

Fixing Tomas's Lab Summary: Seven Energy Errors

Learning target: I can find the errors in a student's explanation of hot and cold packs, explain what idea went wrong in each, and rewrite the explanation correctly.

Error analysis

About 35 min

Individual

MS-PS1-6 · supports

writing

independent practice

Standards connections

MS-PS1-6 (supports): A designer who believes cold flows out of a pack, or that the hottest prototype lasts longest, will modify a device for the wrong reasons. This sheet repairs those ideas before the design project; it produces no device or test data of its own.

Purpose: practice · **Time:** about 35 minutes · **Format:** individual

Answers with reasoning

Tomas's measurements (teaching scenario, room at 21 °C)

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

Packet	What was mixed	Start (°C)	After 3 min (°C)	Other observations
P1	Baking soda and vinegar in a cup	21	16	Fizzed hard for a minute, then stopped
P2	Calcium chloride granules and water in a cup	21	47	No bubbles; granules disappeared
P3	Iron powder pouch, opened to the air	21	36	Still warming at 3 min; 44 °C at 10 min; 24 °C the next day

Tomas's summary (numbered sentences) — (1) P1 fizzed really hard, so it was giving off a lot of energy and must be exothermic. (2) P2 got hot because the calcium chloride dissolved and the net energy transfer was out of the system into the water, the cup and my hand. (3) P1 got cold because the reaction released cold into the water. (4) P3 warmed up because breaking the bonds in the iron released the energy that was stored in them. (5) Since P3 needs air to keep going, it must be endothermic, because endothermic reactions need a continuous supply from outside. (6) Energy was created inside P2 and P3 and destroyed inside P1. (7) The equation for P3 is $4\text{Fe} + 3\text{O}_2 + \text{energy} \rightarrow 2\text{Fe}_2\text{O}_3$. (8) P2 reached 47 °C and P3 only reached 44 °C, so P2 will stay warm longer than P3.

Part A: Diagnose

1. Mark each sentence as correct or error. For each error, name the idea that went wrong in a few words (for example, 'confuses fizzing with energy direction').

Answer: 1: error (fizzing is not evidence of energy direction; the temperature fell, so P1 is endothermic). 2: correct. 3: error (cold is not a substance; energy flowed from the water into the dissolving reactants). 4: error (breaking bonds takes energy in; the energy came from forming new bonds giving out more than breaking took in). 5: error (needing a supply of a reactant, oxygen, is not the same as a net inward flow of energy; P3 is exothermic). 6: error (energy is never created or destroyed; it is transferred and stored). 7: error (energy belongs on the product side for an exothermic reaction). 8: error (peak temperature does not set duration; the amount of reactant and the rate do).

Why: Sentences 2 and 7 are the pair most students hesitate over; 2 is a correct use of net transfer and system/surroundings, and 7 has the energy on the wrong side.

Also acceptable: Accept a shorter label for each error if it points to the right idea (for example, 'wrong side' for sentence 7).

- Sentence 2 marked correct
- All seven errors identified
- Each error named by the idea that went wrong

2. Sentence 1 uses the fizzing as evidence. What measurement in the table is the real evidence for P1's energy direction, and what direction does it show?

Answer: The thermometer readings: the water dropped from 21 °C to 16 °C. The surroundings cooled, so energy flowed into the reacting system; P1 is endothermic, no matter how hard it fizzed.

Why: Gas production and energy direction are separate questions; only the temperature change (or light and sound leaving) tells the direction.

Also acceptable: Accept 'the water got colder, so energy went in.'

- Names the 21 to 16 °C drop
- Concludes endothermic, energy flowing in

3. Sentence 3 says the reaction 'released cold.' Explain what actually moved, and in which direction, when P1's water went from 21 °C to 16 °C.

Answer: Only energy moved, and it moved from the water (and cup and air) into the reacting baking soda and vinegar. The water lost thermal energy, so its temperature fell. Nothing called cold was produced or released; a drop in temperature is what losing energy looks like.

Why: This is the chapter's first misconception; the correction is the direction of energy transfer.

Also acceptable: Accept 'the reaction took energy out of the water.'

- Energy moved from water into the system
- Cold is not a substance

4. Sentence 4 has the bond idea backwards in one important way. What does breaking a bond always do to energy, and where did P3's released energy actually come from?

Answer: Breaking a bond always takes energy in; it never releases energy. P3's released energy came from forming new bonds in iron oxide, which gave out more energy than breaking the attractions in the iron and the bonds in oxygen took in. The difference flowed out to the surroundings.

Why: The 'energy stored in bonds is released when they break' idea is reversed; forming bonds releases energy.

Also acceptable: Accept 'the energy was stored in the arrangement of the atoms, and forming iron oxide released part of it.'

- Breaking takes energy in
- Energy came from forming bonds giving out more than breaking took in

5. Sentence 5 uses the rule 'needs a continuous supply, so endothermic.' P3 does need a continuous supply of something. What is it, and why does needing it not make P3 endothermic?

Answer: P3 needs a continuous supply of oxygen, a reactant, not a continuous supply of energy. The rule in sentence 5 is about energy. P3 warmed the surroundings from 21 to 44 °C, so its net energy transfer is outward and it is exothermic. Needing a reactant, or needing a push to start, does not make a change endothermic; only a net inward flow of energy does.

Why: Students must separate 'needs a reactant' from 'needs energy' and apply the net-transfer rule.

Also acceptable: Accept 'air' for oxygen.

- Names oxygen as what P3 needs
- Explains that a reactant supply is not an energy supply
- Concludes exothermic from the temperature rise

6. Sentence 8 predicts P2 will stay warm longer because it got hotter. Use the table's other observations for P3 to show why peak temperature does not decide how long a pack lasts, and name what does.

Answer: P3 reached only 44 °C (at 10 minutes) but was still warm the next day (24 °C, above the 21 °C room), while P2 reached 47 °C in 3 minutes because calcium chloride dissolves quickly and releases its energy fast; nothing in the table says P2 stayed warm. How long a pack lasts depends on how much reactant it holds (the total energy it can release) and how fast it reacts, not on the peak temperature.

Why: Temperature measures how fast particles move now; duration depends on the amount of reactant and the rate of release.

Also acceptable: Accept 'P2 used up its calcium chloride in a few minutes' as a reasonable inference.

- Uses P3's next-day reading as evidence of long duration
- States that amount and rate, not peak, set the duration

Part B: Rewrite

7. Rewrite sentence 7 as a correct equation for P3, with energy on the correct side:

Answer: $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + \text{energy}$

Why: P3 is exothermic, so energy is written with the products; the atom counts (4 Fe, 6 O each side) are unaffected.

Also acceptable: Accept 'heat' for energy.

8. Rewrite Tomas's whole summary as five correct sentences. Your version must classify each packet (exothermic, endothermic) with its evidence, state the direction of energy flow for each, explain P3's energy using bonds correctly, and replace sentence 6 with a true statement about what happens to energy.

Answer: Sample: (1) P1 is endothermic: the water cooled from 21 to 16 °C, so energy flowed from the surroundings into the reacting system; the fizzing tells us gas formed, not which way energy went. (2) P2 is exothermic: the water warmed from 21 to 47 °C, so the net energy transfer was out of the dissolving calcium chloride into the water, cup and hand. (3) P3 is exothermic: the pouch warmed to 44 °C, so energy flowed from the reacting iron and oxygen out to the air and my hand, and it kept going as long as oxygen reached the iron. (4) P3's energy came from forming new bonds in iron oxide, which gave out more energy than breaking the attractions in the iron and the bonds in oxygen took in; its equation is $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + \text{energy}$. (5) No energy was created or destroyed in any packet; it was transferred between each system and its surroundings, and P3 lasted longest because its reaction released energy slowly over many hours, not because it got hottest.

Why: Full credit needs all three classifications with temperature evidence, correct directions, the bond explanation stated the right way round, the conservation statement, and the correction to sentence 8.

Also acceptable: The sentences may be in any order and may be combined, as long as all five criteria are met. Accept 'exothermic change' or 'exothermic process' for P2, since dissolving is not a reaction in the strict sense.

- P1 endothermic, P2 and P3 exothermic, each with its temperature evidence
- Direction of flow stated for each
- Bonds: forming gives out more than breaking takes in
- Energy transferred, not created or destroyed
- Duration explained by amount and rate, not peak

Teacher notes

Six of the seven errors map onto the chapter's misconception list: fizzing as energy evidence (1), cold as a substance (3), energy released by breaking bonds (4), needing a supply means endothermic (5), creation and destruction of energy (6), and peak temperature as duration (8); sentence 7 is the equation-placement error from the equation section. Sentence 2 is correct on purpose so that students cannot assume everything is wrong; it also models 'exothermic' applied to dissolving, which the chapter treats as an exothermic process accepted by the PE's clarification statement. The measurements are simulated but realistic: calcium chloride solutions can reach 45-50 °C quickly with a strong concentration; baking soda and vinegar cool by a few degrees; an iron pouch warms over 10-20 minutes and stays warm for hours. If students debate whether P2's dissolving counts as a reaction, point them to the chapter accuracy note and accept either 'exothermic process' or 'exothermic change.'

Scaffold offered to students: Three test questions for every sentence

Read each of Tomas's sentences and ask: (1) Is the direction of energy decided by a thermometer reading or by light and sound leaving, or by something else like fizzing or needing a start? Only the first kind counts. (2) Does the sentence say energy was created, destroyed, or let out of a broken bond? Those are always errors. (3) Does it say 'cold' moved? Only energy moves. If a sentence passes all three tests, it is probably correct; sentences 2 and 7 are the ones to check most carefully against the table.

Extension: Write the next bad summary

Write a four-sentence summary of a different pair of changes (hydrogen peroxide with yeast, which foams and warms, and citric acid with baking soda in water, which fizzes and cools) that contains exactly two errors of kinds Tomas did not make. Swap with a partner, find each other's errors, and write the corrections. Then explain in two sentences why the foaming and fizzing in these two changes tell you nothing about the direction of energy flow.