

King of Dumbs

Level: ♦ Intermediate

Can you make something from nothing? Conservation, no fear

Mass, energy and charge are never created or destroyed: they change form.

Lavoisier, a slide, a balloon and $E = mc^2$, with two widgets, in three levels.

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Scan to open the interactive lesson

<https://kingofdumbs.com/en/lessons/conservation-laws>

What you'll learn

- Conservation of mass and atoms (Lavoisier)
- Conservation of energy
- Conservation of charge and of the number of protons and neutrons
- $E = mc^2$: mass is energy too

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 (♠) · x_i index i: item number i (♠) · $\bar{x}$ bar on top: the average (♠) · $\cdot$ dot: multiply (or dot product) (♦♠) · $\rightarrow$ arrow: turns into / tends to (♦♠) · 10^{-3} negative exponent: divide (♦♠) · J/(mol·K) compound units (♠) · ν nu: coefficient or neutrino (♠) · τ tau: a characteristic time (♠) · π pi: 3.14159... (or a pion) (♠) · γ gamma: a photon (♠)

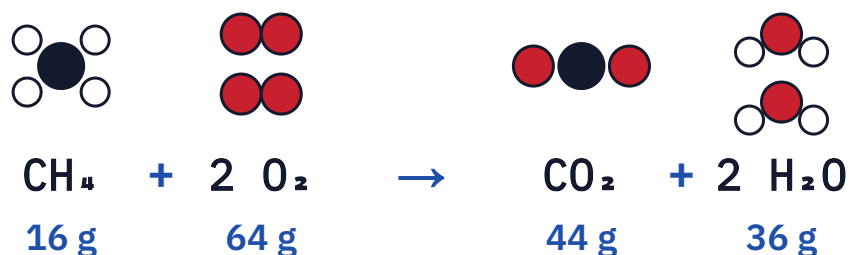
Throw a log on the fire. An hour later there's a handful of ash that weighs far less than the log. Where did the rest go? Did it turn into nothing?

The dumb question of this lesson is: **can you make something from nothing?** Or the other way round: can you make something vanish completely? The short answer is no. The universe keeps a few accounts that never fail. Things change shape, place or look, but the accounts always add up.

This lesson teaches four of those accounts: atoms, energy, electric charge, and the one that links mass and energy, the famous $E = mc^2$.

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

Nothing is lost: mass

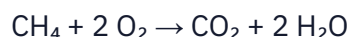


1 C, 4 H and 4 O on each side: 80 g = 80 g

In 1789, Antoine Lavoisier wrote it down in his *Elementary Treatise of Chemistry*, while studying how grape juice turns into wine:

“Nothing is created, either in the operations of art or in those of nature, and it can be taken as a principle that in every operation there is an equal quantity of matter before and after” (our translation).

This is the **law of conservation of mass**. Lavoisier even wrote a kind of equation: grape juice = carbonic gas + alcohol. Today we write it with formulas. Kitchen gas, methane, burns like this:



The **number in front of each substance** says how many molecules go in or come out. It’s chosen so that there are **the same atoms of each element on each side**: that’s called *balancing* the reaction. Here there are 1 carbon, 4 hydrogens and 4 oxygens before and after.

If each number is a mole, the mass comes from adding up the **mass of one mole** of each substance (atoms lesson): 16 g of methane and 64 g of oxygen give 44 g of CO₂ and 36 g of water. That’s 80 g before and 80 g after.

The catch is where you measure. The law holds in a **closed system**, where nothing gets in or out. In an open fireplace, oxygen comes in from the air and the gases leave, which is why the ash weighs so little.

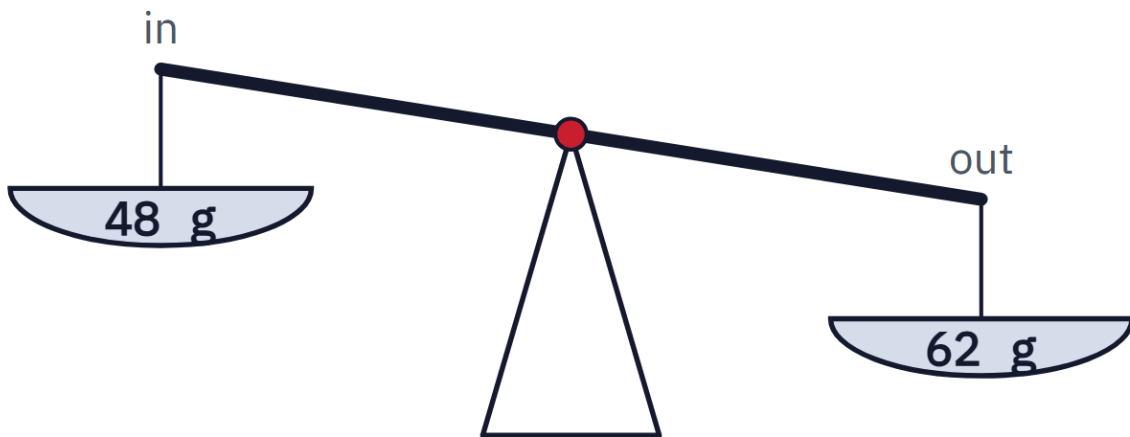
The King of Dumbs says:

The ash is light because the rest went up the chimney. Nothing vanishes: it goes somewhere else.



Try it: balance the recipe

Put a number in front of each substance until the same atoms of each element come out on each side. Watch the scale: when the atoms balance, so does the mass. Start with kitchen gas, then try rusting iron.



Recipe

- ☒ Burn kitchen gas
- ☐ Make water from hydrogen
- ☐ Rust iron
- ☐ Ferment grape juice (Lavoisier)



Atoms of each element

	in	out	
C	1	1	✓
H	4	2	✗
O	2	3	✗

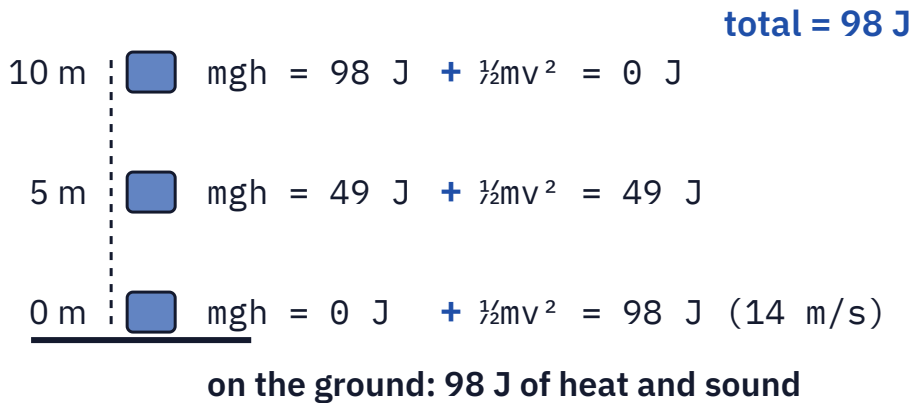
Each number is a mole; mass is in grams.

It doesn't balance: H (4 → 2), O (2 → 3).



Interactive widget. Try it on the web: <https://kingofdumbs.com/en/lessons/conservation-laws>

Energy changes form, but it isn't used up



The **law of conservation of energy** says the total energy is constant in any process: it can change form or pass from one system to another, but the total doesn't change (OpenStax, *College Physics 2e*, 7.6). Some of its forms:

- **Height energy**, or gravitational potential energy: $m \cdot g \cdot h$, mass times gravity ($g = 9.8 \text{ m/s}^2$) times height.
- **Motion energy**, or kinetic energy: $\frac{1}{2} \cdot m \cdot v^2$, with v the speed.
- **Heat**: energy that flows from a hot body to a cold one (energy lesson).
- And chemical, electrical, light...

Example: drop a kilogram from 10 m. At the top it has $1 \times 9.8 \times 10 = 98 \text{ J}$ of height and no motion. Halfway down, 49 J and 49 J. Just before the ground, 98 J of motion: it's going at 14 m/s. When it hits, it stops, and those 98 J are shared out as **heat** and sound.

There's another way to change something's energy: pushing or pulling it, which is called **work**. The energy a body stores inside (the jiggling of its atoms, its bonds) is its **internal energy**. Heating it or doing work on it raises it. That's why **no machine gives out energy without taking it from somewhere**.

Accounts that never fail: charge, protons and neutrons



protons + neutrons

$$14 = 14 + 0 + 0$$

charge

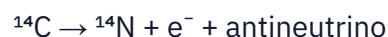
$$+6 = +7 - 1 + 0$$

The element changes; the counts don't

The **law of conservation of charge** says the **total charge** is constant in any process (OpenStax, *College Physics 2e*, 18.1). When two bodies are rubbed together, the charge one gains is the charge the other loses.

In chemistry, conservation of charge means reactions with ions must balance in charge too: if a sodium atom gives up an electron, $\text{Na} \rightarrow \text{Na}^+ + \text{e}^-$, the charge is 0 before and $+1 - 1 = 0$ after.

In a nuclear reaction, the element **can** change. The carbon-14 from the atoms lesson decays by giving off an electron (OpenStax, *Chemistry 2e*, 21.3):



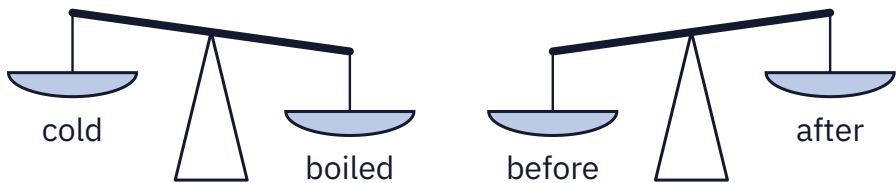
A neutron in the nucleus has turned into a proton: there were 6 protons and now there are 7, so it's nitrogen. But two counts still add up, and they are the rules for balancing any nuclear reaction (OpenStax, 21.2):

- **Protons + neutrons:** 14 before and 14 after. The electron and the **antineutrino**, a particle with no charge and almost no mass, don't count here.
- **Charge:** +6 before; $+7 - 1 = +6$ after.

And what if a proton or an electron just vanished? People have looked for decades and **it has never been seen**: if it happens, an electron takes on average more than 10^{28} years, and the universe is about 10^{10} years old.

$E = mc^2$: mass is energy too

$\Delta m = E / c^2$: real, but tiny



1 L of water: +3.7 ng

80 g of gas and O_2 : -9.9 ng

(difference exaggerated in the drawing)

The formula is $E = mc^2$: the energy carried by a mass m , with c the **speed of light**, exactly 299,792,458 m/s. Since c^2 is enormous, about $9 \times 10^{16} \text{ m}^2/\text{s}^2$, one gram is worth $9 \times 10^{13} \text{ J}$ (OpenStax, *College Physics* 2e, 28.6). That energy of a body at rest is called its **rest energy**.

It works both ways. If a body gains energy, it gains mass; if it gives energy out, it loses mass. The **mass that disappears** is $\Delta m = E / c^2$:

- Boiling 1 L of water puts 334 kJ into it (energy lesson): it weighs 3.7 nanograms more.
- Burning a mole of methane gives out 890 kJ: the 80 g of gas and oxygen lose 9.9 nanograms. One part in 8 billion.

In nuclear reactions the share is big enough to measure. How much of the reacting mass becomes **released energy**:

Process	Share of the mass
Burning methane	1.2×10^{-10}
Fission of uranium-235 (splitting a heavy nucleus)	0.091 %
Fusion of deuterium and tritium (joining two light nuclei)	0.38 %
Matter with antimatter	100 %

And “making something from nothing”: a ray of light with enough energy, passing close to an atomic nucleus, can turn into an electron and a **positron**, its antiparticle, with charge +. That’s an **electron-positron pair**: the total charge is still zero (OpenStax, 18.1). It needs at least the rest energy of the two, 1.022 **MeV** (the electronvolt from the energy lesson, times a million).

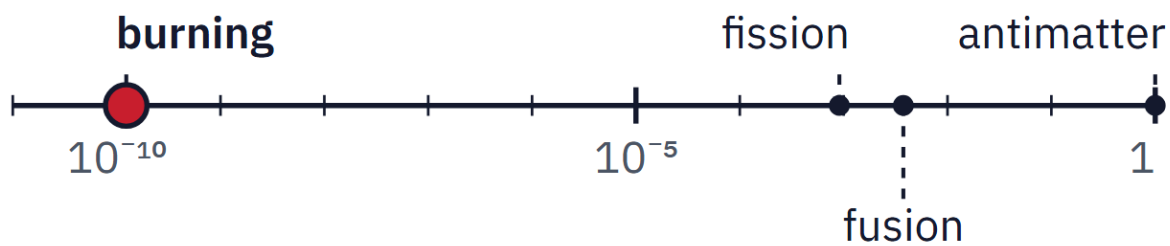
The King of Dumbs says:

You can make matter. But you pay for it in full with energy, and it always comes with its twin of opposite charge.



Try it: how much energy is in mass?

Choose what you do with the mass and how much you use. See how much of it turns into energy and how long that energy would last in a kettle or as food. Try a gram of matter with antimatter.



share of the mass that becomes energy

What you do with the mass

- ☒ Burn it, like gas with its oxygen
- ☐ Split uranium-235 (fission)
- ☐ Fuse deuterium and tritium (fusion)
- ☐ Bring it together with antimatter

Mass that reacts 1 kg

Share of the mass one part in 8.1×10^9

Mass that becomes energy 120 ng

Energy 1.1×10^7 J

2 kW kettle switched on 1.5 h

Food for one person 1.3 days

Of 1 kg, 120 ng turns into energy (one part in 8.1×10^9).



Interactive widget. Try it on the web: <https://kingofdumbs.com/en/lessons/conservation-laws>



Final challenge

1. You burn a log and 200 grams of ash are left. Where's the rest?

- a. It was destroyed by the fire
- b. It went into the air as gases, along with the oxygen it took
- c. It all turned into energy

2. A bike brakes to a stop. What happened to its motion energy?

- a. It disappeared
- b. It turned into heat in the brakes and the wheels
- c. It went back into the rider's legs

3. Can you create an electron?

- a. Yes, from nothing, in a lab
- b. Yes, with enough energy, and it always comes with its positively charged antiparticle
- c. No: matter can never be created



In three sentences

- 1. In a chemical reaction atoms only rearrange: none is created or lost, which is why what goes in weighs the same as what comes out.
- 2. Energy isn't created or destroyed either: it changes form (height, motion, heat...), and "using it up" means turning it into heat that's no longer useful.
- 3. Charge and the number of protons and neutrons always add up too, and mass is very concentrated energy ($E = mc^2$): you can make matter, but only by paying for it in full with energy.

Sources

- Lavoisier, *Traité élémentaire de chimie*, vol. 1 (Paris, Cuchet, 1789), ch. XIII: [Project Gutenberg](#). Cross-check: OpenStax, *Chemistry 2e*, [1.2](#). Balanced equations: [OpenStax, 4.1](#).
- Conservation of energy and the first law: OpenStax, *College Physics 2e*, [7.6](#) and [15.1](#). Symmetries: [Feynman, Lectures on Physics I, ch. 52](#); Noether (1918), [translation on arXiv](#).
- Charge: OpenStax, *College Physics 2e*, [18.1](#). Nuclear reactions: OpenStax, *Chemistry 2e*, [21.2](#) and [21.3](#). Baryon and lepton numbers: [OpenStax, University Physics vol. 3, 11.2](#).
- Experimental limits: [PDG 2024, Tests of conservation laws](#); Borexino, *PRL* 115, 231802 (2015), [doi:10.1103/PhysRevLett.115.231802](#).
- $E = mc^2$: Einstein, *Ann. Phys.* 323, 639 (1905), [doi:10.1002/andp.19053231314](#); [OpenStax, College Physics 2e, 28.6](#). Speed of light and electron mass (CODATA 2022): [c](#) and [\$m_e c^2\$](#) . Pair creation: [HyperPhysics](#) and [NIST XCOM](#).
- Combustion of methane: [NIST WebBook](#) and [OpenStax, Chemistry 2e, 5.3, table 5.2](#). Fission and fusion: OpenStax, *University Physics* vol. 3, [10.5](#) and [10.6](#). Atomic masses: NIST, [hydrogen](#) and [uranium](#).

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 15 October 2026. Numbers without their own link are calculations from them and from the atoms and energy lessons. The drawings are our own.

Answers

1. **b)** It went into the air as gases, along with the oxygen it took. That's it. Atoms don't vanish: they go up the chimney.
2. **b)** It turned into heat in the brakes and the wheels. Good. Energy changes form: here, into heat.
3. **b)** Yes, with enough energy, and it always comes with its positively charged antiparticle. Exactly. You pay in energy and the total charge stays at zero.

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

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