Endothermic against exothermic reactions: the table, the diagrams and 40 examples

Exothermic: energy out to the surroundings, temperature rises, products lower in energy than reactants, delta H negative. Endothermic: energy in from the surroundings, temperature falls, products higher, delta H positive. The thermometer measures the surroundings, not the chemicals.

	Exothermic	Endothermic
Energy	released to surroundings	absorbed from surroundings
Temperature of surroundings	rises	falls
Products against reactants	lower energy	higher energy
Delta H	negative	positive
Bond energies	made > broken	broken > made
Diagram	reactants above products, arrow down	reactants below products, arrow up
Everyday sign	hot, light, glow	cold, needs heating or light

The energy level diagram: three labels

[ ] Reactants (left) and products (right) at their energy levels
[ ] Activation energy E a: the hump both kinds of reaction must climb to start (a match must be struck even though burning is exothermic)
[ ] Delta H: the vertical gap between the reactants' level and the products' level; down = exothermic, up = endothermic
[ ] A catalyst lowers the hump only; the levels and delta H do not move

20 exothermic

Burning fuels; respiration; neutralisation (acid + alkali); rusting; hand warmers (iron oxidising); self-heating cans (CaO + water); setting cement; thermite; adding concentrated sulfuric acid to water; dissolving NaOH or CaCl2; sodium in water; explosions and airbags; glow sticks; condensation of steam; freezing of water; compost heaps; fermentation; setting epoxy; catalytic converters; quicklime + water.

20 endothermic

Photosynthesis; thermal decomposition of CaCO3 (lime kiln) and of CuCO3; instant cold packs (NH4NO3 dissolving); dissolving NH4Cl or KCl; citric acid + sodium hydrogencarbonate (sherbet); baking; cooking an egg; melting ice; evaporating sweat; electrolysis of water; charging a battery; cracking hydrocarbons; decomposing ammonia; N2 + O2 to NO in lightning; steam reforming of methane; making ozone; dissolving sugar; Ba(OH)2 + NH4Cl (freezes the board); any reaction that stops when the heating stops.

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Deciding which is which, the mistakes, and a practice set

Two ways to decide

[ ] Thermometer: temperature before and after, in a polystyrene cup with a lid. Up = exothermic; down = endothermic

[ ] Bond energies: delta H = (energy to break every bond in the reactants) - (energy released making every bond in the products). Negative = exothermic

Bond	kJ/mol	Bond	kJ/mol	Bond	kJ/mol	Bond	kJ/mol
H-H	436	O=O	498	O-H	464	C-H	413
C-C	347	C=C	614	C-O	358	C=O	805
N≡N	945	N-H	391	N=O	607	Cl-Cl	243
H-Cl	432	C-Cl	346	N-N	158	C≡C	839

Worked: 2H2 + O2 -> 2H2O. Break 2 H-H (872) + 1 O=O (498) = 1,370 in. Make 4 O-H (1,856) out. Delta H = 1,370 - 1,856 = -486 kJ: exothermic. Worked: N2 + O2 -> 2NO. Break 945 + 498 = 1,443; make 2 x 607 = 1,214; delta H = +229 kJ: endothermic. (Average bond energies as on GCSE data sheets.)

Mistakes that cost marks

[ ] Saying an exothermic reaction 'has more energy' (the surroundings gain it; the chemicals lose it)

[ ] Products drawn above reactants on the exothermic diagram; no activation hump on one of the diagrams

[ ] Catalyst changing delta H (it lowers the hump only)

[ ] Bond-energy subtraction backwards (broken minus made)

[ ] Respiration called endothermic; 'needs heating to start' called endothermic (the test is the overall change)

Practice

1. Two solutions are mixed and the temperature drops from 21 to 14 °C. Endothermic or exothermic? Where did the energy go?
2. Sketch the energy level diagram for question 1 with reactants, products, E a and delta H labelled.
3. Classify: rusting, photosynthesis, a cold pack, a glow stick, melting butter, neutralisation.
4. CH4 + 2O2 -> CO2 + 2H2O. Use the table to find delta H and classify the reaction.
5. A catalyst is added to an exothermic reaction. What changes on the diagram and what does not?
6. Why must a match be struck if burning releases energy?

Answers

1. Endothermic; energy moved from the solution (surroundings) into the chemicals. 2. Products above reactants, hump between, delta H arrow up. 3. Exo, endo, endo, exo, endo, exo. 4. Break 4 C-H (1,652) + 2 O=O (996) = 2,648; make 2 C=O (1,610) + 4 O-H (1,856) = 3,466; delta H = -818 kJ, exothermic. 5. The hump (E a) is lower; the reactant and product levels and delta H are unchanged. 6. The activation energy must be supplied first; the reaction then releases more than it took.