



Energy in Chemical Reactions

Chapter 14 of 29 • Chemical Reactions

Lesson 14: Which way does the energy go, and how can we put that flow to work?

Angela's Wand • Bring Science Alive! 7th Grade Integrated

PHENOMENON

Two white pouches, one squeeze, opposite results

A camping-store clerk squeezes a white pouch until the water bubble inside bursts. Within a minute it is almost too warm to hold: about 45 °C. She squeezes a second, identical-looking pouch. It turns cold enough to fog over: about 5 °C. Nothing was plugged in, lit or chilled. Where did the energy come from in the first pouch, and where did it go in the second?

- Notice: what was the same about the two pouches, and what was different?
- Wonder: does the cold pouch send 'cold' into your hand, or does something leave your hand?
- Predict: if you doubled the powder, would the pouch get hotter, last longer, or both?





What you will be able to do

Learning targets

- Identify the system and surroundings and use evidence to say which way energy flows.
- Explain qualitatively why a reaction releases or absorbs energy using bond breaking and forming.
- Show energy in a chemical equation on the reactant side or the product side.
- Design, test and modify a pack that warms or cools, judged by amount, time and temperature.
- Analyze data from several prototypes and combine their best features into a better design.

Every reaction moves energy; the question is which way

- A firework bursting: light, sound and heat pour out of the reacting chemicals.
- Magnesium burning: a white flash so bright you must not look straight at it. Light is energy too.
- An instant cold pack: energy pours in from your hand, and your hand feels it leave.
- To follow energy we need a boundary: what is reacting, and what is around it?

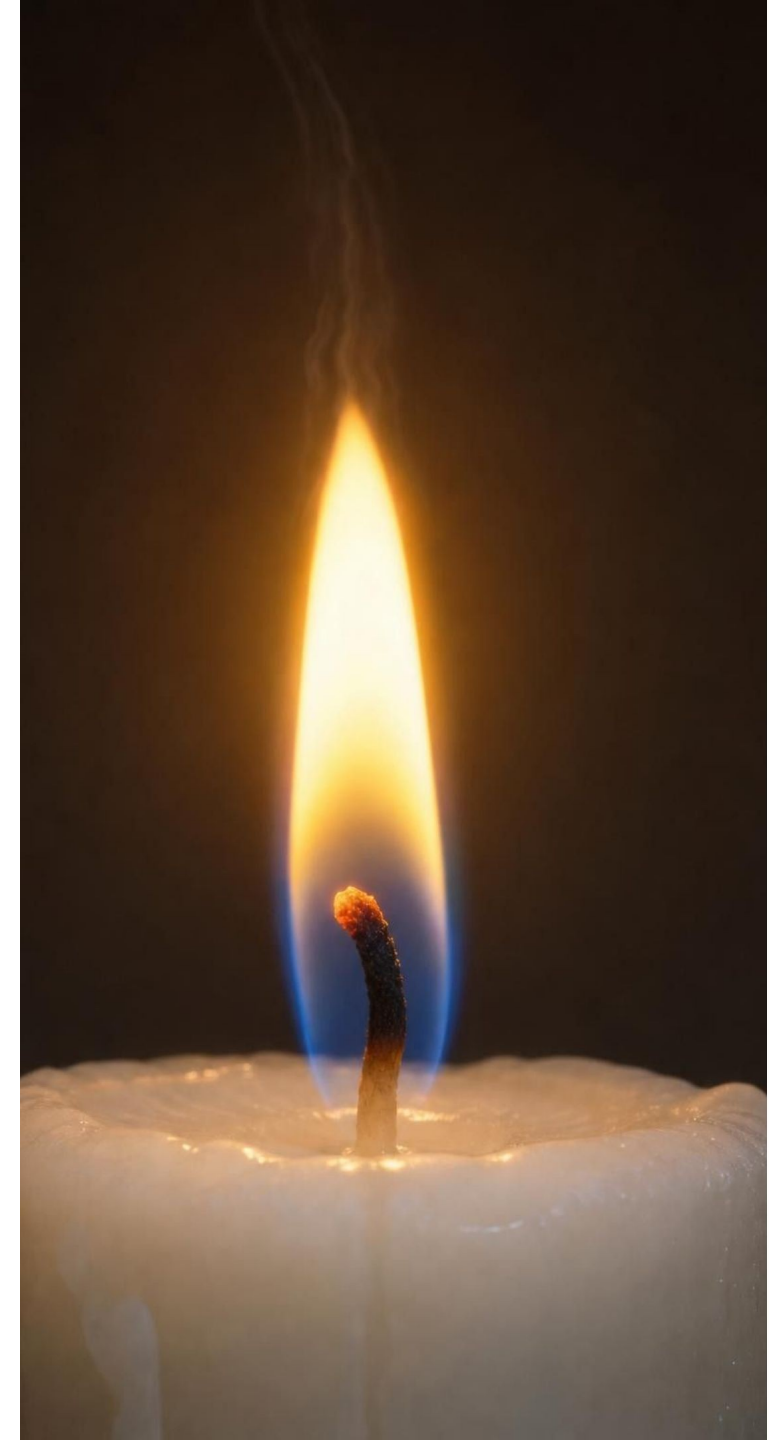


Drawing the line: three words for tracking energy

system: The matter you are tracking: the reactants and the products they become. *For a burning candle: the wax, the oxygen that joins in, and the carbon dioxide and water vapor they form.*

surroundings: Everything outside the system that can trade energy with it. *The candle holder, the air in the room, your hand near the flame.*

thermal energy: The energy matter has because its particles are moving; its transfer from warm to cool is called heat. *A hand warmer passes thermal energy to your skin, so your skin's particles speed up and it feels warm.*



MODEL

The boundary model: one match, two sides of a line

Model: System and surroundings for a lit match

System: match-head chemicals and wood: The reactants. They hold chemical energy because of how their atoms are arranged.

System: oxygen that joins the reaction: Still part of the system; it becomes part of the products.

System: ash, carbon dioxide, water vapor: The products. Same atoms as before, regrouped.

Surroundings: nearby air, fingers, the striker: Receive energy as thermal energy and light. The air warms; the light reaches your eyes.

Boundary: An imaginary line. Energy crossing it outward means exothermic; inward means endothermic.

Energy leaves the system across the boundary, so the surroundings warm up and light up: exothermic.





Exothermic: the system gives out more than it takes in

- Net flow is out of the system; the surroundings warm up, light up, or hear a bang.
- Burning anything: wood, candle wax, a match, the gas in a stove.
- Iron hand warmer: iron reacts with oxygen from the air; the pouch warms for hours.
- Calcium chloride pellets dissolving in water: the water gets hot fast (not a reaction, but exothermic).
- Exo- means out; -thermic means heat. Exothermic: energy goes out.

CHECK FOR UNDERSTANDING

Quick check: what shows energy leaving the system?

A student drops a pellet into water in a cup. Which observation is evidence that energy is leaving the system?

A. The pellet disappears into the water

B. The outside of the cup becomes warm to the touch

C. Bubbles rise through the water

D. The water level rises slightly



Endothermic: the system takes in more than it gives out

- Net flow is into the system; the surroundings lose energy and usually cool down.
- Instant cold pack: ammonium chloride dissolves in water and absorbs energy from your hand.
- Citric acid + baking soda in water: fizzes and gets cold at the same time.
- Photosynthesis: leaves absorb light energy to build sugar; endothermic, powered by light.
- Endo- means in. Endothermic: energy goes in.



Two directions, one rule: compare energy in with energy out

MODEL

Model: Exothermic versus endothermic

Exothermic	Endothermic
Net energy flows out of the system	Net energy flows into the system
Surroundings warm up, or receive light and sound	Surroundings cool down, or supply light
Energy released by forming new bonds is greater than energy needed to break old ones	Energy needed to break old bonds is greater than energy released by forming new ones
Examples: burning, iron hand warmer, calcium chloride in water	Examples: instant cold pack, citric acid with baking soda, photosynthesis

The only test that always works: measure the surroundings. Warmer means out; cooler means in.





Think, pair, share

Discuss: does cold flow into your hand?

- Claim A: cold moves from the pack into the hand.
- Claim B: thermal energy moves from the hand into the pack.
- Think: which direction does energy move on its own between warm and cool objects?
- Think: the pack's water got cold first. What did the dissolving salt do to it?

When you hold an instant cold pack, your hand feels cold. Is something flowing from the pack into your hand, or from your hand into the pack? What evidence would settle it?

The two names, and the number that decides between them

exothermic reaction: A reaction that gives out more energy than it takes in; net flow out of the system. *Iron reacting with oxygen in a hand warmer keeps a pocket warm for hours.*

endothermic reaction: A reaction that takes in more energy than it gives out; net flow into the system. *Citric acid reacting with baking soda in water makes the cup cold to the touch.*

net energy transfer: The overall direction and size of the flow after adding up all energy in and all energy out. *A match takes a little energy to start and releases much more, so its net transfer is outward.*

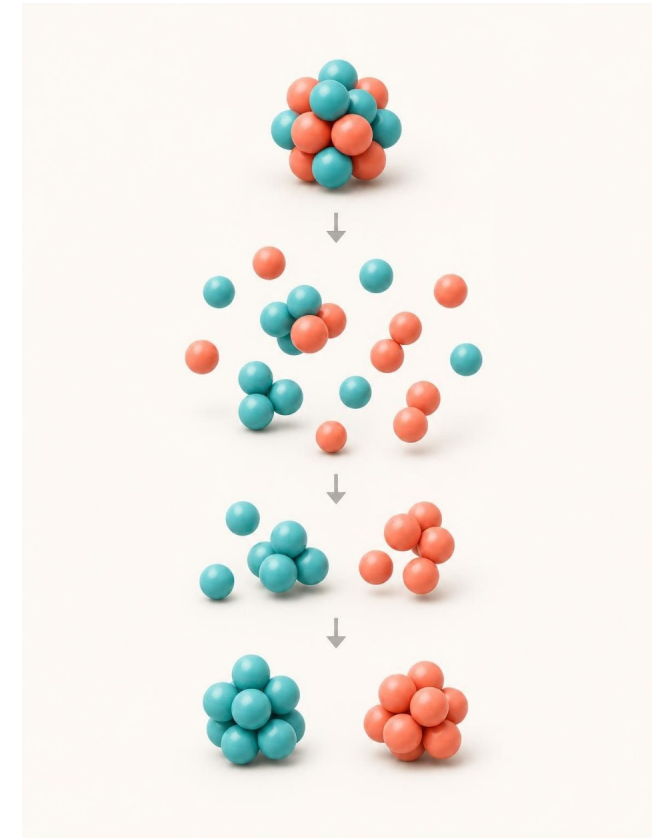


Bonds: pay in to break, get paid to form

Model: Where the energy of a reaction comes from

- 1 Reactants: atoms held by old bonds → (always costs energy)
- 2 Energy goes IN to break old bonds → (same atoms, new partners)
- 3 Atoms regroup → (always releases energy)
- 4 Energy comes OUT as new bonds form → (bigger OUT: exothermic; bigger IN: endothermic)
- 5 Compare the two amounts

Breaking a bond never gives out energy. The net result depends on which total is larger.





Nothing is created or lost: energy is moved and stored

- An exothermic reaction releases energy that was stored in how the reactants' atoms were arranged.
- An endothermic reaction stores the energy it absorbs in how the products' atoms are arranged.
- Burning sugar releases energy; photosynthesis stored it there using light (Lessons 4 and 5).
- A used pack cools to room temperature because its energy spread into the room, not because it vanished.
- Track it like money: it changes accounts, but the total stays the same.

CHECK FOR UNDERSTANDING

Quick check: needs a spark, then burns on its own

A camp stove needs a spark to light. Once lit, it burns for hours and warms the pot above it. Is the burning exothermic or endothermic, and what is the evidence?

A. Endothermic, because it needed a spark to start

B. Exothermic, because the surroundings (the pot) gain energy for hours

C. Endothermic, because gas is used up

D. Neither, because the spark and the heat cancel out



Showing energy in the equation

Energy is not matter, so it has no atoms to count. Chemists still write it into the equation to show which way it flows. Energy that flows IN is written with the reactants; energy that flows OUT is written with the products.

Hand warmer (exothermic): $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + \text{energy}$

Cold pack (endothermic): $\text{NH}_4\text{Cl} + \text{energy} \rightarrow \text{NH}_4^+(\text{aq}) + \text{Cl}^-(\text{aq})$

- Adding the word energy never changes the atom count on either side.
- The iron equation is a simplified model; real pouches hold other helpers too.



CHECK FOR UNDERSTANDING

Quick check: where does the energy term go?

Citric acid and baking soda react in water. The thermometer drops from 22 °C to 14 °C. Where does the word 'energy' belong in the equation for this reaction?

A. With the reactants, because the system absorbed energy

B. With the products, because the reaction made gas

C. On both sides, because energy is conserved

D. Nowhere, because dissolving is not a reaction



A large wildfire is burning on a hillside, with a dirt road in the foreground. The fire is intense, with bright orange and yellow flames rising from the brush. Thick, dark smoke billows from the fire, filling the sky. The background shows rolling hills under a hazy, orange-tinted sky.

REAL-WORLD CONNECTION

California connection: why a wildfire keeps itself going

Every autumn, Cal Fire crews face burning brush in the Sierra foothills and the Santa Ana wind country of Southern California. Burning is strongly exothermic: energy released by one patch of burning plants heats the plants beside it until they react. The reaction supplies the start-up energy for the next patch, so a fire spreads by itself. Fuel breaks remove the reactants: no fuel ahead of the flames, no reaction.



Engineering a hand warmer: criteria, constraints, prototype

- Criteria (goals): reach about 45 °C and stay warm for several hours.
- Constraints (limits): safe to hold (never above 50 °C), cheap, light, no flame.
- Prototype: a working test version. The lesson's team sealed iron powder away from air, then opened it.
- Test 1 measured temperature: their first pouch reached only a few degrees above room temperature.
- Test 2 measured time: the hotter pouch was back at room temperature in under an hour.

MODEL

The design cycle the hand-warmer team followed

Model: Build, test, read, change

1. Define criteria and constraints → (amount of reagent, pouch material)
2. Build a prototype → (probe thermometer, timer)
3. Test: record temperature over time → (too cool? too short? too hot?)
4. Compare the data with the criteria → (more iron, slower air, more insulation)
5. Change one feature → (same test, same conditions)
6. Retest the new prototype → (repeat until criteria are met within constraints) (back to the start)

Each loop produces data; the data, not a guess, decides the next change.



Task: read the data, choose the next change

Simulated data for practice.

A team wants a hand warmer that holds at least 42 °C for 3 hours and never passes 50 °C. Room temperature was 23 °C. Using the test data, what single change should they make for trial 4, and why?

Trial	Iron (g)	Pouch	Peak temp (°C)	Time above 42 °C	Time above 35 °C
1	15	thin cotton	33	0 min	0 min
2	30	thin cotton	46	50 min	95 min
3	30	thick felt	39	0 min	4 h 10 min





THINK, PAIR, SHARE

Discuss: why change only one thing at a time?

- If two things change and the result improves, which change deserves the credit?
- If two things change and the result gets worse, did both hurt, or did one help and one hurt more?
- Testing costs time and money. Is there a case for changing two things anyway?
- How does this connect to controlled variables in a science investigation?

Changing two features at once would reach a good design faster, if it worked. Why do engineers usually resist that, and when might they break the rule?

CHECK FOR UNDERSTANDING

Quick check: criterion or constraint?

Drops at least 8 °C within 2 minutes.

Costs no more than \$1.50 in materials.

Stays at least 4 °C below start after 10 minutes.

Must be vented so gas can escape; no sealed bags.

Uses no more than 12 g of reagent mix.

For a classroom cold pack: sort each item as a criterion (a goal to hit) or a constraint (a limit you must not cross).





MISCONCEPTION CHECK

True or false? Breaking bonds releases energy

"Burning releases energy because the bonds in the fuel are broken, and energy was stored inside those bonds."

True or false? Explain your reasoning.

Putting it together

Draw the boundary: system inside, surroundings outside.
Measure the surroundings to read the direction.

Exothermic: net energy out; the surroundings warm, light up or hear it. Endothermic: net energy in.

Breaking bonds costs energy; forming bonds pays it back. The bigger total decides the direction.

Energy in goes with the reactants; energy out goes with the products. It never changes the atom count.

Engineers test prototypes by amount, time and temperature, change one feature, and loop.





EXIT TICKET

Exit ticket

- A cup gets cold when two powders dissolve in it. Which way did energy flow, and what is the system?
- Write the energy term into this equation on the correct side: $A + B \rightarrow C$, where the surroundings warmed up.
- Name one criterion and one constraint from your Lab 2 pack and label which is which.
- Finish the sentence: breaking bonds ____ energy; forming bonds ____ energy.