

Which Way Did the Energy Go? An Evidence Sort for Pack Designers

Learning target: I can work with a group to sort evidence cards by the direction of energy flow, justify each placement with the right kind of evidence, and choose which processes could power a warming pack or a cooling pack.

Collaborative investigation

About 50 min

Small group

MS-PS1-6 · practice

MS-ETS1-2 · practice

collaboration

discussion

data analysis

Standards connections

MS-PS1-6 (practice): Choosing a chemical process for a device that releases or absorbs thermal energy is the first decision of the design project. Here groups judge eleven candidate processes by temperature change and safety, which builds that decision without constructing or testing a device.

MS-ETS1-2 (practice): In the group task students evaluate the sorted processes against three supplied criteria (direction, size of temperature change, safety) using a decision table. The criteria are given rather than defined by students, so the role is practice.

Purpose: practice · **Time:** about 50 minutes · **Format:** small-group

Answers with reasoning

Eleven evidence cards (teaching data, room at 21 °C unless stated)

1 Card 1: Calcium chloride in water

8 g of white calcium chloride granules stirred into 50 mL of water in a foam cup. The thermometer in the water rose from 21 °C to 45 °C in 3 minutes. No bubbles. The granules disappeared. The cup was warm for about 20 minutes.

2 Card 2: Citric acid and baking soda in water

10 g of citric acid and 10 g of baking soda stirred into 50 mL of water. Fizzed strongly for about a minute. The thermometer fell from 21 °C to 14 °C in 2 minutes, then slowly climbed back toward 21 °C.

3 Card 3: Hydrogen peroxide and yeast

A spoonful of dry yeast stirred into 50 mL of 3 percent hydrogen peroxide. Thick foam rose up the cup. The thermometer rose from 21 °C to 34 °C in 4 minutes.

4 Card 4: Ammonium chloride in water

15 g of white ammonium chloride crystals stirred into 50 mL of water. No bubbles. The crystals disappeared. The thermometer fell from 21 °C to 9 °C in 2 minutes; droplets formed on the outside of the cup.

5 Card 5: Steel wool after a vinegar rinse

A pad of fine steel wool was dipped in vinegar, squeezed out and placed in a jar with a thermometer, lid loosely on. Over 10 minutes the air in the jar warmed from 21 °C to 27 °C. The wool darkened to red-brown.

6 Card 6: Sugar in water

15 g of table sugar stirred into 50 mL of water. The sugar disappeared. The thermometer read 21 °C before and 20.5 °C after; the half-degree drop was barely readable.

7 Card 7: A snapped light stick

A plastic light stick was bent until the inner glass tube broke and shaken. It glowed bright green for hours. A thermometer taped to it read 21 °C before and 21.5 °C after 10 minutes.

8 Card 8: Baking soda and vinegar

10 g of baking soda added to 50 mL of vinegar. Fizzed over the rim of the cup. The thermometer fell from 21 °C to 17 °C in 1 minute.

9 Card 9: A gel pack from the freezer

A sealed gel pack taken from a freezer. A thermometer pressed to it read -8 °C, rising to 5 °C after 30 minutes on the bench. Nothing was mixed, opened or broken; the gel was the same before and after.

10 Card 10: Magnesium ribbon in a flame (teacher demo)

A 3 cm strip of magnesium held in a burner flame with tongs. It caught and burned with a brilliant white light that students could not look at directly, leaving a white powder. The air half a meter away felt warm for a moment.

11 Card 11: A struck match

A wooden match would not burn until it was scraped on the box. After the scrape, it burned on its own for about 20 seconds with a yellow flame and a wisp of smoke; a thermometer 5 cm above the flame rose from 21 °C to 58 °C.

Part A: Sort (group)

1. Lay out three labeled areas: ENERGY LEFT THE SYSTEM, ENERGY ENTERED THE SYSTEM, NO CHEMICAL PROCESS.
2. For each card, find the evidence that shows the direction: a thermometer in the surroundings going up or down, or light and sound leaving the system. Fizzing, foaming, glowing color and needing a start are not direction evidence by themselves.
3. Place the card and say the reason aloud. If the group disagrees, the card goes face-down until the whole group can state the evidence.
4. Fill in the group record table: card number, pile, and the one piece of evidence that decided it.

Group record (fill in)

Card	Pile	The evidence that decided it
1		

Card	Pile	The evidence that decided it
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

1. Group answer: Which card caused the most disagreement, and what evidence finally settled it?

Answer: Most often card 7 (the light stick: the thermometer barely moved, but light leaving is energy leaving), card 9 (the gel pack: cold, but no chemical process), or card 11 (the match: needed a start). The settling evidence: light leaving for card 7; nothing mixed or changed for card 9; the thermometer rising to 58 °C for card 11.

Why: Any card with a correct settling argument earns credit; the three listed are the designed traps.

Also acceptable: Card 6 (sugar, tiny drop) is also a fair answer if the group argued about whether a half-degree counts; accept 'slightly endothermic, too small to matter.'

- Names a card
- Names the evidence that settled it

Part B: Decide (group)

A camping-supply company wants one process for a single-use warming pack and one for a single-use cooling pack. Their criteria: (1) the process must move energy in the right direction; (2) it must change the temperature of 50 mL of water by at least 12 °C within 3 minutes; (3) it must be safe to hold against skin inside a sealed plastic pouch, so no flame, no gas that could burst the pouch, and nothing that could burn skin or eyes.

2. Group answer: Judge each exothermic card against the three criteria for the warming pack. Write yes or no in each cell and circle the group's choice.

Answer: Card 1: yes, yes (24 °C rise), yes, choose. Card 3: yes, no (its 13 °C rise took 4 minutes; at that rate it would be only about 10 °C at 3 minutes), no (foam and gas would burst a sealed pouch), reject. Card 5: yes, no (only 6 °C in 10 min), yes, reject for size of change. Card 10: yes, yes, no (flame and blinding light; burns), reject. Card 11: yes, yes, no (flame), reject. The group's choice should be card 1.

Why: Only calcium chloride meets all three criteria; the chart forces students to reject a right-direction process for a safety or size reason.

Also acceptable: Accept 'uncertain' for card 3 on criterion 2, since the card gives no 3-minute reading; the safety rejection stands either way.

- Card 1 chosen
- Cards 10 and 11 rejected on safety
- Card 5 rejected on size of change
- Card 3 rejected on gas or marked uncertain on time

3. Group answer: Which process did you choose for the cooling pack, and which endothermic card did you reject even though it moved energy the right way? Give the criterion that eliminated it.

Answer: Cooling pack: card 4, ammonium chloride (12 °C drop in 2 minutes, no gas, nothing dangerous in a sealed pouch). Rejected: card 2 or card 8, which moved energy the right way (cooled) but produce gas that would swell or burst a sealed pouch (criterion 3); both also fall short on size (7 °C and 4 °C). Card 6 (sugar) moved the right way but by only half a degree (criterion 2).

Why: Students must apply a criterion other than direction to reject a correctly-directed process.

Also acceptable: Accept card 2 rejected on gas production or card 6 rejected on size of change.

- Card 4 chosen
- A rejected endothermic card named with the eliminating criterion

Part C: Individual accountability (complete alone)

4. Card 7's thermometer barely moved, yet the card belongs in the energy-left-the-system pile. Explain what evidence shows energy leaving and why a thermometer can miss it.

Answer: The light stick gives off light for hours, and light is energy leaving the system, so the net transfer is outward. A thermometer only records thermal energy that reaches it; the energy of this process leaves mostly as light, which passes straight through the air without warming it much, so the thermometer barely moves.

Why: This is the 'light is energy too' idea from the chapter's accuracy notes; the chemical reaction in a light stick is exothermic even though it is not noticeably warm.

Also acceptable: Accept 'the energy went out as light instead of heat.'

- Light leaving identified as energy leaving
- Explains that a thermometer only measures thermal energy transferred to it

5. A classmate argues that card 8 is exothermic 'because it fizzed harder than anything else on the table.' Write the reply you would give, naming the evidence that decides.

Answer: Sample reply: Fizzing shows that a gas formed; it says nothing about which way energy moved. The thermometer is the evidence that decides, and it fell from 21 °C to 17 °C, so the surroundings lost energy to the reaction. Card 8 is endothermic. Card 3 foamed hard too and warmed up, which proves foaming and direction are separate.

Why: Students should separate gas production from energy direction and use the comparison with card 3.

Also acceptable: Accept a reply that cites card 2 instead of card 3 as the contrast.

- Fizzing is not direction evidence
- Cites the 4 °C drop
- Concludes endothermic

6. Card 9 made your hand cold just as card 4 did. Explain why card 9 is in a different pile from card 4, and what the words system and surroundings mean for a gel pack.

Answer: Card 4 is a chemical process: a solid dissolved and the surroundings' energy was absorbed as the ions separated, so energy entered the system. Card 9 is just a cold object: nothing was mixed, broken or changed, so there was no chemical process to classify; the gel pack is cold because it was chilled in a freezer, and energy flows from your hand (surroundings) into the gel (a cold object, but not a reacting system). For a gel pack there is no reacting system at all, only a cold piece of matter receiving energy from warmer things around it.

Why: Feeling cold is not the test; a chemical process absorbing energy is. The chapter's accuracy note distinguishes freezer packs from instant cold packs.

Also acceptable: Accept 'card 9 is physics, not chemistry' with the hand-to-pack direction stated.

- Card 4: dissolving absorbs energy, so endothermic process
- Card 9: no chemical process; it was chilled
- Energy still flows from hand into the pack

7. Card 11 needed a scrape to start. Explain why it still belongs in the energy-left pile, using the thermometer reading and the idea of net energy transfer.

Answer: The scrape supplied a small amount of energy to start the reaction, but once burning, the match released far more: the thermometer above it rose from 21 °C to 58 °C, a 37 °C rise, and light left the flame. Counting everything in and everything out, the net energy transfer is outward, so burning the match is exothermic. Needing a start does not change the net direction.

Why: The net transfer, not the start-up, decides the classification.

Also acceptable: Accept 'the scrape is like a push to get a ball rolling downhill.'

- Small start-up input versus large output
- Cites the 37 °C rise or light leaving
- Uses net energy transfer to conclude exothermic

8. Write the process on card 1 as an equation with the energy term on the correct side, given that calcium chloride separates into calcium ions (Ca^{2+}) and chloride ions (Cl^-) in water: $\text{CaCl}_2 \rightarrow$ _____

Answer: $\text{CaCl}_2 \rightarrow \text{Ca}^{2+} + 2\text{Cl}^- + \text{energy}$

Why: The process released energy to the surroundings (water rose 24 °C), so energy is written with the products; one calcium chloride unit gives one calcium ion and two chloride ions.

Also acceptable: Accept '(aq)' labels; accept 'heat' for energy; accept the equation without the coefficient 2 only if the student is asked to fix the chloride count.

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Sorting and evidence	All eleven cards placed correctly, each with the evidence that decided it (thermometer direction, light leaving, or no process); the three trap cards (7, 9, 11) are placed with correct reasons.	Ten cards correct with evidence; one trap card misplaced or placed without a reason.	Several cards placed by fizzing, feel or needing a start rather than by direction evidence.	Cards sorted by appearance or guessed; no evidence recorded.
Decision table and choices	Every cell of the warming-pack table justified; card 1 chosen and card 4 chosen for cooling, with at least one correctly-directed process rejected on size or safety.	Correct choices, but one or two cells unjustified or one rejection missing its criterion.	Choices made on direction alone, ignoring size or safety criteria.	No decision, or a flame-based process chosen for a sealed pouch.
Group process	Every member read cards aloud, stated a reason for at least two placements, and can explain any card's placement when asked.	Most members contributed; one member mostly listened.	One or two members did the sorting while others copied the table.	No shared reasoning; the table was filled by one person.
Individual accountability (Part C)	All five Part C answers accurate, each citing card evidence; q8 equation correct with energy on the product side.	Four accurate with evidence; one thin, or q8 missing the coefficient.	Two or three accurate; others restate the group's result without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Print and cut the eleven cards; shuffle before dealing. All card numbers are simulated but realistic: calcium chloride solutions warm by 20–30 °C at this concentration; ammonium chloride cools by about 10–15 °C; citric acid with baking soda cools by several degrees and fizzes; hydrogen peroxide with yeast foams and warms by 10–15 °C; a light stick is a chemical reaction whose energy leaves mostly as light. The three trap cards are deliberate: card 7 (light, not heat), card 9 (a cold object with no process; the chapter distinguishes freezer gel packs from instant cold packs), and card 11 (needs a start). Card 6 is a genuinely small endothermic dissolving and may be placed in the endothermic pile or argued as 'too small to tell'; either is acceptable with the evidence stated. Do not demonstrate cards 10 or 11; the chapter has no flames, and both are described examples only. Lab 1 lets students measure four of these processes themselves.

Scaffold offered to students: One question per card

For every card ask only this: did a thermometer in the surroundings go up, go down, or barely move, and did light or sound leave? Up or light leaving means energy left the system. Down means energy entered. Barely moved with nothing leaving means little or no net transfer. Then ask a second question only for the barely-moved and the no-mixing cards: did any new substance form? If nothing was mixed, broken or changed, there was no chemical process to classify, even if the object felt hot or cold.

Extension: Design the twelfth card

Write a twelfth evidence card that would be hard to sort: a change where the thermometer in the surroundings rises, but the rise comes from something other than a chemical process (for example, a pouch warmed by rubbing, or a cup warmed by a lamp). Then explain what extra observation a group would need, beyond the thermometer, to keep it out of the exothermic pile. Finish with one sentence on why engineers testing a hand warmer sealed it in nitrogen before opening it to the air.