water after 1-minute intervals, for five minutes. This further work may show larger changes in the heat lost from the different beakers. I could also use a more accurate stopwatch. I could also repeat my experiment as to gain more results. The more results I have to find the average of, the more accurate the end result will be. By repeating the experiment f or around four or five times, it would improve the reliability of the evidence. I could then make a more reliable conclusion. I could also improve the range of materials that I use in my experiment. For example, I could use a different range of shiny materials, a range of thick materials etc. I did not do this in the original experiment as I had only limited materials and lack of time, but from experimenting with different materials, I could gain results to support a different conclusion.