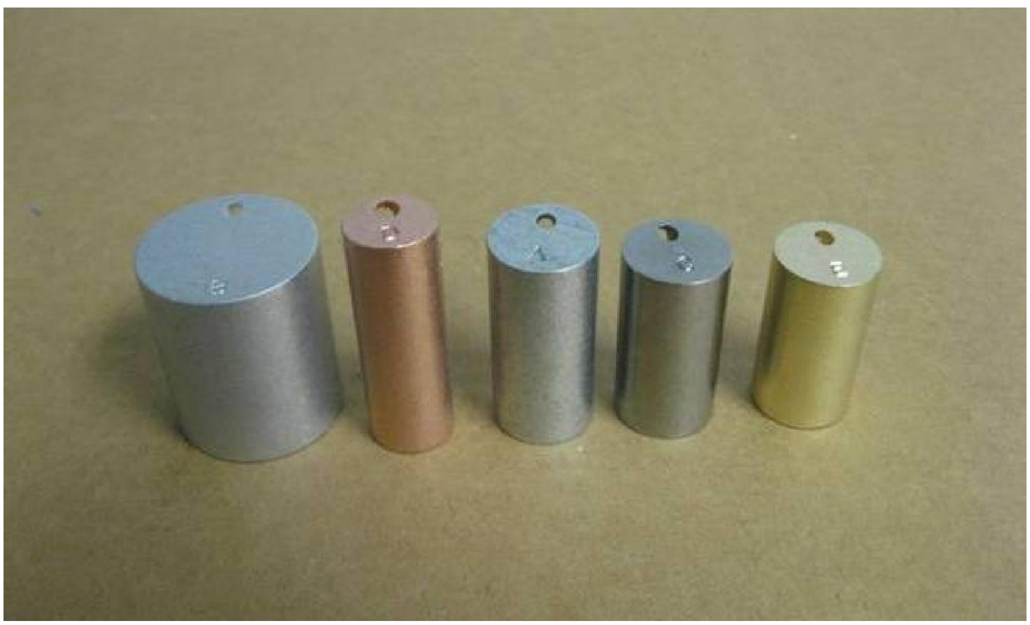
This product is intended for use by students aged 13 years or older, under competent adult supervision.

INSTRUCTIONS AND EXPERIMENTS for the

Specific Heat Set



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Notes for the instructor

This is a set of five metal specimens, each having a mass of approximately 80 grams. Each specimen has been stamped with a letter A-E, which identifies the type of substance. These specimens are intended for lab exercises involving finding the specific heat of a substance. They may also be used for other purposes, such as density determination. Included is a standard lab exercise that guides students through a typical method for determining the specific heat of each of the samples. Likely sources of inaccuracy in the lab stem from inadequate mixing of the water around the sample as the heat is transferred, as well as incorrect placement of the thermometer within the Styrofoam® container while measuring (if too near the metal sample, inaccuracy will result). Some teachers may prefer to supply only the first page of the experiment (containing the basic theory of the lab), thus allowing for a more challenging laboratory experience.

Letter	Sample	J/g C^0	cal/g C^0
A.	Zinc	**.39**	**.092**
B.	Aluminum	**.90**	**.21**
C.	Stainless Steel (iron)	**.45**	**.11**
D.	Copper	**.39**	**.092**
E.	Brass	**.35**	**.090**

Additional materials needed

- 1 metric balance
- 1 thermometer or temperature sensor
- 3 Styrofoam® coffee cups, or (better) 1 Styrofoam® calorimetry cup with lid, available from certain suppliers
- 1 insulating cover such as foam or wood (not needed if using a calorimetry cup)
- 1 glass beaker, 250 ml, or similar
- 1 heat source such as electric hot plate
- 1 stirring rod
- 1 piece of string, heavy thread, or fine wire

Safety:

Please teach and expect safe behavior in your classroom and lab. Safety considerations call for supervision of students at all times, use of safety eyewear, no horseplay, and immediate reporting to the instructor of accidents or breakages, among others. This set is intended primarily for students aged 13 years and older, when working under competent adult supervision.

Of particular concern with this experiment is that students will be exposed to both hot plates and boiling water. Extreme care should be taken to prevent students from getting burned.

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Experiment: Finding the specific heat of a substance

Theory

When heat flows into or out of an object, the object's temperature gradually changes. (*An exception to this concept is when the object undergoes a phase change such as melting or boiling.)*

When looking at temperature changes from heat transfer, there are several variables involved:

First, a larger temperature change suggests a larger heat flow.

Second, a temperature change in an object of greater mass would suggest a greater heat transfer than the same temperature change in an object of lesser mass.

Finally, we must consider a basic thermal property of the substance. This inherent property of a substance is termed the "specific heat" of the substance, or "specific heat capacity."

These ideas can be incorporated into the following equation:

$$Q = \Delta T \; m \; C$$

Where:

Q is the amount of heat transferred

ΔT is the temperature change

m is the mass of the object

C is a constant that depends on the type of material (its specific heat or specific heat capacity). This value is NOT the same as "heat capacity," which is the property of a particular <u>object</u> rather than a property of the <u>substance in general</u>.

Experimental overview

In this experiment, you will heat a substance (a metal sample) in boiling water to assure the metal has reached a temperature of 100^0C. The object will then be immediately placed in an insulated cup of cooler water of a known starting temperature. When the hot metal is placed in the cooler water, heat energy will be transferred from the metal to the water. A key point here is that <u>the amount of heat gained by the water ($Q_{(water)}$) is the same amount of heat lost by the metal ($Q_{(metal)}$).</u> Knowing this value, the mass of the metal, and the specific heat of water (given as 1 calorie/g C^0, or 4.184 J/g C^0 in SI units) will allow you to calculate the specific heat capacity for that metal.

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Procedure

1. Obtain a metal sample from your instructor.
2. Record the letter stamped on the metal sample: ______
3. Obtain a hot plate and a heat resistant container. Place the metal sample in the container and fill it with enough hot tap water to completely cover the metal sample. Remove the sample. Place the container on the hot plate. *Be sure that you have placed the hot plate in a safe location, free of obstructions and the possibility that it will be accidentally bumped.*
4. Turn on the hot plate and set it to its highest setting. While the water is coming to a boil, go on to the next steps.
5. Dry the sample. Using a balance, find the mass of the sample: ______
6. Obtain three stacked Styrofoam® coffee cups with a lid containing a hole for a thermometer, or one Styrofoam® calorimetry cup. Find the mass of the cup(s).

   Initial cup(s) mass: ______

7. Tie a string through the hole in the metal sample such that the sample can be lowered into and raised from the water on the burner and the water in the Styrofoam® cup(s) without your hands touching the water.
8. Place the metal sample in the cup with the string hanging outside of the cup. Using the coolest available tap water, cover the sample with the minimum amount of water required to completely submerge it. Remove the metal using the string. Now reweigh the cup(s) with the water:

   Water with cup(s) mass: __________

9. Find the mass of the water by subtracting the mass of the cup(s) from the mass of the cup(s) with water.

   Mass of the water: _________

10. Once the water on the burner has come to a boil, place the metal sample in the boiling water with the string hanging out of the container. Allow the metal sample to sit in the boiling water for at least 2 minutes. Meanwhile, complete step 11. *Be sure not to allow the string to touch the burner of the hot plate.*

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11. While your sample is heating in the boiling water, measure the temperature of the cool tap water in the Styrofoam® cup(s) with a thermometer. Be sure to replace the lid.

    Water temperature **<u>before</u>** heating: __________

12. Once your sample has been in the boiling water for at least 2 minutes, transfer it to the water in the Styrofoam® cup(s). This step must be done quickly but safely. Immediately replace the cup's lid and put the thermometer in the hole in the lid. Be sure that the thermometer never touches the metal sample. Now monitor the temperature of the water in the Styrofoam® cup(s) while <u>gently</u> swishing the cup(s) on the table. Record the highest temperature achieved below. This is the point at which the metal sample and the water have come to thermal equilibrium:

    Maximum water temperature **<u>after</u>** heating: ___________

    Be sure to turn off the burner!

13. Now calculate $\Delta T_{(water)}$ (the difference between the starting temperature of the water (from step 11) and the maximum temperature after heating (step 12)): _______

    Note that the units of this value should be C^0 (Celsius degrees), not ^0C (degrees Celsius), as it denotes a difference in temperature, not a specific temperature.

14. You are now ready to calculate the amount of <u>heat transferred to the water by the metal.</u> To do this we will use the equation:

$$Q_{(water)} = \Delta T_{(water)} \; m_{(water)} \; C_{(water)}$$

Where:

$\Delta T_{(water)}$ = the temperature change (found in step 13): _______

$m_{(water)}$ = the mass of the water (found in step 5): ______

$C_{(water)}$ = the specific heat of water, given as 1 calorie/g C^0 (or in other units, 4.184 J/g C^0)

Show your work here:

$Q_{(water)}$ = ____________

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15. You can now calculate the specific heat of your metal ($C_{(metal)}$).

Given that the amount of heat gained by the water must have been the same as the amount of heat lost by the metal, we can assume that $Q_{(water)}$ and $Q_{(metal)}$ are equal in magnitude. Therefore:

$$Q_{(water)} = Q_{(metal)} = \Delta T_{(metal)}\, m_{(metal)}\, C_{(metal)}$$

Solving for $C_{(metal)}$ we get:

$$C_{(metal)} = \frac{Q_{(metal)}}{\Delta T_{(metal)}\ m_{(metal)}}$$

$\Delta T_{(metal)}$ = the difference between the initial temperature of the metal (100^0C in this case, as it was in boiling water at the time) minus its final temperature (this will be the same temperature as the maximum temperature of the water in the Styrofoam® cup(s) when the water and the metal came to thermal equilibrium – step 12).

100^0C - ________ (from step 12) = __________

Again note that the units of this value should be C^0 (Celsius degrees), not ^0C (degrees Celsius), as it denotes a difference in temperature, not a specific temperature.

$m_{(metal)}$ = the mass metal sample (found in step 5): _______

Show your work here:

$C_{(metal)}$ = ____________

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