The Specific Heat of a Liquid

Purpose: To experimentally determine the specific heat of ethyl alcohol.

Principles: Heat is a form of energy which can pass spontaneously from an object at a higher temperature to an object at a lower temperature. One of the properties of matter is that when heat flows into a substance, the temperature is raised; if heat is withdrawn, the temperature is lowered (provided that there is no change in state).

Traditionally, the unit of heat is the calorie (cal) which is defined as the quantity of heat required to raise the temperature of 1 gram of water by 1 degree Celsius. In keeping with the gradual trend toward SI units, the Joule (J) is now being used increasingly in chemistry. The conversion factor between these units is 1 cal = 4.184 J. The quantity of heat Q required to cause a temperature change in a substance depends on the nature of the substance and is proportional to the mass of the substance (m) and the temperature change (Δt):

$$Q = (S.H.) * (m) * (\Delta t)$$

S.W. stands far specific heat, which is a physical constant far a given substance. The specific heat's value depends greatly on the nature of the substance and very little on the temperature.

The specific heat can be defined the quantity of heat energy required to raise the temperature of 1 gram of a substance by 1 degree Celsius.

The units for specific heat are: $\frac{cal}{g°C}$

Specific heat is an important quantity because it can be used to calculate the number of calories required to heat a known mass of a substance from one temperature to another.

The higher the specific heat of a substance, the less its temperature will change when it absorbs a given amount of heat. Conversely, the lower the specific heat of a substance, the more its temperature will change when it absorbs a given amount of heat.

Among common substances that are part of our environment, water has a relatively high specific heat (1.00 cal/g°C): it is thus a very effective coolant.

The water in oceans, lakes and swimming pools can absorb large amounts of heat without undergoing extreme temperature changes, whereas the dry land surrounding these bodies of water changes its temperature drastically when it absorbs a comparable amount of heat. This is why large bodies of water act as natural temperature moderators; as a result coastal areas enjoy mild winters and cool summers unlike desert areas which are well known for their extreme high and low temperatures.

The specific heat of a liquid can readily be measured in a well insulated container which gains or loses very little heat to the surroundings. A container of this sort is called a calorimeter. In this experiment a small thermos (Snack-Jar) will be used as a calorimeter.

If this is not available two Styrofoam sups, one placed inside the other (placed into a 250 mL beaker for stability) and covered with a piece of cardboard may be used instead.

A thermometer is then inserted through a hole in the cover of the calorimeter. When using the Snack-Jar, a split rubber stopper will be used. When using Styrofoam cups a cardboard cover will be used. The thermometer will be used to measure the temperature of the calorimeter contents.

Part I of this experiment, the specific heat of deionized water at room temperature will be determined. Part II of this experiment, the specific heat of ethyl alcohol at room temperature will be determined.

In both parts of the experiment a precisely massed amount of deionized water and ethyl alcohol at room temperature (cooler liquids) will be mixed with precisely massed warm water. The warm water will be poured into the cooler liquids. At this time the heat flows from the warm water into the cooler liquid. The temperature of the warm water decreases and the temperature of the cooler liquid increases until they both reach the same temperature.

By determining the temperature of the warm water, the temperature of the cooler liquid and the temperature of' the mixture at the time of mixing, the specific heat of the cooler liquid may be determined.

Temperature measurements at the exact time of mixing are rather difficult to obtain since no reliable temperature readings can be taken while the two liquids are being mixed. But we can determine this temperature at the time of mixing using Microsoft Excel which will be explained in the calculation section of this experiment.

During the mixing of the two liquids a small amount of heat is lost to the calorimeter which absorbs some of the heat lost by the hot water. In this experiment the heat lost to the calorimeter is vey small and will be assumed to be negligible. This provides the following equation:

$$Q_{lost\ by\ warm\ water} = Q_{gained\ by\ cool\ liquid}$$

Understanding that $Q = (S.H.) * (m) * (\Delta t)$ the following equation is acheived:

$$(S.H._{warm\ water}) * (m_{warm\ water}) * (\Delta t_{warm\ water}) = (S.H._{cool\ liquid}) * (m_{cool\ liquid}) * (\Delta t_{cool\ liquid})$$

> $\Delta t_{warm\ water}$ is the temperature change of the warm water. This is calculated from the temperature of the warm water at mixing minus the temperature of the mixture at mixing. These temperatures are only obtainable from the graph.
>
> $\Delta t_{cool\ liquid}$ is the temperature change of the cool liquid. This is calculated from the temperature of the mixture at mixing minus the temperature of the cool liquid at mixing. These temperatures are only obtainable from the graph.

In the above equation the specific heat of warm water $(S.H._{warm\ water})$ is given as 1.00 cal/g°C (this is true for water between 60°C and 90°C.) The $m_{warm\ water}, \Delta t_{warm\ water}, m_{cool\ liquid}\ and\ \Delta t_{cool\ liquid}$ are determined experimentally. This allows for the calculation of the $S.H._{cool\ liquid}$.

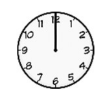
PART I: THE SPECIFIC HEAT OF WATER AT ROOM TEMPERATURE

1. Heat the warm water
    a. Place a 250 mL beaker on a ring stand supported by a wire gauze.
    b. Add between 150 to 200 mL of deionized water.
    c. Heat the water

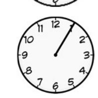
2. Prepare cool water.
    a. Measure about 70 mL of deionized water using your graduated cylinder.
    b. Place your cool liquid calorimeter on the centigram balance
    c. Tare the balance with the calorimeter on it.
    d. Add the 70 mL of water from your graduated cylinder.
    e. **Record** the mass of cool water in your notebook to the nearest 0.01g.

3. Prepare warm water.
    a. Heat the water from step one above to about 85°C
    b. Place the hot water calorimeter on the centigram balance
    c. Tare the balance with the calorimeter on it.
    d. Add about 70g of hot water to the calorimeter.
    e. **Record** the mass of the hot water in your notebook to the nearest 0.01g.

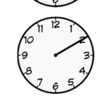
4. Time = 0 minutes; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



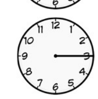
5. Time = 1 minute; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



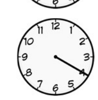
6. Time = 2 minutes; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



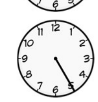
7. Time = 3 minutes; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



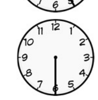
8. Time = 4 minutes; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



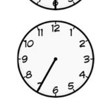
9. Time = 5 minutes; mix
    a. Pour the contents of the cold water calorimeter into the hot water calorimeter.



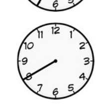
10. Time = 6 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



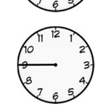
11. Time = 7 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



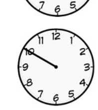
12. Time = 8 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



13. Time = 9 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



14. Time = 10 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



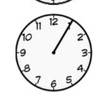
15. Discard the water down the drain.

PART II: THE SPECIFIC HEAT OF ETHYL ALCOHOL AT ROOM TEMPERATURE

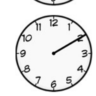
1. Prepare ethyl alcohol.
    a. Measure about 70 mL of ethyl alcohol using your graduated cylinder.
    b. Place your cool liquid calorimeter on the centigram balance
    c. Tare the balance with the calorimeter on it.
    d. Add the 70 mL of ethyl alcohol from your graduated cylinder.
    e. **Record** the mass of cool water in your notebook to the nearest 0.01g.

2. Prepare warm water.
    a. Place a 250 mL beaker on a ring stand supported by a wire gauze.
    b. Add between 150 to 200 mL of deionized water.
    c. Heat the water to about 85°C
    d. Place the hot water calorimeter on the centigram balance
    e. Tare the balance with the calorimeter on it.
    f. Add about 70g of hot water to the calorimeter.
    g. **Record** the mass of the hot water in your notebook to the nearest 0.01g.
3. Time = 0 minutes; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.

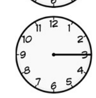
4. Time = 1 minute; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



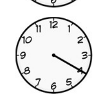
5. Time = 2 minutes; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



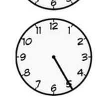
6. Time = 3 minutes; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



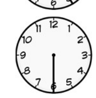
7. Time = 4 minutes; Temperature Measurement
    a. **Record** the temperature of the cool liquid in the calorimeter.
    b. **Record** the temperature of the hot water in the calorimeter.



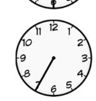
8. Time = 5 minutes; mix
    a. Pour the contents of the hot water calorimeter into the cool liquid calorimeter.



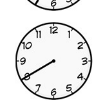
9. Time = 6 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



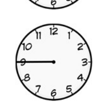
10. Time = 7 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



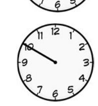
11. Time = 8 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



12. Time = 9 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.



13. Time = 10 minutes; Temperature Measurement
    a. **Record** the temperature of the mixture in the calorimeter.

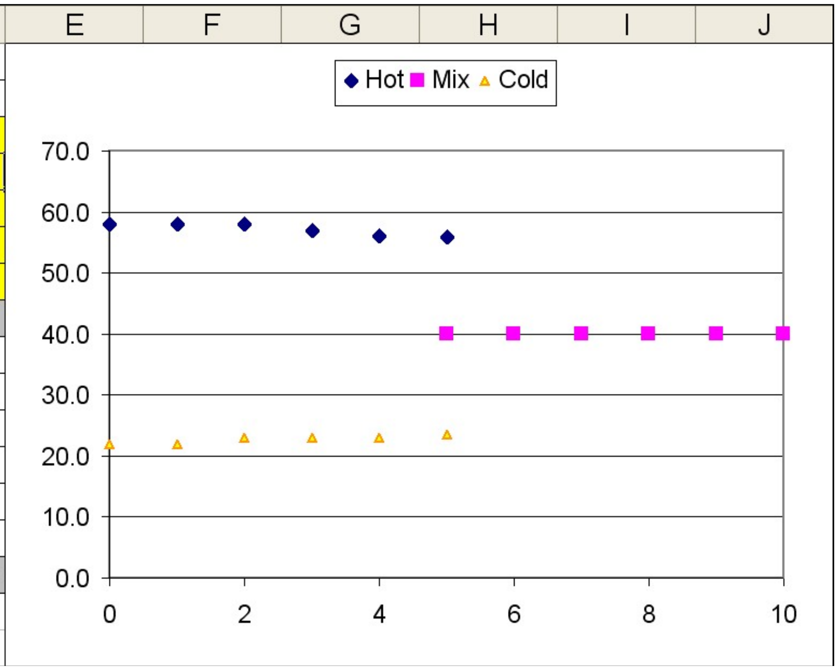


14. Discard the water and alcohol in an appropriate waste container.

Use the Microsoft Excel workbook called ***Chem 51 – Specific Heat of a Liquid.xls*** for this section.

Enter your data in the highlighted yellow boxes as shown below.

	A	B	C	D
1		**Hot**	**Mix**	**Cold**
2	**Time**			
3	0	58.0		22.0
4	1	58.0		22.0
5	2	58.0		23.0
6	3	57.0		23.0
7	4	56.0		23.0
8	5	55.9	40.0	23.5
9	6		40.0	
10	7		40.0	
11	8		40.0	
12	9		40.0	
13	10		40.0	
14				
15	T Change	15.9		16.5
16				
17				



Print the worksheet and attach it to your datasheets.

Transfer the grayed data into your notebook and your datasheets.

NOTE: The calculations performed by Microsoft Excel uses the function called TREND. TREND returns values along a linear trend. It fits a straight line (using the method of least squares) to the arrays known_y's and known_x's. It returns the y-values along that line for the array of new_x's that are specified.

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Specific Heat of a Liquid
Datasheet
Part I

Name: ________________

Date: ________________

Partner: ________________

Mass of cold water ______________________ g

Mass of hot water ______________________ g

Time 0 minutes ....Cold water temperature_________°C ... Hot water temperature _____ °C

Time 1 minute ....Cold water temperature_________°C ... Hot water temperature _____ °C

Time 2 minutes ....Cold water temperature_________°C ... Hot water temperature _____ °C

Time 3 minutes ....Cold water temperature_________°C ... Hot water temperature _____ °C

Time 4 minutes ....Cold water temperature_________°C ... Hot water temperature _____ °C

Time 6 minutes ....Mixture temperature ________ °C

Time 7 minutes ....Mixture temperature ________ °C

Time 8 minutes ....Mixture temperature ________ °C

Time 9 minutes ....Mixture temperature ________ °C

Time 10 minutes ....Mixture temperature ________ °C

From Microsoft Excel:

Time 5 minutes ....Cold water temperature_________°C ... Hot water temperature _____ °C

Time 5 minutes ....Mixture temperature ________ °C

Calculations:

Heat lost by warm water: $Q_{lost\,by\,warm\,water} = (S.H._{warm\,water}) * (m_{warm\,water}) * (\Delta t_{warm\,water})$

Heat gained by cold water: $Q_{gained\,by\,cool\,liquid} = Q_{lost\,by\,warm\,water}$

Specific heat of cold water: $Q_{gained\,by\,cool\,liquid} = (S.H._{cool\,liquid}) * (m_{cool\,liquid}) * (\Delta t_{cool\,liquid})$

Specific Heat of a Liquid
Datasheet
Part II

Name: ________________

Date: ________________

Partner: ________________

Mass of Ethyl Alcohol water ______________ g

Mass of hot water ______________________ g

Time 0 minutes ....Ethyl Alcohol temperature _______ °C ... Hot water temperature _____ °C

Time 1 minute ....Ethyl Alcohol temperature _______ °C ... Hot water temperature _____ °C

Time 2 minutes ....Ethyl Alcohol temperature _______ °C ... Hot water temperature _____ °C

Time 3 minutes ....Ethyl Alcohol temperature _______ °C ... Hot water temperature _____ °C

Time 4 minutes ....Ethyl Alcohol temperature _______ °C ... Hot water temperature _____ °C

Time 6 minutes ....Mixture temperature ________ °C

Time 7 minutes ....Mixture temperature ________ °C

Time 8 minutes ....Mixture temperature ________ °C

Time 9 minutes ....Mixture temperature ________ °C

Time 10 minutes ....Mixture temperature ________ °C

From Microsoft Excel:

Time 5 minutes ....Cold water temperature_________ °C ... Hot water temperature _____ °C

Time 5 minutes ....Mixture temperature ________ °C

Calculations:

Heat lost by warm water: $Q_{lost\,by\,warm\,water} = (S.H._{warm\,water}) * (m_{warm\,water}) * (\Delta t_{warm\,water})$

Heat gained by ethyl alcohol: $Q_{gained\,by\,cool\,liquid} = Q_{lost\,by\,warm\,water}$

Specific heat of ethyl alcohol: $Q_{gained\,by\,cool\,liquid} = (S.H._{cool\,liquid}) * (m_{cool\,liquid}) * (\Delta t_{cool\,liquid})$

Specific Heat of a Liquid
Questions

Name: ________________

Date: __________________

Partner: ________________

1. Calculate the Percentage Error in your experiment. (The theoretical value for the ethanol is 0.46 cal/g°C)

2. What assumption did you make that could explain the reason for your percent error?

3. The ΔT for alcohol is (greater, lesser) than the ΔT for water. (Circle the correct answer.)

4. The calculated specific heat of alcohol is (greater, lesser) that the specific heat of water. (Circle the correct answer.)

5. ΔT and specific heat are (directly, inversely) proportional. (Circle the correct answer.)