

Rubbing or Reacting? A Claim-Evidence-Reasoning Case

Learning target: I can use temperature, mass and color evidence from a controlled test to argue what makes an iron hand warmer warm and which direction energy flows, and explain the result with the bond model.

Claim, evidence, reasoning

About 40 min

Individual

MS-PS1-6 · practice

writing

data analysis

Standards connections

MS-PS1-6 (practice): Students use test data on a device that releases thermal energy by a chemical process to decide what controls the release (oxygen reaching the iron) and which way energy flows. Knowing the cause is what lets a designer control the transfer in the design project; the sheet itself builds no device, so it is practice.

Purpose: assess · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

The scenario

Dev is sure he knows why a cloth hand warmer gets hot. 'You rub it between your hands,' he says. 'Rubbing makes heat. It's friction, not chemistry.' His lab partner Priya is not convinced: the pouches are sealed in a plastic wrapper, and the instructions say to open the wrapper and *shake*, not rub. They decide to settle it with a test. They buy three identical 30.0 g pouches of iron-powder hand warmer and one pouch of plain sand of the same mass and size, and they borrow a probe thermometer, a balance and a large zip bag that can be filled with nitrogen gas from the chemistry stockroom.

How each pouch was treated (room at 21 °C) — Pouch 1: wrapper opened in ordinary air; pouch laid still on the bench, never rubbed. **Pouch 2:** wrapper opened in ordinary air; rubbed steadily between gloved hands for all 20 minutes. **Pouch 3:** wrapper opened inside the zip bag after the bag had been flushed with nitrogen and sealed; rubbed steadily through the bag for 20 minutes. **Pouch 4:** the sand pouch, opened in ordinary air and rubbed steadily for 20 minutes. Each pouch was weighed before opening and again the next morning, and its color was recorded.

Probe temperature of each pouch (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Time (min)	Pouch 1: air, still (°C)	Pouch 2: air, rubbed (°C)	Pouch 3: nitrogen, rubbed (°C)	Pouch 4: sand, air, rubbed (°C)
0	21	21	21	21
2	26	27	22	22
5	33	34	22	22
10	41	42	21	22
20	45	45	21	22

Simulated readings for a classroom scenario. The probe was pressed against the outside of each pouch; gloved hands were used so that skin warmth did not reach the pouch.

Mass and color notes (same teaching scenario)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Pouch	Mass before (g)	Mass next morning (g)	Change (g)	Color of powder next morning
1: air, still	30.0	31.9	+1.9	red-brown
2: air, rubbed	30.0	32.0	+2.0	red-brown
3: nitrogen, rubbed	30.0	30.0	0.0	gray, unchanged
4: sand, air, rubbed	30.0	30.0	0.0	tan, unchanged

Warm-up: organize the evidence

1. Compare pouches 1 and 2. What do they have in common, what is different, and what does the comparison tell you about rubbing?

Answer: Both were opened in ordinary air and both reached 45 °C by 20 minutes with almost identical readings along the way (41 versus 42 °C at 10 min). The only difference is that pouch 2 was rubbed and pouch 1 was left still. Rubbing made no real difference to the warming, so rubbing is not what supplies the energy.

Why: This pair isolates rubbing as the variable; equal results mean rubbing is not the cause.

Also acceptable: Accept 'rubbing added at most 1 °C.'

- Same air exposure, same result
- Rubbing was the only difference
- Concludes rubbing is not the cause

2. Compare pouches 2 and 3. What is the only difference in how they were treated, and what happened to the temperature in each?

Answer: The only difference is the gas around the pouch: pouch 2 was opened in air, pouch 3 inside a nitrogen-filled bag. Both were rubbed. Pouch 2 climbed to 45 °C; pouch 3 stayed at 21-22 °C the whole time.

Why: This pair isolates air (oxygen) as the variable and shows it is required for warming.

Also acceptable: Accept 'oxygen versus no oxygen.'

- Air versus nitrogen named as the only difference
- 45 °C versus about 21 °C stated

3. Why did Priya include the sand pouch (pouch 4)? What result from it matters for Dev's idea?

Answer: The sand pouch tests whether rubbing alone can warm a pouch of this size, with no reaction possible. It rose only from 21 to 22 °C in 20 minutes, which shows that friction from rubbing adds about 1 °C, nowhere near the 24 °C rise of the iron pouches.

Why: The sand pouch is the control for friction heating itself.

Also acceptable: Accept 'it shows how much rubbing by itself can do.'

- Identifies it as a test of rubbing alone
- Cites the 1 °C rise

4. Pouches 1 and 2 gained about 2 g and turned red-brown; pouch 3 did neither. What do a mass gain and a color change tell you about what happened to the iron, and where could the extra mass have come from?

Answer: A mass gain means something was added to the pouch, and a color change to red-brown means a new substance formed (like rust). The only thing that reached the iron was air, so the extra mass must be oxygen from the air that combined with the iron to make iron oxide. Pouch 3 had no oxygen available, so no new substance formed and no mass was gained.

Why: Students connect mass gain and color to the formation of a new substance from iron and oxygen, matching the chapter's hand-warmer model.

Also acceptable: Accept 'it rusted' with the oxygen source named.

- Mass gain means matter was added
- Color change means a new substance formed
- Oxygen from the air named as the source

Your argument

Answer: Claim: the hand warmer warms because iron in the pouch reacts with oxygen from the air; the process is exothermic. Evidence: (1) pouches 1 and 2 reached the same 45 °C whether rubbed or not, so rubbing is not the cause; (2) pouch 3, rubbed in nitrogen, stayed at 21-22 °C, so without oxygen there is no warming; (3) the sand pouch rose only 1 °C with rubbing, so friction cannot produce a 24 °C rise; (4) pouches 1 and 2 gained 1.9-2.0 g and turned red-brown while pouch 3 did neither, so a new substance formed from iron and oxygen only when air was present. Reasoning: the system is the iron and the oxygen that reacts with it, plus the iron oxide they form; the surroundings are the pouch, the bench, the gloves and the air. The surroundings warmed (the probe on the outside of the pouch rose 24 °C), so energy crossed the boundary out of the system, which is what exothermic means. The energy was not created: breaking the attractions in the iron and the bonds in oxygen took some energy in, but forming the new bonds in iron oxide gave out more, and the difference was released to the surroundings. Without oxygen, no new bonds could form, so no energy was released, which is exactly what pouch 3 showed.

Why: Full credit requires the oxygen-reaction claim with the exothermic label, three or more numbered pieces of evidence each tied to friction or reaction, and reasoning that names system and surroundings, uses the temperature of the surroundings as the direction evidence, and explains the source of the energy by the bond balance without creation language.

Also acceptable: A student who calls the process 'rusting' or 'oxidation' is correct. A student who says the water and salt inside a real pouch help the reaction is adding accurate information beyond the data; credit it if the core argument is complete.

- Claim names the iron-oxygen reaction and says exothermic
- At least three pieces of evidence with numbers, each linked to what it rules out or supports
- System and surroundings named
- Direction of flow justified by the surroundings warming
- Bond balance explains the released energy; no 'energy was created' or 'energy stored in bonds was let out'

Follow-up

5. Dev now agrees but asks: 'Then why do the instructions say to shake the pouch?' Using what the nitrogen bag showed, give a reason that shaking might help even though rubbing does not supply the energy.

Answer: Shaking mixes the powder and opens up the pouch so that more of the iron is exposed to air; the nitrogen test showed that oxygen reaching the iron is what matters. Shaking helps oxygen reach more of the iron, so the reaction starts faster, but the energy still comes from the reaction, not from the shaking.

Why: This separates 'helps the reactant get to the iron' from 'supplies the energy.'

Also acceptable: Accept 'it loosens the powder so air gets in.'

- Shaking exposes more iron to oxygen
- Energy still comes from the reaction

6. Describe one result that, if it had appeared in the table, would have **supported** Dev's friction claim instead.

Answer: Any of: pouch 3 (rubbed in nitrogen) warming to about 45 °C like pouch 2; pouch 1 (still, in air) staying near 21 °C while pouch 2 warmed; or the sand pouch warming by about as much as the iron pouches when rubbed.

Why: Students must name a result in which rubbing, not air, tracks the warming.

Also acceptable: Accept 'the rubbed pouches gaining no mass and not changing color while still warming.'

- Describes a result where warming follows rubbing rather than air

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	States clearly that the iron reacting with oxygen from the air causes the warming and labels the process exothermic.	States the oxygen reaction or the exothermic label, but not both.	Claim is vague ('a chemical reaction happens') or mixes friction and reaction.	No claim, or claims friction.
Evidence	Three or more specific pieces of evidence with numbers, each stating whether it supports the reaction idea or rules out friction; includes both the nitrogen result and the mass or color result.	Three pieces of evidence with numbers, but one is not linked to an idea, or the mass/color evidence is missing.	One or two pieces of evidence, or evidence restated from the table without numbers.	Evidence missing, invented, or contradicts the table.
Reasoning	Names system and surroundings, uses the surroundings' temperature rise to justify the outward flow, and explains the released energy as forming bonds giving out more than breaking took in; no creation language.	Names system and surroundings and the direction of flow, but the bond explanation is incomplete or one-sided.	Restates the evidence without a system-surroundings model, or gives the bond idea without linking it to the data.	No reasoning, or reasoning says energy was created or that breaking bonds released it.
Use of the controlled comparisons	Uses the pairs (1 versus 2, 2 versus 3, and the sand control) explicitly, naming what each pair held constant and what it changed.	Uses two of the three comparisons correctly.	Uses one comparison, or compares pouches that differ in more than one way without noticing.	No use of comparisons.

Teacher notes

All data are simulated but realistic: iron-powder warmers reach 40-55 °C and gain mass as oxygen combines with iron; the chapter's W1 pouch gained 3.1 g, this one about 2 g for a slightly smaller pouch. The nitrogen bag mirrors the lesson's own prototype-testing method. Gloved hands are specified so that skin warmth does not confound pouch 2 and pouch 4; if students ask, say this is why the hands were gloved. Do not run this test with pure nitrogen in class without a stockroom-approved setup; the sheet is a paper case. The follow-up q5 is a good moment to distinguish 'helps the reaction happen' from 'supplies the energy,' the same distinction as a match's strike. If a student writes 'the energy stored in the iron's bonds was released,' return

it with the balloon warning: the energy is stored in the arrangement of atoms in the whole system, and bonds forming, not breaking, is what gives it out.

Scaffold offered to students: A comparison grid before you write

On scrap paper, draw a grid with the four pouches across the top and these rows down the side: air or nitrogen; rubbed or still; temperature at 20 min; mass change; color change. Fill it in from the tables. Then look for pairs that differ in only one way: pouches 1 and 2 differ only in rubbing; pouches 2 and 3 differ only in air versus nitrogen. Each pair is one piece of evidence, and the thing that differed is what the pair tests.

Extension: Hot enough from friction?

The sand pouch rose only 1 °C with 20 minutes of steady rubbing. Rubbing does transfer energy (your hands do work on the pouch), so friction is not nothing. Design a test that would measure how hard and how long you would have to rub a sand pouch to reach 45 °C, and predict whether it is possible before your hands tire. Then write two or three sentences explaining why engineers chose a chemical reaction rather than friction for a device that must stay warm for hours, using the word surroundings.