

Energy in Reactions: Mastery Check

Learning target: I can identify the direction of energy flow from evidence, explain it with system, surroundings and bonds, place energy in an equation, and use prototype data to judge a device by temperature and time.

Retrieval and mastery check

About 30 min

Individual

MS-PS1-6 · practice

MS-ETS1-3 · supports

independent practice

writing

Standards connections

MS-PS1-6 (practice, the test-and-modify reasoning, judged by amount, time and temperature): Items 8 and 13 give prototype readings and ask whether the device meets its criteria and what to modify; the understanding of energy release and absorption in items 1-7 and 9-12 is what the design project depends on. No device is built here, so the role is practice.

MS-ETS1-3 (supports): The synthesis item asks what characteristic to change in a prototype that fails one criterion, a small piece of the analysis of test data that Lab 3 assesses in full.

Purpose: assess · **Time:** about 30 minutes · **Format:** individual

Answers with reasoning

Part A: Retrieval (items 1-12)

1. Which observation, by itself, shows that a reaction is exothermic? 1 pt

Answer: B. A thermometer in the surroundings rises.

Why: Only a change in the surroundings (or light and sound leaving) shows the direction of energy flow; fizzing, needing a spark and color change do not.

Also acceptable: None.

2. A candle burns. Which of these belongs to the **surroundings**? 1 pt

Answer: D. The nitrogen in the nearby air.

Why: Wax and oxygen are reactants and carbon dioxide is a product, so all three are the system; nitrogen takes no part and is surroundings.

Also acceptable: None.

3. True or false: An instant cold pack feels cold because cold flows out of the pack and into your hand. 1 pt

Answer: False.

Why: Only energy moves, from the warmer hand into the colder pack where the dissolving salt absorbs it; cold is not a substance.

Also acceptable: None.

4. A warming pack reads 23 °C when opened and 47 °C eight minutes later. Calculate the temperature rise and the average warming rate in °C per minute. Show your work. 2 pts

Answer: Rise: $47\text{ °C} - 23\text{ °C} = 24\text{ °C}$. Rate: $24\text{ °C} \div 8\text{ min} = 3.0\text{ °C per minute}$.

Why: Subtract the starting temperature, then divide the rise by the elapsed time.

Also acceptable: Accept 3 °C/min.

5. Which equation correctly shows the energy term for an instant cold pack in which ammonium chloride dissolves? 1 pt

Answer: A. $\text{NH}_4\text{Cl} + \text{energy} \rightarrow \text{NH}_4^+ + \text{Cl}^-$

Why: The cold pack absorbs energy, so energy is written with the reactant; the products are ammonium ions and chloride ions. B has energy on the wrong side; C lists water as a product, but no water forms, so hydrogen and oxygen atoms appear from nowhere and the atom count does not match; D makes chlorine gas, which does not form.

Also acceptable: None.

6. In two sentences, explain why 'breaking the bonds in the iron' cannot be the source of a hand warmer's released energy, and what the real source is. 2 pts

Answer: Breaking any bond takes energy in, so breaking bonds in the iron could only absorb energy, never release it. The real source is the new bonds forming in iron oxide, which give out more energy than breaking the old bonds and attractions took in; the difference flows out to the surroundings.

Why: This is the chapter's bond misconception; full credit needs both halves.

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
- Forming new bonds gives out more than breaking took in, and the difference is released

7. A match will not burn until it is struck, and then it burns on its own. What does this show? 1 pt

Answer: B. An exothermic reaction can need a small input to start; the net transfer decides.

Why: The strike supplies a small start-up input; the match then releases far more, so the net transfer is outward.

Also acceptable: None.

8. Use the prototype table below. The criterion is 'stays at or above 38 °C for at least 2 hours.' From the readings, how long did the prototype stay at or above 38 °C, in hours, and by how much did it miss or beat the criterion? 2 pts

Answer: First reading at or above 38 °C: 30 min. Last reading at or above 38 °C: 120 min (40 °C). Time: $120 - 30 = 90\text{ min} = 1.5\text{ h}$. It missed the 2-hour criterion by 0.5 h.

Why: The span runs from the first qualifying reading to the last; 150 min reads 37 °C, below the line.

Also acceptable: Accept about 1.8 h if the student interpolates the downward crossing between 120 and 150 min (40 → 37 °C means 38 °C at about 140 min, so $140 - 30 = 110\text{ min} \approx 1.8\text{ h}$, missing by about 0.2 h).

Prototype readings for items 8 and 13 (teaching scenario, room at 22 °C)

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

Time (min)	0	30	60	90	120	150	180
Pouch temperature (°C)	22	39	44	43	40	37	33

9. Draw a cold pack resting on a hand. Draw a boundary around the system, label the system and two parts of the surroundings, and draw one energy arrow across the boundary pointing the correct way. Write exothermic or endothermic under the drawing. 2 pts

Answer: A pack on a hand; a boundary around the salt and the water it dissolves in, labeled system; the hand and the air (or the bag) labeled surroundings; one arrow pointing from the hand or air into the boundary; the word endothermic.

Why: The cold pack absorbs energy, so the arrow points in and the label is endothermic.

Also acceptable: Accept a boundary around the salt alone with the water labeled as surroundings, if the arrow still points into the salt.

- Boundary around the salt and water
- Two surroundings labeled
- Arrow points into the system
- Labeled endothermic

10. A design brief says a warmer 'must reach 40 °C' and 'must not cost more than one dollar.' Which statement is a criterion and which is a constraint? Explain the difference in one sentence. 2 pts

Answer: 'Must reach 40 °C' is a criterion, a goal the design tries to meet or beat. 'Must not cost more than one dollar' is a constraint, a limit the design may not cross. Criteria describe success; constraints describe what is not allowed.

Why: The distinction used throughout the engineering half of the chapter.

Also acceptable: Accept 'goal versus limit.'

- Correct labels
- A one-sentence distinction

11. Two warming packs are both at 45 °C. One holds three times as much reacting powder as the other. Which statement is correct? 1 pt

Answer: B. The larger pack holds more thermal energy and can keep warming a hand for longer.

Why: Thermal energy depends on the amount of matter as well as its temperature; same temperature, three times the matter, about three times the thermal energy.

Also acceptable: None.

12. Which change is endothermic? 1 pt

Answer: B. Citric acid and baking soda react in water and the cup cools.

Why: Cooling surroundings mean energy entered the system. A and D warm the surroundings; C gives off light, which is energy leaving.

Also acceptable: None.

Part B: Synthesis (item 13)

13. The prototype in the table above holds 15 g of iron in a thin cloth pouch. Its criteria are a peak of at least 42 °C and at least 2 hours at or above 38 °C; its constraint is never above 50 °C. (a) Say which criteria it met and which it missed, with numbers. (b) Using the ideas of reaction rate, total energy released and the surroundings, propose ONE change to the design, predict its effect on both peak temperature and time, and explain why you would change only one thing before the next test. 4 pts

Answer: (a) Met: the peak criterion (44 °C at 60 min, above 42 °C) and the constraint (never above 50 °C). Missed: the time criterion (at or above 38 °C from 30 to 120 min, about 1.5 h, short of 2 h). (b) Sample change: keep 15 g of iron but use a thicker pouch that lets oxygen in more slowly. Prediction: the reaction runs slower, so energy is released to the surroundings at a lower rate; the peak will drop a little (perhaps to about 41-42 °C, so check it still meets 42 °C) but the same 15 g of iron releases the same total energy over a longer time, so the time at or above 38 °C should grow past 2 hours. Alternative change: more iron (say 20 g) in the same thin pouch, predicting a higher peak (check it stays under 50 °C) and a longer time because more total energy is released. Only one thing is changed so that any difference in the next test can be traced to that change; if both were changed, the team could not tell which one caused the result.

Why: Full credit needs the numeric judgment of both criteria, one named change, predictions for both peak and time that follow from rate and total energy, and the one-variable reason.

Also acceptable: A student who proposes a thicker pouch and predicts the peak may fall below 42 °C, then suggests adding a little iron as the following iteration, is reasoning well; credit the plan if the first test changes only one factor.

- Peak met (44 °C) and time missed (1.5 h) with numbers
- One specific change named
- Predicts effects on both peak and time using rate or total energy
- Explains one change at a time as a way to identify the cause

Teacher notes

Twelve retrieval items (17 points) plus a 4-point synthesis, 21 points in total; a reasonable mastery line is 17 (about 80 percent). Items 1, 7 and 12 target the fizzing and needs-a-start misconceptions; item 3 the cold-flows idea; item 6 the bonds idea; item 11 temperature versus thermal energy. Item 5's option C adds water as a product and fails the atom count, and option D makes chlorine gas; the textbook's ammonium hydroxide equation is deliberately not shown (chapter accuracy note). If a student brings it up, explain that dissolving ammonium chloride separates it into ions and does not make ammonium hydroxide or hydrochloric acid. The prototype readings in the table are simulated. For item 8, accept either the reading-to-reading span (1.5 h) or an interpolated crossing (about 1.8 h) with work shown; both miss the criterion.

Scaffold offered to students: Two rules that answer most items

Rule 1: the direction of energy flow is decided only by what the surroundings do (warm up, cool down) or by light and sound leaving; fizzing, color and needing a start do not count. Rule 2: breaking bonds always takes energy in and forming bonds always gives energy out, so the energy a reaction releases comes from forming new bonds giving out more than breaking old ones took in. For the numeric items, write the subtraction first and the division second, with units on every number.

Extension: Write the fourteenth item

Write one more multiple-choice item for this check that tests the difference between a freezer gel pack and an instant cold pack. Include four options, exactly one correct, and write a one-sentence explanation for why each wrong option is wrong. Then write a second item that tests the equation placement rule for an exothermic dissolving process such as calcium chloride, with the correct balanced ion equation as one option.