# SPECIFIC HEAT CAPACITY

> **IDEA TO REMEMBER!**
>
> Substances capture and release limited amounts of heat energy!

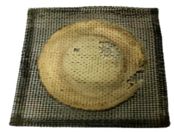
## OBJECTIVE:

Learn what specific heat capacity is, why it is important, and calculate it from sample substances.

## MATERIALS:


Bunsen burner


Burner stand


Wire mesh


Calorimeter

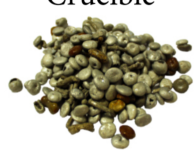

Beaker


Crucible


Digital scale


Temperature Sensor

PASCO Interface/Capstone

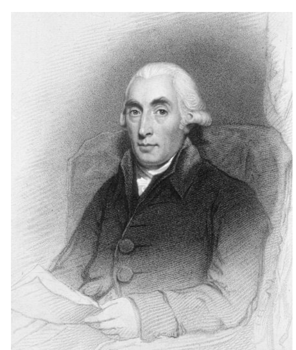

Aluminum shot


Copper shot


Gloves

## CONCEPT:

**Specific heat capacity** is the amount of energy—calories or joules—needed to raise or lower the temperature of 1g of a substance by 1°C. The knowledge we have about heat capacity was developed by Joseph Black, a Scottish physicist, chemist, and professor of medicine in the $18^{th}$ century. He is also known for discovering magnesium, carbon dioxide, and latent heat—the foundation of thermodynamics.


**Joseph Black**

Like all measurements, a reference point was needed. Thus, pure water was chosen as the reference substance because of its abundance and importance. It was assigned a specific heat capacity of 1.00 cal/g°C (equivalent to 4,184 J/kgK). This also happens to be one of the highest heat capacities of all liquids. Read the *Real World Applications* section to see why the heat capacity of water is important!

The change in heat energy ΔQ of an object depends on the product of its mass m, its specific heat capacity c, and the change in temperature ΔT experienced.

$$\Delta Q = mc\Delta T \tag{1}$$

*THINK: Why does each substance have its own specific heat capacity?*

Each substance is different in their molecular composition and structure, affecting heat energy propagation. See molecular mass in Table (1). Regardless, the law of conservation of energy states that energy can only be transformed from one form of energy to another and cannot be created or destroyed, and the laws of thermodynamics further describe how heat energy moves: <u>energy dissipates (hot to cold) and temperature difference dictates the amount of heat loss</u>:

$$\Delta Q_{hot,lost} = -\Delta Q_{cool,gain}$$
$$m_h c_h \Delta T = -m_c c_c \Delta T \qquad (2)$$

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Of course, the change in temperature is the difference between the initial and final temperature $\Delta T = T_f - T_i$.

In this lab, a **calorimeter** is used to restrict the flow of heat. See Figure (1). Therefore, let us assume that the heat energy gained by the cold system is equivalent to the heat energy lost by the hot system. We transfer a hot metal sample (s) to the inner cup (c) with room temperature water (w). We can account for the heat energy transfer with the following:

$$m_s c_s \Delta T_s = -\left(m_c c_c \Delta T_c + m_w c_w \Delta T_w\right)$$
$$m_s c_s \Delta T_s + m_c c_c \Delta T_c + m_w c_w \Delta T_w = 0 \qquad (3)$$

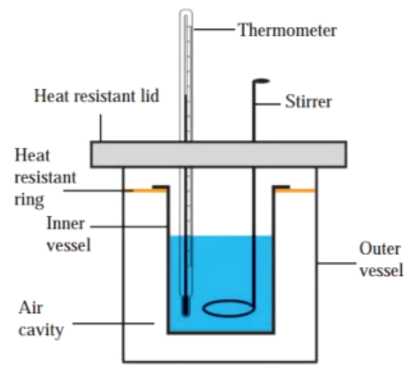



**Figure 1**

Below is a table with specifications for the metals in this lab:

Table 1

| Metal | Specific Heat Capacity (cal/g°C) | Molecular mass (g/mol) |
|---|---|---|
| Aluminum | 0.214 | 27.0 |
| Copper | 0.092 | 63.5 |

## Real World Applications

- Materials with high heat capacity are useful for **insulation**, such as wood and fiberglass for buildings. Liquids with high heat capacity are valuable as **coolants** for heat-generating machines, like internal combustion engines or steam generators.
- Low heat capacity is useful when rapid, low-energy heat transmission is needed, such as copper and aluminum for **computer heat pipes**, **heat sinks**, and **cookware**.
- Since water has a high heat capacity it **controls the weather!** Places near oceans or lakes have less extreme ranges and changes in temperature because the water in the air (humidity) slows the energy transfer in the air.

1) The Action Lab—How heat pipes work!
2) How sea breezes work!

## PRECAUTIONS:

*Please, please, be careful with the bunsen burners! Live fire can cause extensive damage to your body and to property!* ***Always turn off gas when not in use.***

## PROCEDURE:

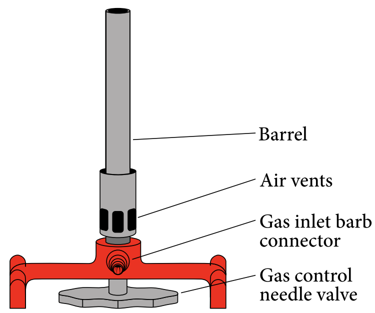
1. ☐ Fill out the top information on the worksheet **and** complete the memory exercise—Questions M1–M3.

2. ☐ REQUIRED: Read the *Concept* section.

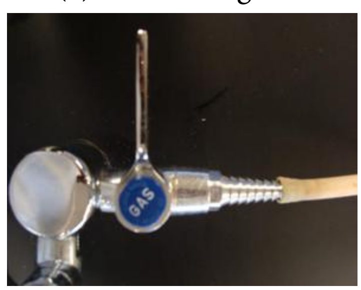
3. ☐ Fill the Beaker with water from the lab sink to the 450mL mark.

***** You will complete these steps twice: one round for each sample.***

4. ☐ Heat the Beaker with the Bunsen Burner.
   4.1. **PUSH** the hose securely onto the gas supply and Burner inlet barbs.
   4.2. **TURN ON** the gas supply valve. Figure (2b) shows the OFF position.
   4.3. **OPEN** the Burner's Gas control needle valve, if needed.
   4.4. Ask the TA to light your Burner, as in Figure (3a). Adjust the flame size by turning the Burner's Gas control needle valve, as in Figure (3b). The optimal flame is 2–3 inches long and remains blue.
   4.5. Move the Burner stand over the Burner so that the flame is at the center of its ring. Then place the Wire mesh on top of the Burner stand and then the Beaker on top of the mesh, as in Figure (3c).




(a) Burner diagram




(b) **OFF** Position

**Figure 2**

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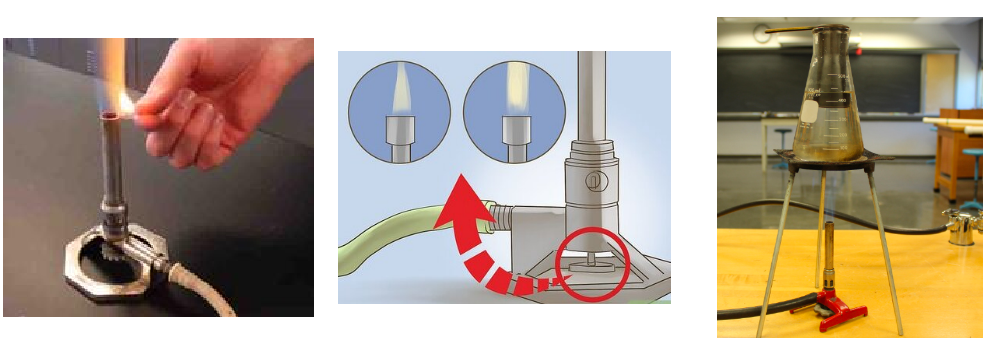
CONCEPT & PROCEDURE VIDEOS:



(a) (b) (c)

**Figure 3**

5. ☐ While the water heats up, place the Crucible on your scale and tare the scale so that it reads "0g". Then scoop a metal sample into the Crucible and weigh it with your tared scale. Add or remove metal to obtain close to "50g". Record the actual mass ($m_s$) in Table (2) on the worksheet and then place the sample-filled Crucible into the Beaker. The bottom of the Crucible should be in the water.

6. ☐ Reset the scale and weigh the inner cup of the Calorimeter ($m_c$). Record it in Table (2) on the worksheet. With the inner cup still on the scale, tare the scale.

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7. ☐ Use the inner cup to collect about 1" of water from the lab sink. Weigh the water-filled cup to get the mass of the water ($m_w$) and record it in Table (2) on the worksheet. Insert the Calorimeter ring and then the inner cup into the outer cup, as in Figure (1).

8. ☐ Prepare the Temperature sensor in the PASCO Capstone software:

   8.1. Ensure the Temperature sensor is plugged into the PASCO Interface, as shown in Figure (4).

   8.2. In PASCO Capstone, click "Hardware Setup", then click on the channel where the Temperature sensor is plugged in, and select "Temperature Sensor (Stainless Steel)".

   8.3. Open a Graph and ensure that Temperature is on the y-axis and time is on the x-axis.

9. ☐ Answer Question 1 on the worksheet (Question 3 during the second round).

10. ☐ Around the time that bubbles begin to form at the bottom of the Beaker, take an initial temperature of the <u>cool water in the Calorimeter inner cup</u> ($T_{i,w}$) by clicking "Record" in Capstone. Document the temperature in Table (2) on the worksheet.

11. ☐ Place the Temperature sensor in the Crucible and wait for it to get near 80°C ± 5°C. Record the actual initial temperature of the sample in the Crucible ($T_{i,s}$) in Table (2) on the worksheet.

12. ☐ Put on the heat-resistant Gloves and lift the Crucible out of the Beaker, then empty the hot metal into the cool water in the Calorimeter's inner cup and quickly cover the Calorimeter with its lid with the rubber cork inserted. Place the Temperature sensor in the hole of the rubber cork and click "Record" again. See Figure (4).

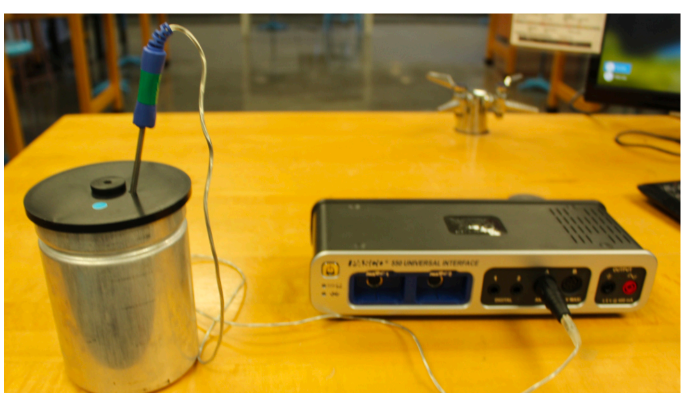

**Figure 4**

13. ☐ Turn off the Burner by turning the gas supply valve to the OFF position, as in Figure (2b).

14. ☐ While waiting for the temperature to reach a steady equilibrium, answer Question 2 on the worksheet (Question 4 during the second round).

15. ☐ Record the final, equilibrium temperature of the sample and water ($T_{final}$) in Table (2) on the worksheet.

16. ☐ Answer Questions 5–6 and complete Table (2) on the worksheet. Of course, the theoretical heat capacities are given in the *Concept* section.

17. ☐ Repeat steps 4–7, 9–16 for the second round with the other sample.

18. ☐ Answer Question 7 on the worksheet.

19. ☐ Follow the **Let's THINK!** instructions below.

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## Let's THINK!

- **Ask questions**: What are you learning here?... Why is this Physics concept important and how can it be used?... What do you not understand?... (For more information on this Physics topic, scan the QR codes in the *Real World Applications* and at the start of the *Procedure* section.)
- **Discuss** the concept and demonstration with your partner to help each other understand better. Discussion makes learning active instead of passive!
- For **FULL PARTICIPATION [15 points]** you must call on the TA when you have finished your group discussion to answer some comprehensive questions. If you do not fully understand and the TA asks you to discuss more, you must call on them one more time to be dismissed with full marks.
- **CONCLUSION [10 points]**: In the Conclusion section at the end of the worksheet, write 3 or more sentences summarizing this concept, how this lab helped you understand the concept better, and the real world implications you see. Do you still have questions? If so, write those as well.

| Updated Date | Personnel | Notes |
|---|---|---|
| 2022.08 | Chase Boone | 2022 Summer Improvement: Created new format. |

Name: ______________________ *PH1123* Section #: __________

Name: ______________________ TA Name: __________

# SPECIFIC HEAT CAPACITY
*WORKSHEET [70 points]*

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**Memory exercise** [each 2 extra credit points]:

M1) Positivity (in lens or otherwise) brings things __________, and negativity, __________.

M2) Spectral maxima appear when waves are in __________.

M3) The bending of light is called __________ and spreading waves is __________.

Table 2: Data [18 points; 1 point per cell]

| Sample | $m_s$ (g) | $m_c$ (g) | $m_w$ (g) | $T_{i,w}$ (°C) | $T_{i,s}$ (°C) | $T_{final}$ (°C) | Theoretical $c_s$ (cal/g°C) | Calculated $c_s$ (cal/g°C) | % error |
|---|---|---|---|---|---|---|---|---|---|
| Copper | | | | | | | | | |
| Aluminum | | | | | | | | | |

1) Which liquid is the reference substance for specific heat capacity and has one of the highest capacities? What is its capacity in cal/g°C and J/kgK? [3 points]

2) Why does each substance have its own specific heat capacity? [5 points]

3) How does the specific heat capacity of water affect the weather? [7 points]

(Hint: *Real World Applications* video.)

4) How do the laws of thermodynamics describe how heat energy moves? [5 points]

5) Calculate specific heat capacity of aluminum metal. Show your calculations below. [8 points]

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6) Calculate specific heat capacity of copper metal. Show your calculations below. [8 points]

7) Which of the two metal samples can be heated to a higher temperature with less heat? [6 points]

## Conclusion

Write 3 or more sentences summarizing this concept, how this lab helped you understand the concept better, and the real world implications you see. Do you still have questions? If so, write those here as well. [10 points]