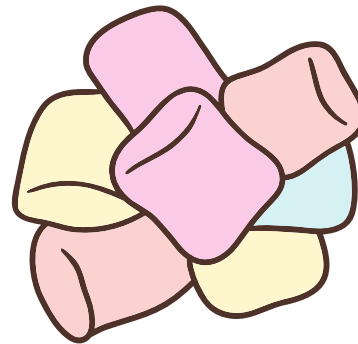
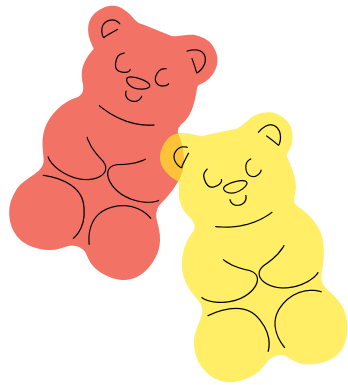


Candy Chemistry Combustion Calorimetry STEM Lab

Scientific Method • Variables • Data & Graphing

✓ Classroom-Ready

✓ Data tables + bar graph templates included



Teach With
Fergy

Candy Chemistry Combustion Calorimetry – Laboratory Experiment

Concepts: Energy in Food • Conservation of Energy • Heat Measurement
Time: 45–70 minutes (plus ~10–15 min prep) | Groups: pairs/triads

Essential Question

How much energy is stored in candy, and how can we measure it by transferring heat to water?

Learning Targets

- Measure temperature change of water heated by a burning candy sample.
- Calculate energy transferred to water using $q = m \cdot c \cdot \Delta T$ and estimate food energy (Calories).
- Explain sources of error and energy loss in a simple calorimeter and relate results to nutrition labels.

Standards

- NGSS MS-PS3-3/4 (relationship between energy transfer and temperature change; conservation of energy)
- NGSS HS-PS3-1/4 (qualitative/quantitative energy conservation; calorimetry, advanced extension)
- Science & Engineering Practices: Planning Investigations; Analyzing & Interpreting Data; Using Mathematics; CER

Materials (for ~8 groups + teacher demo/ignition)

Per Group

- Soda can calorimeter (clean, dry aluminum can with top opening)
- 250 mL beaker or cup to hold the can upright (or ring stand)
- 100 mL room-temperature water (~100 g)
- Thermometer (~10 to 110 °C or digital)
- Heat-resistant tray or ceramic tile under apparatus
- Weighing tray or small foil square
- Balance (0.01 g preferred; shared)
- Metal paperclip or wire stand to hold the candy
- One small candy sample (e.g., mini marshmallow, small sugar cube, or small hard candy)
- Wooden splint or long match (teacher uses to ignite)
- Tongs/forceps for safe handling

Shared/Teacher

- Safety goggles (class set), heat-resistant gloves for teacher
- Fire extinguisher or fire blanket; water for extinguishing
- Lighter or matches (teacher-only)

Safety (post & read aloud)

- Goggles on for everyone. Long hair tied back; no loose clothing.
- TEACHER ignites samples. Students keep hands and faces away from flame.
- Set apparatus on a nonflammable tray; keep combustibles clear. Have an

Setup & Pacing

- Prep (~10–15 min): Fill labeled cups with 100 mL water; lay out cans, stands, balances, thermometers, trays.
- Review ignition procedure and designate a safe ignition zone.
- Flow (45–60 min): Intro + safety (5 min). Station work & measurements (25–35 min). Calculations & CER start (10–15 min). Debrief (5 min).
- Cleanup (5–10 min): Extinguish fully; cool cans; discard residues; wipe benches.

Cleanup & Disposal

- Extinguish any remaining flame; allow metal parts to cool completely.
- Dispose of burned candy and foil in trash; pour cooled water down sink.

Task

Goal: Measure the energy released by burning a small candy by heating water in a soda-can calorimeter. You'll need (per group): can calorimeter, 100 mL water, thermometer, balance, small candy, wire stand, tray, tongs.

Steps: Each Group

- Measure the mass of your candy on a tray: $m_{\text{candy, initial}} = \underline{\hspace{1cm}}$ g.
- Add 100 mL water to your cauldron (can) = 100 g. Record initial water temperature: $T_i = \underline{\hspace{1cm}}$ °C.
- Your teacher will ignite the candy on the wire stand beneath the cauldron using their wand. Center the flame beneath the cauldron opening.
- Gently swirl the cauldron occasionally (use tongs on the rim) and watch the thermometer. When the flame goes out, record the highest water temperature: $T_f = \underline{\hspace{1cm}}$ °C.
- Measure the remaining mass of the candy residue + tray, then subtract tray mass to find $m_{\text{candy, final}}$. Compute mass burned: $\Delta m_{\text{candy}} = m_{\text{initial}} - m_{\text{final}} = \underline{\hspace{1cm}}$ g.

Record: All masses, temperatures, and calculated values in your data table.

Once each group is done, compile all data on the board for their reference.

Answer Key / Teacher Notes

$q = m \cdot c \cdot \Delta T$

Assume: $m_{\text{water}} = 100 \text{ g}$, $T_i = 22.0 \text{ °C}$, $T_f = 36.5 \text{ °C} \rightarrow \Delta T = 14.5 \text{ °C}$

$q_{\text{water}} = 100 \text{ g} \times 4.18 \text{ J/g} \cdot \text{°C} \times 14.5 \text{ °C} = 605 \text{ J}$

If $\Delta m_{\text{candy}} = 0.90 \text{ g}$, then Energy per gram = $6060 \text{ J} / 0.90 \text{ g} = 6730 \text{ J/g}$

Food Calories per gram = $(6060 \text{ J} / 4184 \text{ J/Cal}) / 0.90 \text{ g} = 1.61 \text{ Cal/g (kcal/g)}$

Note: Real values are lower than label values due to heat loss to air/can/soot and incomplete combustion.

Pre-Lab Warm-Up – Sample Answers

1) Definitions:

Calorimetry: Measurement of heat transfer by observing temperature change in a known mass (usually

chemical $\rightarrow$ thermal) and

variation in heat absorption and

Analysis Questions:

1) Where did some of the energy from the burning candy NOT go? List two loss pathways.

- To the surroundings: warm air rising around the flame (convection/radiation).
- Into the apparatus: heating the aluminum can/wire/thermometer instead of the water.
(Other acceptable: incomplete combustion in a sooty flame; evaporation heating of water vapor; heat lost to the bench/tray.)

2) If two groups burned the same mass but recorded different ΔT , what procedural differences could explain it?

- Flame–can distance different $\rightarrow$ poorer heat transfer for the lower ΔT group.
- Insufficient shielding from drafts $\rightarrow$ more convective loss.
- Stirring frequency/consistency $\rightarrow$ thermal stratification vs. well-mixed water.
- Thermometer placement/lag $\rightarrow$ tip not centered in water; read too early/late.
- Starting temperatures / water volume not the same.
- Candy position off-center so heat missed the can bottom.

3) Compare your kcal/g estimate to “4 kcal/g” for sugar. Explain differences.**

- Student result is usually **lower** than 4 kcal/g because the simple calorimeter **doesn't capture all the heat**: energy warms the can/air/thermometer and some combustion is **incomplete** (soot).
- If a result is higher, it's typically due to **measurement error** (misread mass/temperature, water volume, or timing).

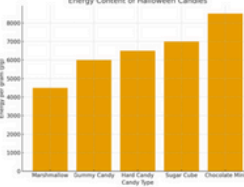
4) CER – Example

- Claim:** The tested candy contains “1.6 kcal/g (example value) of usable energy in our setup.
- Evidence:** We heated 100 g of water from 22.0 °C to 36.5 °C ($\Delta T = 14.5 \text{ °C}$).
 - Candy mass burned = 0.90 g.
 - Energy per gram = $6060 \text{ J} / 0.90 \text{ g} = 6.73 \times 10^3 \text{ J/g} = 1.61 \text{ kcal/g}$.
- Reasoning:** By conservation of energy, chemical energy in the candy became heat. Our calorimeter only measures heat **gained by water**, not losses to air/can, so the measured value underestimates the true food energy.

5) Graph of class data

Candy Type	Energy (J/g)	Energy (kcal/g)
Marshmallow	4,500	1.08
Gummy Candy	6,000	1.43
Hard Candy	6,500	1.55
Sugar Cube	7,000	1.67
Chocolate Mini	8,500	2.03

Energy Content of Halloween Candies



ry Combustion Calorimetry – Laboratory Experiment

Date: _____

Energy but how much energy is there in food?

Lab Extensions: Optional

Prompt: “Your first setup leaked heat! Redesign your can calorimeter to capture more energy in the water.”

Student tasks:

- Modify one variable: distance from flame, insulation (foil wrap, cardboard sleeve, cotton), or can height.
- Collect new ΔT data under the same candy mass.
- Compare before/after efficiency:

$$\text{Efficiency} = \frac{q_{\text{water}}}{m_{\text{candy}} \times 4184}$$

- Rank designs and explain why the optimized one worked better (using surface area, convection, and insulation reasoning).

Follow Up Question:

“Estimate how many mini marshmallows (2 g each) would you need to power a 60-Watt lightbulb for one minute.”

Given Data

- Power of lightbulb: 60 W = 60 J/s
- Time: 1 minute = 60 seconds
- Energy used by bulb:

$$E_{\text{bulb}} = 60 \text{ J/s} \times 60 \text{ s} = 3600 \text{ J}$$

- Average energy content of a mini marshmallow from the lab: = 4,500 J/g

Let's assume one mini marshmallow has a mass of 2 g.

Step 1: Energy per marshmallow

$$E_{\text{marshmallow}} = 4500 \text{ J/g} \times 2 \text{ g} = 9000 \text{ J}$$

Step 2: Compare to bulb energy

Each marshmallow contains 9,000 J, while the bulb needs 3,600 J for one minute.

$$\text{Marshmallows needed} = \frac{E_{\text{bulb}}}{E_{\text{marshmallow}}} = \frac{3600}{9000} \approx 0.4$$

Final Answer:

It would take about half of one mini marshmallow (~0.4 marshmallows) to power a 60-W lightbulb for one minute—if all the candy's chemical energy could be perfectly converted into electrical energy.

Extension Discussion

- Real systems are not 100% efficient — only a small fraction of chemical energy becomes usable electricity.
- In practice, powering a lightbulb from candy would require many marshmallows once conversion losses are included.

What You Get

- **Teacher Guide:** Setup checklist, materials, safety/ignition protocol, timing/roles; background on combustion, heat transfer ($q = m \cdot c \cdot \Delta T$), and conservation of energy; quick troubleshooting.
- **Student Packet:** Driving question, hypothesis template, variables table (IV/DV/controls), and a numbered, step-by-step procedure for fair tests and repeats.
- **Data Tables:** Trial logs for mass (initial/final), water volume, T_i/T_f , ΔT , with spaces for averages and quick notes.
- **Calculations & Graph Page:** Structured prompts for $q = m \cdot c \cdot \Delta T$, J/g $\leftrightarrow$ kcal/g conversions, and a bar-graph template (Candy Type vs. Energy per gram) with labeled axes/units.
- **Analysis + Model Answers:** Focused questions on energy losses, procedural differences, comparison to ~4 kcal/g sugar value, and an exemplar CER; concise answer key.
- **Simple Rubric:** Single-point rubric with 4 performance levels for Safety/Setup, Design & Procedure, Data Quality, Calculations/Units, Graphing, and Analysis/CER.