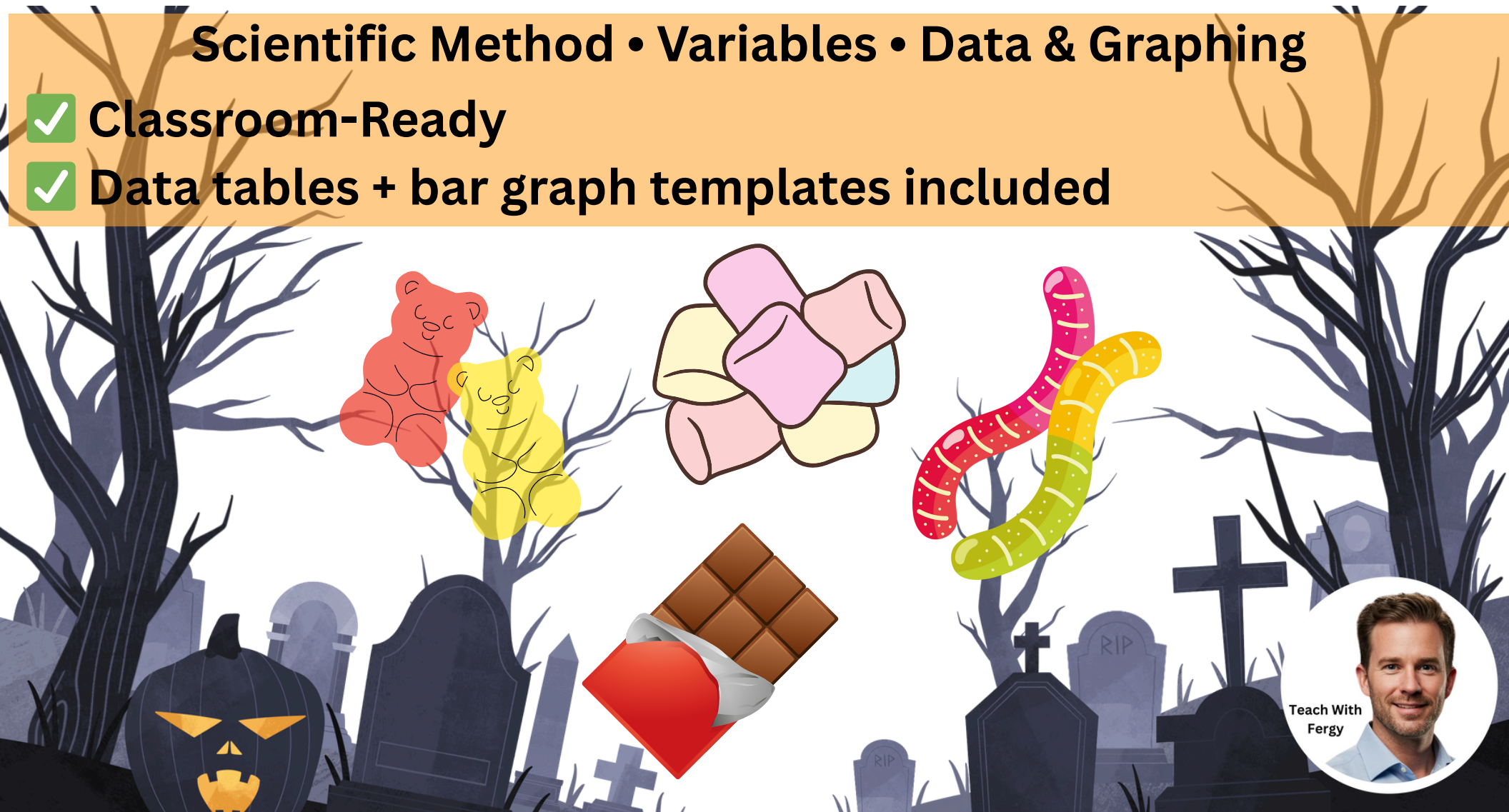


Halloween Candy Combustion Calorimetry STEM Lab

Scientific Method • Variables • Data & Graphing

- ✓ **Classroom-Ready**
- ✓ **Data tables + bar graph templates included**



Halloween Candy 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 Halloween candy, and how can we measure it by transferring heat to water?

Learning Targets

- Measure temperature change of water heated by a burning Halloween 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

Teacher Guide

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 flames and hot metal.
- Set apparatus on a nonflammable tray; keep combustibles clear. Have an extinguisher available.
- Do not eat lab food.
- Handle hot can and wire with tongs; allow to cool before disposal/cleanup.

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.

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

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.

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: $m_{\text{candy, initial}} = \text{_____ g}$.
- Add 100 mL water to your cauldron (can) +100 g. Record initial water temperature: $T_i = \text{_____}^\circ\text{C}$.
- 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: $T_f = \text{_____}^\circ\text{C}$.
- Measure the remaining mass of the candy residue + tray, then subtract tray mass to find $m_{\text{candy, final}}$. Compute mass burned: $\Delta m_{\text{candy}} = m_{\text{candy, initial}} - m_{\text{candy, final}} = \text{_____ g}$.

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

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

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 water).
Conservation of Energy: Energy cannot be created or destroyed; it transforms (chemical → thermal) and transfers (to water, can, air).

2) Consistency ensures a fair test—same water mass and geometry reduce variation in heat absorption and loss, making results comparable.

3) Prediction: A pure sugar cube likely releases more energy per gram than a marshmallow (which contains air and water that do not add much fuel).

Halloween Candy Combustion Calorimetry – Laboratory Experiment

Names: _____ Date: _____

We all love candy, but have you ever thought about how much energy is stored in that Halloween candy you get each year?

Pre-Lab Warm-Up

1) Define:

- Calorimetry = _____
- Conservation of Energy = _____

2) Why must we keep the water volume and can position consistent for all groups?

3) Predict which candy type would release more energy per gram and why (use evidence).

Procedure

- Measure the mass of your candy on a tray: $m_{\text{candy, initial}} = \text{_____ g}$.
- Add 100 mL water to your cauldron (can) +100 g. Record initial water temperature: $T_i = \text{_____}^\circ\text{C}$.
- Your teacher will ignite the candy on the wire stand 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: $T_f = \text{_____}^\circ\text{C}$.
- Measure the remaining mass of the candy residue + tray, then subtract tray mass to find $m_{\text{candy, final}}$. Compute mass burned: $\Delta m_{\text{candy}} = m_{\text{candy, initial}} - m_{\text{candy, final}} = \text{_____ g}$.

Record: All masses, temperatures, and calculated values in your data table. On the data from your teacher.

Data & Observations

A – Measurements

Candy type/description	
$m_{\text{candy, initial}}$ (g)	
$m_{\text{candy, final}}$ (g)	
$\Delta m_{\text{candy, burned}}$ (g)	
Water volume (mL) (= mass, g)	
T_i (°C)	
T_f (°C)	

B – Calculations (show work)

$\Delta T = T_f - T_i$ (°C) = _____

$q_{\text{water}} = m_{\text{water}} \cdot C_{\text{water}} \cdot \Delta T$ ($C_{\text{water}} = 4.18 \text{ J/g}^\circ\text{C}$) = _____

Energy per gram of candy (J/g) = $q_{\text{water}} / \Delta m_{\text{candy}}$ = _____

Food Calories per gram (kcal/g): 1 Cal = 4184 J → $(q_{\text{water}} / 4184) / \Delta m_{\text{candy}}$ = _____

Percent difference vs. label (if available) = _____

Analysis

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

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

3) Compare your kcal/g estimate to a typical nutrition label value for sugar (~4 kcal/g). Explain any differences.

4) CER: Make a claim about your candy's energy content. Support with calculated evidence and reasoning based on energy conservation.

5) Create a **bar graph**: Candy Type vs. Energy per gram (J/g or Cal/g) after looking at the class data.



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 → poorer heat transfer for the lower ΔT group.
- Insufficient shielding from drafts → more convective loss.
- Stirring frequency/consistency → thermal stratification vs. well-mixed water.
- Thermometer placement/tag → 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.**

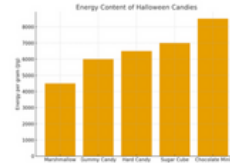
- Student result is usually **lower** than 4 kcal/g because the simple calorimeter **doesn't capture all the heat**: energy warms the can/air/thermometer and some combustion is **incomplete** (soot).
- If a result is **higher**, it's typically due to **measurement error** (misread mass/temperature, water 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 ($\Delta T = 14.5^\circ\text{C}$).
 - 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



Grading Rubric

Criterion	4 – Exemplary (4 pts)	3 – Proficient (3 pts)	2 – Developing (2 pts)	1 – Beginning (1 pt)
Safety & Setup	Goggles on at all times; hair/clothes secured; apparatus stable on tray; ignition zone respected; quick spill/heat response.	Minor reminders; apparatus stable; follows ignition directions.	Frequent reminders; occasional unsafe placement (flame–can distance, clutter).	Unsafe behavior or disregards safety directions; apparatus unstable.
Experimental Design & Procedure Fidelity	I/V/OV/controls explicitly stated; procedure followed exactly with consistent flame–can distance and water volume; timing/stirring standardized.	Variables identified; small deviations but kept consistent enough for fair test.	Variables partially identified; inconsistent distances/volumes or timing.	Variables unclear; major deviations invalidate comparison.
Measurement & Data Quality	Masses (initial/final), water volume, T_i/T_f recorded with correct units and significant figures; ΔT computed correctly; outliers noted/justified.	Most values recorded with units; ΔT mostly correct; minor sig fig issues.	Some missing units/values; calculation mistakes; little attention to precision.	Sparse or unreliable measurements; major errors make data unusable.
Calculations & Units (g = m • c • ΔT; J ↔ kcal)	All steps shown; units carried correctly; q, J/g, and kcal/g accurate; clear statement of assumptions ($m_{\text{water}} = \text{volume}$).	Steps shown; minor math/unit slips corrected in final; answers reasonable.	Incomplete steps; repeated unit/math errors; answers plausible but unsupported.	Incorrect method or missing work; results not interpretable.
Graphing & Data Presentation	Clean bar graph Candy Type vs Energy per gram with title, labeled axes + units; sensible scale; bars accurate to data; legend/notes as needed.	Graph present with title and labels; small scaling or bar-height issues.	Graph missing labels/units or scale distorts comparison; errors in values.	No graph or graph not related to data collected.
Analysis & CER	Claim aligns with data; Evidence cites specific numbers (ΔT , J/g, kcal/g); Reasoning correctly uses conservation of energy and heat loss pathways; addresses discrepancies vs. 4 kcal/g.	Claim supported with general evidence; reasoning mostly correct; mentions at least one loss pathway.	Vague claim/evidence; reasoning thin or partially incorrect.	Claim absent or contradicted by data; no reasoning.

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.