LAB L9.2 — CALORIMETRY: SPECIFIC HEAT OF A METAL

WARMUP **Retrieval — yesterday's equation, today's tool**

(a) A pot holds 0.300 kg of water. The water warms from 21.0 °C to 27.0 °C. Using $c_{water} = 4186$ J/(kg·°C), compute the heat Q the water absorbed. Carry units through every step.

(b) The same quantity of heat from part (a) now enters 0.300 kg of aluminum ($c_{Al} = 900$ J/(kg·°C)). Compute the aluminum's temperature rise.

(c) Circle one: for the same mass and the same heat, the material with the **smaller** specific heat changes temperature **more / less**.

The lab question. Your group receives an unlabeled metal cylinder (about 0.150 kg). Determine its specific heat c_{metal}, attach an uncertainty to your value, and identify the metal from the reference table on page 4.

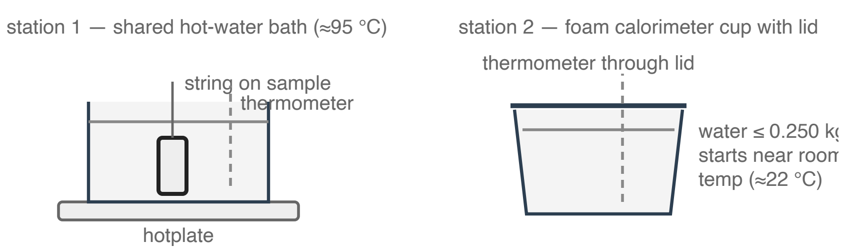
No instrument on your bench measures heat directly. But water's specific heat is known, so **the cup of water is your heat meter**: every joule the water absorbs shows up as a temperature rise you CAN measure, through $Q = m_w c_w \Delta T_w$.

THE METHOD IN ONE EQUATION

Drop the hot metal into cool water inside an insulated cup and let the mixture reach one shared final temperature T_f. If the cup keeps the heat in, the energy the metal releases is the energy the water absorbs:

$$m_m c_m (T_{m,0} - T_f) = m_w c_w (T_f - T_{w,0})$$

Each object uses its **own** ΔT: the metal falls a long way while the water rises a little, because the two mc products differ. Since a 1 °C change and a 1 K change are the same size, ΔT may stay in °C, and c in J/(kg·°C) equals c in J/(kg·K).



The two stations. Your procedure decides what gets measured, with what, and when.

Safety — burns. The bath water and the metal sample are near 95 °C. Move the sample only by its string or with tongs; keep hands and sleeves out of the space above the bath; wipe spills at once. Goggles on while anyone at the table handles hot water.

DESIGN — YOU WRITE THE PROCEDURE

The equation on page 1 names five quantities: m_m, m_w, $T_{m,0}$, $T_{w,0}$, T_f. Plan how your group will get each one.
Constraints: the cup holds at most 0.250 kg of water; the bath is shared by the class; you get two trials' worth of time.

DESIGN 1 Measurement Plan

Quantity	Instrument	When / how measured	Instrument reads to ±
m_m — mass of metal			
m_w — mass of water			
$T_{w,0}$ — water start temp			
$T_{m,0}$ — metal start temp			
T_f — shared final temp			

DESIGN 2 The Metal's Starting Temperature

No thermometer touches the metal itself. What reading do you record as $T_{m,0}$, and what must be true about how long the sample sat in the bath for that reading to be valid?

DESIGN 3 The Transfer and the Reading

(a) Why must the move from bath to cup be fast? Name the quantity in the page-1 equation that a slow transfer corrupts.

(b) After the metal is in and the lid is on, do you record T_f the instant the metal enters, or stir and wait for the thermometer's **highest steady reading**? Why?

Checkpoint — before touching the bath: teacher initials that your plan covers all five quantities and the safety rules: ________

DATA

Measurement	Trial 1	Trial 2
m_m — mass of metal (kg)		
m_w — mass of water in cup (kg)		
$T_{w,0}$ — water start temperature (°C)		
$T_{m,0}$ — metal start temperature = bath (°C)		
T_f — highest steady mixture temperature (°C)		
$\Delta T_w = T_f - T_{w,0}$ (°C)		
$\Delta T_m = T_{m,0} - T_f$ (°C)		

ANALYSIS I — FROM TEMPERATURES TO A SPECIFIC HEAT

A1 Heat Absorbed by the Water (Trial 1)

Compute $Q_w = m_w c_w \Delta T_w$ from your Trial 1 data, with $c_w = 4186$ J/(kg·°C). Write every quantity WITH its unit and show the units combining to joules: kg × J/(kg·°C) × °C = J.

A2 Specific Heat of the Metal (Trial 1)

Assuming the cup kept the heat in, the metal released the Q_w you just computed. Solve for the metal's specific heat and carry units to the end:

$$c_m = \frac{m_w c_w (T_f - T_{w,0})}{m_m (T_{m,0} - T_f)}$$

c_m (Trial 1) = _______________ J/(kg·°C)

A3 Trial 2, Same Road

Repeat the A2 computation with your Trial 2 data. Then compare: do the two values of c_m agree more closely than either agrees with its nearest reference-table value?

c_m (Trial 2) = _______________ J/(kg·°C) mean c_m = _______________ J/(kg·°C)

A4 Uncertainty — the Water's Small Rise Is the Weak Link

Your thermometer reads to ±0.5 °C. ΔT_w is the **difference of two readings**, so its uncertainty is ±0.5 °C + ±0.5 °C = ±1.0 °C.

(a) Percent uncertainty of your Trial 1 water rise: $\dfrac{1.0\ ^\circ\mathrm{C}}{\Delta T_w} \times 100\%$ = ___________ %

(b) ΔT_m is also a difference of two ±0.5 °C readings. Compute ITS percent uncertainty and state, in one sentence naming both percentages, why ΔT_w dominates the uncertainty of c_m.

(c) Apply the part-(a) percentage to your mean c_m: c_m = _____________ ± _____________ J/(kg·°C)

ANALYSIS II — IDENTIFY THE METAL, ACCOUNT FOR THE ENERGY

REFERENCE — SPECIFIC HEATS

Metal	c (J/(kg·°C))
aluminum	900
iron / steel	450
zinc	390
copper	385
brass	380
lead	130

Which reference values fall inside your interval from A4(c)? List every metal whose table value lands between your $c_m - \Delta c$ and $c_m + \Delta c$:

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If more than one metal qualifies, note which non-thermal observation (color, magnet test, heft) breaks the tie:

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A5 Energy Accounting — Where Did the Missing Joules Go?

(a) Take the reference-table c for the metal you named above and compute the heat the metal SHOULD have released: $Q_{released} = m_m\, c_{table}\, \Delta T_m$ (units at every step).

(b) $Q_{released}$ – Q_w (from A1) = ____________ J. Name two physical paths this energy could have taken instead of warming the water.

(c) Circle one and defend below: heat that escapes to the cup and room air makes the c_m computed in A2 come out **too high / too low**, because c_m is computed from Q_w, which now **understates / overstates** what the metal actually released.

CER Claim — Evidence — Reasoning

Claim: the sample is ______________________.

Evidence: quote your mean c_m with its uncertainty interval and the reference value it brackets or approaches.

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Reasoning: connect evidence to claim through the physics — why a measured c_m a little BELOW the table value still supports your claim (use your A5(c) direction argument). A miss with a known direction is evidence, not error.

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