

King of Dumbs

Level: ♦ Intermediate

Why doesn't diamond turn into graphite?

Breaking bonds costs energy and making them pays it back, but almost no reaction starts without climbing a hill. Why diamond lasts and water works as a battery.

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<https://kingofdumbs.com/en/lessons/chemical-reactions-energy>

What you'll learn

- Why some reactions give off heat and others take it in: the energy in bonds
- Activation energy: the hill to climb before reacting
- Stable isn't the same as fast: why diamond lasts
- Oxidation and reduction: splitting water and burning it is charging and draining a battery

Before this lesson

If something sounds like gibberish, these lessons explain it from scratch:

1. [What is a wall made of? Atoms and elements without fear](#)
2. [Joules, watts or calories? Energy and power without fear](#)

Symbols you'll meet

Δ change: how much it moved (♠) · E_a subscript: the label underneath (♦♠) · H° ° for standard, not degrees (♠) · Σ sum: add them all up (♠) · $\approx$ approximately equal (♠) · $|x|$ absolute value: drop the sign (♠) · · dot: multiply (or dot product) (♠) · $\rightarrow$ arrow: turns into / tends to (♦♠) · J/(mol·K) compound units (♦♠) · e the number e (≈ 2.718) (♠) · log logarithm: how many times do I multiply? (♠) · ν nu: coefficient or neutrino (♠)

A diamond ring can pass from grandmother to granddaughter for centuries and stay the same. But a chemist would tell you that diamond “should” turn into graphite, the stuff in a pencil, because graphite is more stable. And it doesn’t.

This lesson’s dumb question is: **why doesn’t diamond turn into graphite?** The answer is the same one that explains why the gas on your stove doesn’t catch fire by itself, why food keeps longer in the fridge and why hydrogen stores energy like a battery. Every reaction has a bill, the energy it gives off or asks for, and a hill to climb before it starts.

Pick your card: ♣ if you’re starting from zero, ♦ if a simple formula doesn’t scare you, ♠ if you want the notation. You can switch at any time.

Breaking costs, joining pays

break 2 H–H and 1 O=O: costs



form 4 O–H: gives back



486 kJ left over: heat

≈ 243 kJ per mole of water (measured: 242)

A **bond** is the link between two atoms in a molecule. Its **bond energy** is what it costs to break a mole of those bonds (OpenStax). Some average values:

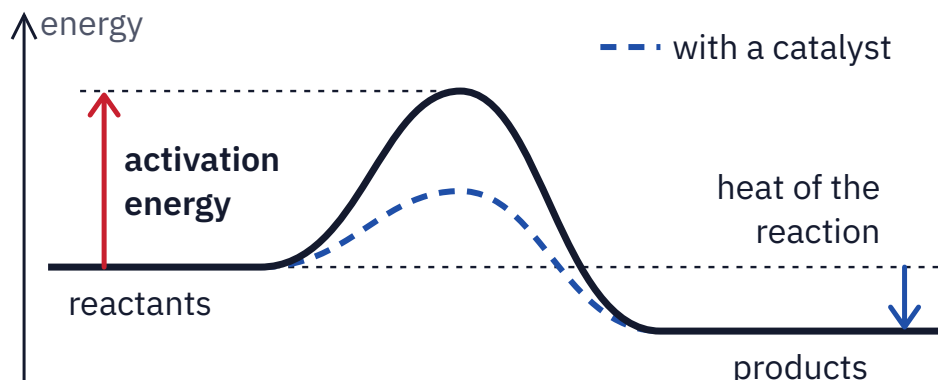
Bond	Bond energy
H–H (hydrogen)	436 kJ/mol
O=O (oxygen)	498 kJ/mol
O–H (water)	464 kJ/mol

Hydrogen and oxygen make water vapour: $2 \text{ H}_2 + \text{O}_2 \rightarrow 2 \text{ H}_2\text{O}$. Two H–H and one O=O are broken, which costs $2 \times 436 + 498 = 1370$ kJ. Four O–H are formed, which give back $4 \times 464 = 1856$ kJ. **486 kJ is left over**, about 243 per mole of water. Measured: 242 kJ (OpenStax; NIST-JANAF gives 241.8).

When energy is left over and comes out as heat, the reaction is **exothermic**. When you have to put it in, it's **endothermic**. That energy left over or missing is called **the heat of the reaction**.

Bond energies are **averages** over many molecules, so the sum comes out approximate. For the exact figure, tables give **the energy of forming each substance from its elements**, and with them you can do the sum without bonds.

The hill: why almost nothing starts by itself



For two molecules to react, they have to collide with enough energy to start breaking their bonds. That minimum energy is the **activation energy** (OpenStax). In an **energy profile** it's the height of the hill: you start from the reactants, climb to the top and go down to the products. The drop between start and finish is the heat of the reaction, from the previous block. The hill says something else: not how much you gain, but how much it costs to get going.

The energy differs from collision to collision: almost all are weak and a few are very strong. **The share of collisions that reaches the top** drops enormously if the hill is higher and **rises enormously with temperature**. With a 50 kJ/mol hill, which is just an example value:

- at 25 °C, roughly 1 in 575 million collisions reaches the top;
- in the fridge, at 4 °C, the reaction runs **4.6 times slower**;
- at 35 °C, **1.9 times faster**.

These are our own calculations. That's where the "every 10 degrees, twice as fast" rule comes from, and it only holds for hills about that size: with a 100 kJ/mol hill, the same 10 degrees multiply by 3.7.

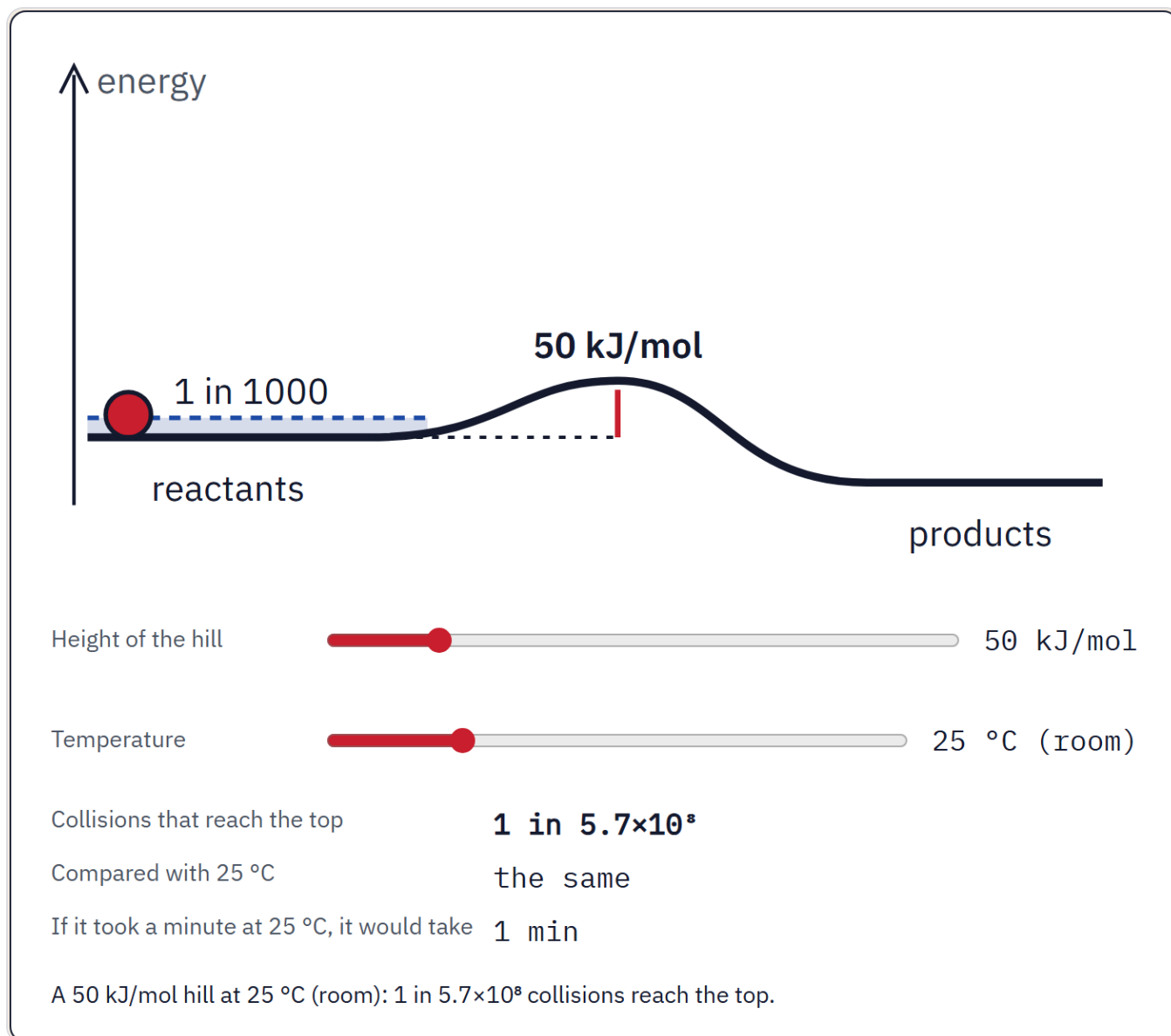
A **catalyst** opens another path with a lower hill. The reaction runs faster, and the start and finish don't change (OpenStax). Car catalytic converters and the body's enzymes do this.

The King of Dumbs says:

It's not enough for a reaction to be worth it: first you have to climb the hill. That's why paper doesn't burst into flames on the shelf.

Try it: climb the hill

Move the height of the hill and the temperature. The blue band marks how high 1 in 1000 collisions gets: when it's over the top, the reaction runs fast. Try 190 kJ/mol, close to the hill measured in diamond powder, and turn up the temperature: even at 1,500 °C the band doesn't get there, but look how much faster it goes.



Interactive widget. Try it on the web: <https://kingofdumbs.com/en/lessons/chemical-reactions-energy>

Diamond: stable isn't the same as fast

what is gained

| 2.9 kJ/mol

the hill in diamond powder

 188 kJ/mol

the hill on one face of a diamond

 728 kJ/mol

in vacuum it turns to graphite at 1,500–1,800 °C

with nickel: 500 °C as a film, 800 °C as a crystal

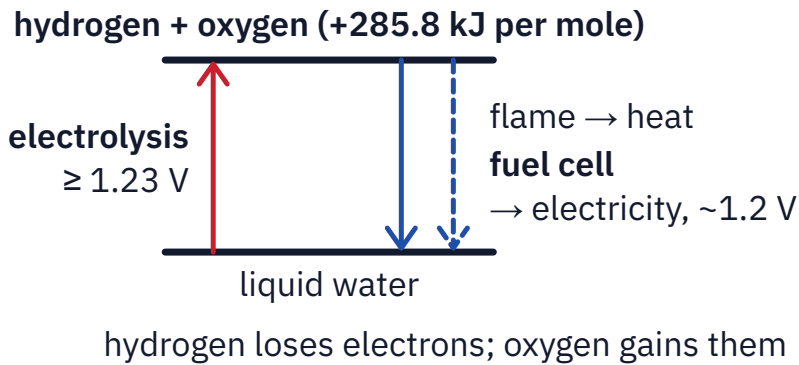
To know whether a reaction **can** go by itself, heat isn't enough. Chemists use the **Gibbs energy**, which combines heat and **disorder**. If the Gibbs energy goes down, the reaction can go by itself. From diamond to graphite, at 25 °C, it **goes down by 2.9 kJ/mol** (OpenStax; UW–Madison). That's very little, and **the heat it gives off** is even less: 1.9 kJ for every 12 grams of carbon, which would warm a glass of water by less than 2 °C (our own calculation).

But being able to doesn't mean it happens. OpenStax puts it this way: «The spontaneity of a process is not correlated to the speed of the process». To rearrange the carbon, each atom has to break loose from the diamond, and that takes a huge amount of energy.

The hill has been measured: 188 kJ/mol in **a powder of tiny diamonds** (Butenko and others, 2000) and about 730 kJ/mol on **one face** of a natural diamond (Davies and Evans, 1972). Each figure comes from a single study. With the 188 one, at 1,600 °C **the boundary between diamond and graphite moves** 1.5 nanometres per hour. At 25 °C it would take more than 10^{20} years to move one (our own calculation, stretching their formula far beyond what they measured). The universe is about 10^{10} years old.

Diamond is **thermodynamically unstable but kinetically stable**: it's said to be **metastable** (OpenStax). And catalysts work here too: with a layer of nickel, a film of tiny diamonds starts turning into graphite at around 500 °C, and the surface of a diamond crystal above 800 °C (Sedelnikova and others, 2025, who gather it from other studies).

Oxidising and reducing: water as a battery



In chemistry, **oxidation** is losing electrons and **reduction** is gaining them (OpenStax). They always go together, because the electrons one loses, another gains. When hydrogen burns, the hydrogen is oxidised and the oxygen is reduced.

Splitting water with electricity is called **electrolysis**: $2 \text{H}_2\text{O} \rightarrow 2 \text{H}_2 + \text{O}_2$, combustion in reverse. You need **at least 1.23 volts** across the two electrodes (OpenStax). The energy is the one from block 1, but with liquid water: **285.8 kJ per mole** (NIST-JANAF; OpenStax). At 1.23 volts, about 237 kJ of that goes in as electricity and **the rest as heat from the surroundings**. A litre of water is 55.5 moles: 15.9 MJ, or 4.4 kWh (our own calculation).

Burning the hydrogen gives that energy back, as heat. A **fuel cell** runs the same reaction without a flame and gives electricity, at about 1.2 volts. Its **efficiency** is about 50–75 %, against 20–25 % for an engine (OpenStax).

The King of Dumbs says:

Hydrogen isn't an energy mine: it's a battery. What you get out by burning it, you put in before by splitting the water.



Final challenge

1. The gas on your stove and the oxygen in the air sit together and don't burn until you light the burner. Why?

- a. Because burning gas doesn't give off energy
- b. Because first there's a hill to climb: it needs a push, like a spark
- c. Because the gas has no energy until it's heated

2. Graphite is more stable than diamond. Why doesn't a diamond ring turn into graphite?

- a. Because diamond is actually the most stable
- b. Because the hill between them is huge and at room temperature almost no atom gets across
- c. Because diamond and graphite are different elements

3. You split water with electricity and then burn the hydrogen that comes out. How much energy do you get?

- a. More than you spent: hydrogen is a source of energy
- b. At most what you spent: the water works as a battery
- c. None, because water doesn't burn



In three sentences

- 1. A reaction breaks bonds, which costs energy, and makes others, which give it back: if there's some left over it comes out as heat (exothermic), and if there's some missing you have to put it in (endothermic).
- 2. Almost no reaction starts by itself, because first there's a hill to climb, the activation energy: heat and catalysts help get over it.

3. That's why diamond lasts even though graphite is more stable, and why splitting water and burning the hydrogen is charging and draining a battery, never gaining energy.



Sources

- Bond energy and estimating ΔH : OpenStax, *Chemistry 2e*, [7.5](#). Enthalpy, exothermic and endothermic, Hess's law and enthalpies of formation: [5.3](#) and [appendix G](#). NIST-JANAF tables at 298.15 K: [H](#), [O](#), [water vapour](#) and [liquid water](#).
- Temperature and speed (the fridge): [OpenStax, 12.2](#). Activation energy and Arrhenius: [12.5](#). Catalysts: [12.7](#). Gas constant and Faraday constant (CODATA 2022): NIST, [R](#) and [F](#).
- Spontaneity and Gibbs energy: OpenStax, [16.1](#) and [16.4](#). Metastable diamond: [UW–Madison, Chem 109, D26.1](#).
- Diamond kinetics: G. Davies and T. Evans, *Proc. R. Soc. Lond. A* 328, 413 (1972), [doi:10.1098/rspa.1972.0086](#); Yu. V. Butenko and others, *J. Appl. Phys.* 88, 4380 (2000), [doi:10.1063/1.1289791](#); O. V. Sedelnikova and others, *Beilstein J. Nanotechnol.* 16, 887 (2025), [doi:10.3762/bjnano.16.67](#).
- Oxidation and reduction: [OpenStax, 4.2](#). Electrolysis of water: [17.7](#). Fuel cells: [17.5](#).

How this lesson was made: researched and written with help from Claude from the sources above, checked and cross-checked against a second source on 16 October 2026 and reviewed again on 17 October 2026. Figures without their own link are calculations from them and from the atoms and energy lessons. The drawings are our own.

Answers

1. **b)** Because first there's a hill to climb: it needs a push, like a spark. That's it. First the push; after that the flame pushes itself.
2. **b)** Because the hill between them is huge and at room temperature almost no atom gets across. Right. Stable isn't the same as fast.
3. **b)** At most what you spent: the water works as a battery. Exactly. Climbing the slope costs what going down gives back.

A King of Dumbs lesson, kingofdumbs.com. Offline version; the original, with widgets you can play with, is at: <https://kingofdumbs.com/en/lessons/chemical-reactions-energy>

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