

Atoms, Isotopes & Ions

CHEM 50 · Dr. Karmach

By the end of this unit, you can...

- Locate protons, neutrons, and electrons in the atom and state what each count determines
- Read and write isotope symbols, converting between mass number, atomic number, and particle counts
- Calculate the average atomic mass of an element from isotope masses and abundances
- Give an element's period, group, family, and metal/nonmetal/metalloid class
- Predict the charge an atom takes when it forms an ion, and count the particles in that ion
- Name ionic and molecular compounds and acids, and write formulas from names
- Recognize the common polyatomic ions and build formulas that contain them
- Name a straight-chain alkane from its carbon count, build its C_nH_{2n+2} formula, and recognize the common functional-group families
- Choose the right naming system for any formula (fixed or variable ionic, molecular, acid), rejecting the other systems' names

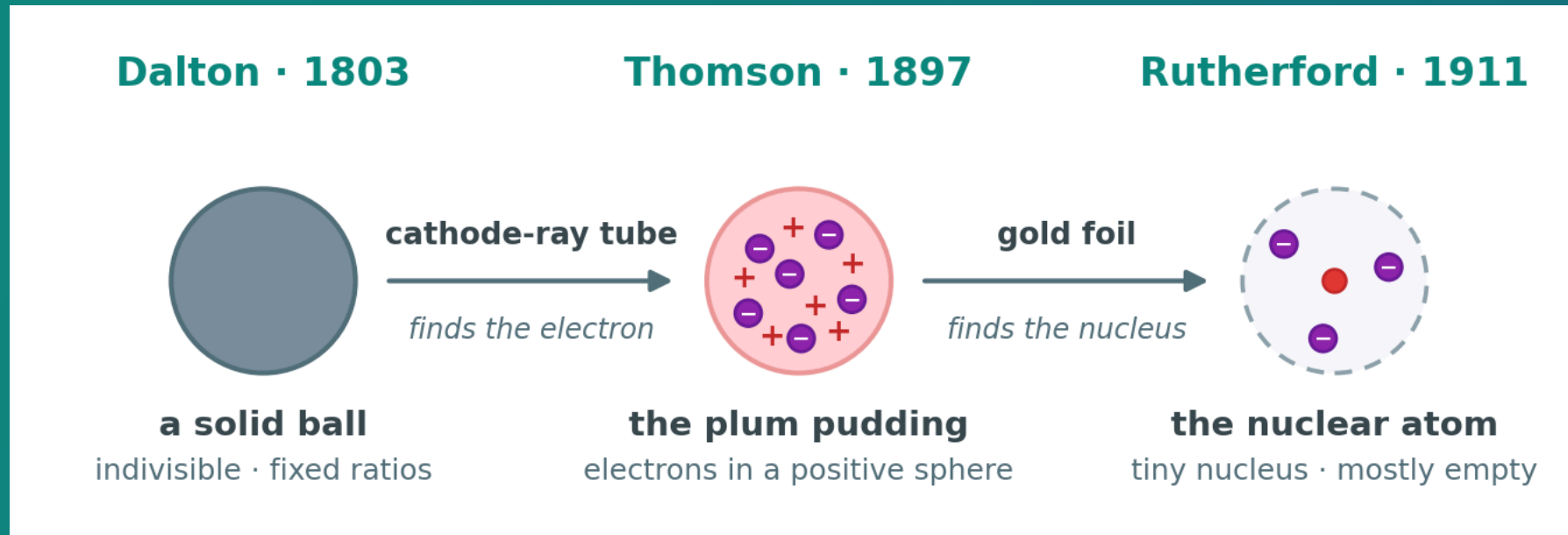
Today's route

1. How We Found the Atom
2. Atomic Structure
3. Isotope Notation
4. Average Atomic Mass
5. Periodic Table Organization
6. Ions
7. Naming Ionic Compounds
8. Polyatomic Ions
9. Naming Molecular Compounds and Acids
10. Organic Nomenclature Basics
11. Choosing the Naming System

1 • How We Found the Atom

Name the two mass laws the balance measured first, trace how the atomic model was redrawn twice, Dalton's atoms to Thomson's electron to Rutherford's nucleus, and state the experiment that forced each redraw.

Nobody has ever seen an atom



Yet you know what one looks like. That picture was redrawn twice in about a century, each time because an experiment said no. Here is the evidence trail.

A model earns its keep

solid ball → plum pudding → nuclear atom
each arrow: one experiment the old picture could not explain

A model is not a guess: it is the simplest picture that explains every experiment. A result the picture cannot explain forces a redraw, and each redraw keeps the parts that still work.

The law of conservation of mass

total mass before a reaction = total mass after

Lavoisier, 1789: reactions run in sealed flasks, weighed before and after

Two measured laws came before any atom. The first is Lavoisier's: weigh everything in, weigh everything out, and the totals match. Matter changes form; it never appears or disappears.



Worked example: heating limestone



given: 15.9 g CaCO_3 heated · 8.3 g CaO remains · wanted: mass of CO_2 released

Heating 15.9 g of limestone leaves 8.3 g of solid calcium oxide; the carbon dioxide escapes into the air. Find the mass of that gas without catching it.

✓ Worked example: solution



given: 15.9 g CaCO_3 · 8.3 g CaO remains · wanted: mass of CO_2

Apply the law

Subtract

$$\text{mass of CO}_2 = 15.9 \text{ g} - 8.3 \text{ g} = 7.6 \text{ g}$$

$$8.3 + 7.6 = 15.9 \checkmark \cdot \text{the totals match}$$

 **Sense check:** The gas escaped unseen, yet its mass is known: conservation turns one subtraction into a measurement. ✓

The law of definite proportions

100 g of water = 11.2 g hydrogen + 88.8 g oxygen

rain, seawater, or lab-made: the same split in every sample

The second law is Proust's: a compound's elements always combine in the same proportions by mass. And when two elements form two compounds, those proportions shift by whole-number steps: multiple proportions.

Dalton: matter comes in atoms

element = one kind of atom · compound = a fixed ratio of atoms

water: 2 H for every 1 O, in every sample ever measured

a reaction rearranges atoms

none created, none destroyed, none split

In 1803 Dalton explained both laws with one idea: matter comes in tiny indivisible pieces, atoms. Indestructible atoms keep mass conserved; atoms combining only in whole numbers keep proportions definite.

Thomson: the atom has parts

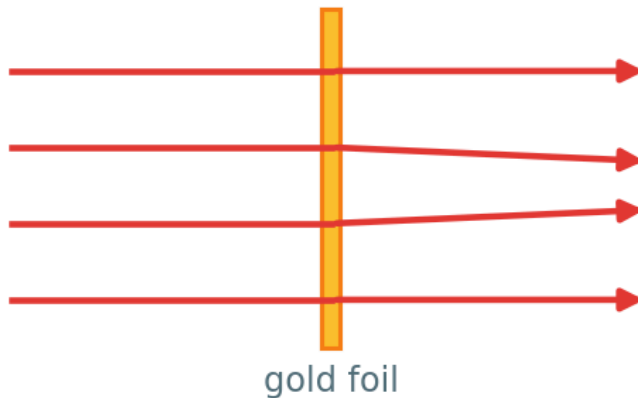
every metal tested → the same negative particle
the electron: about 1,800 times lighter than a hydrogen atom

In 1897 Thomson pulled identical negative particles from every metal he tried: the electron. Atoms have parts. To keep the atom neutral, he dotted the electrons through a diffuse positive sphere: the plum pudding model.

Rutherford: a tiny, dense nucleus

expected: pudding atom

charge spread thin, nothing to bounce off



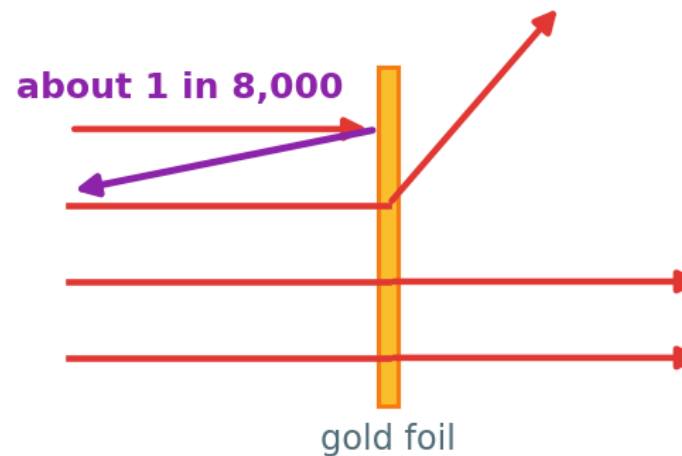
all pass, barely nudged

a nudge of a degree or two at most

alpha particles: small, fast, positive projectiles fired at foil a few thousand atoms thick

observed: 1909

counted flash by flash, all the way around



a few bounce straight back

some deflected past 90°, some nearly 180°

Left: what the pudding atom predicts. Right: what Rutherford's team observed in 1909. A bounce that hard needs a center holding the atom's positive charge and nearly all its mass.

2 · Atomic Structure

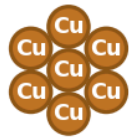
Count the protons, neutrons, and electrons in any neutral atom, and name the element from its proton count.

About 90 kinds of atoms

three objects · each a single element



gold ring
every atom Au



copper wire
every atom Cu

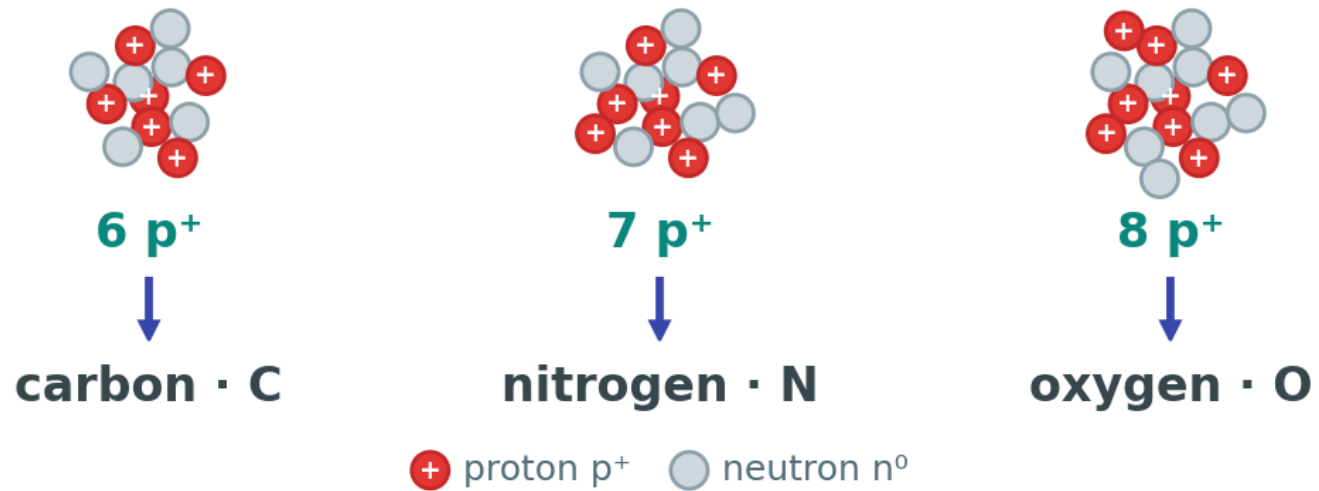


diamond
every atom C

A gold ring, a copper wire, a diamond: each one kind of atom. Nature supplies about 90 of 118 known kinds, the naturally occurring elements; labs make the rest.

Protons name the element

the proton count names the element



An atom with six protons is carbon, every time. Electrons come and go in ordinary chemistry; neutron counts vary among atoms of one element. Change the proton count and the atom is a different element.

Three particles build every atom

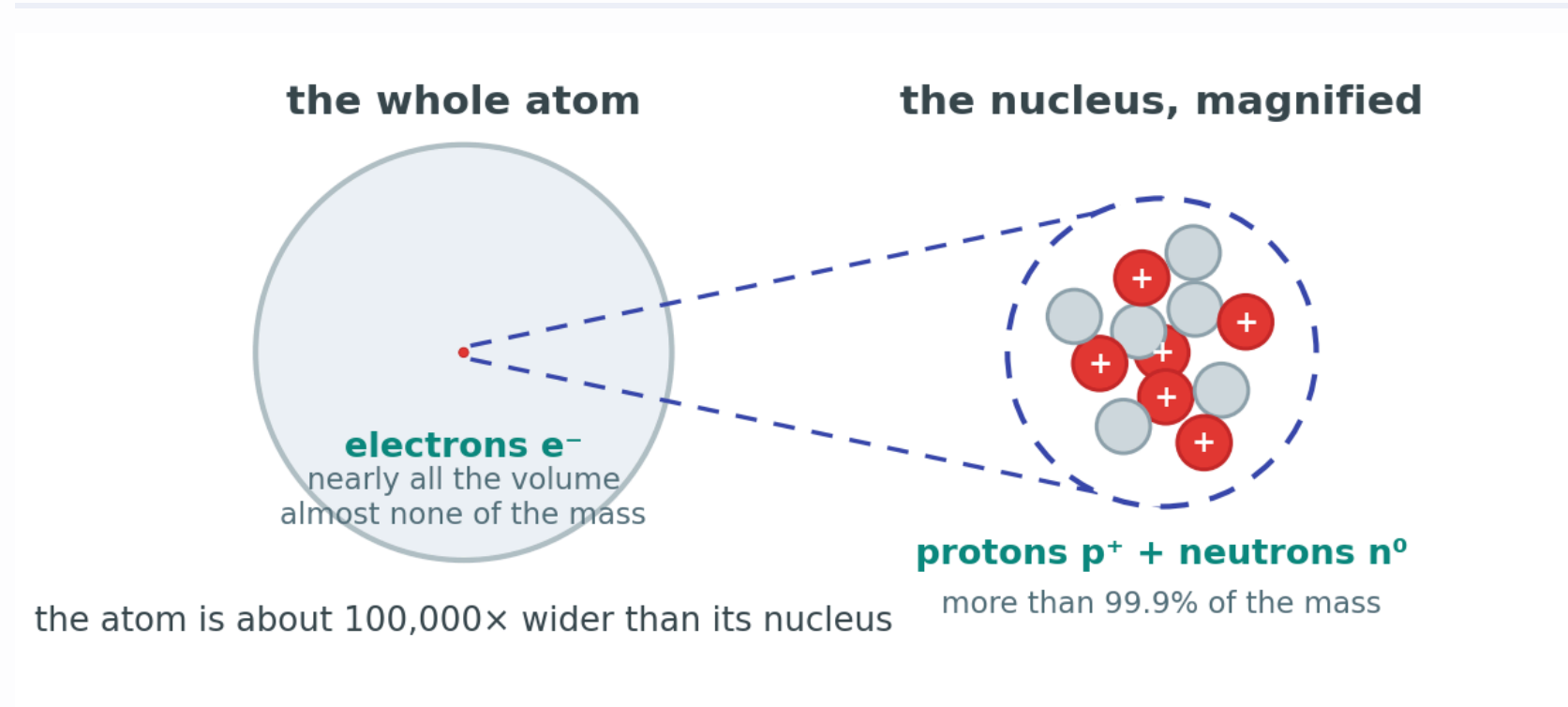
proton p^+ · charge $1+$ · relative mass 1
in the nucleus

neutron n^0 · charge 0 · relative mass ≈ 1
in the nucleus

electron e^- · charge $1-$ · relative mass $\approx 1/1840$
outside the nucleus

The nucleus is the dense center; electrons fill the space around it. The names carry the charges: Proton Positive, Neutron Neutral.

Where the mass sits



Protons and neutrons give the atom nearly all its mass, packed into the tiny nucleus. If the nucleus were a marble, the atom would be a stadium.

Two numbers describe an atom

atomic number Z = protons

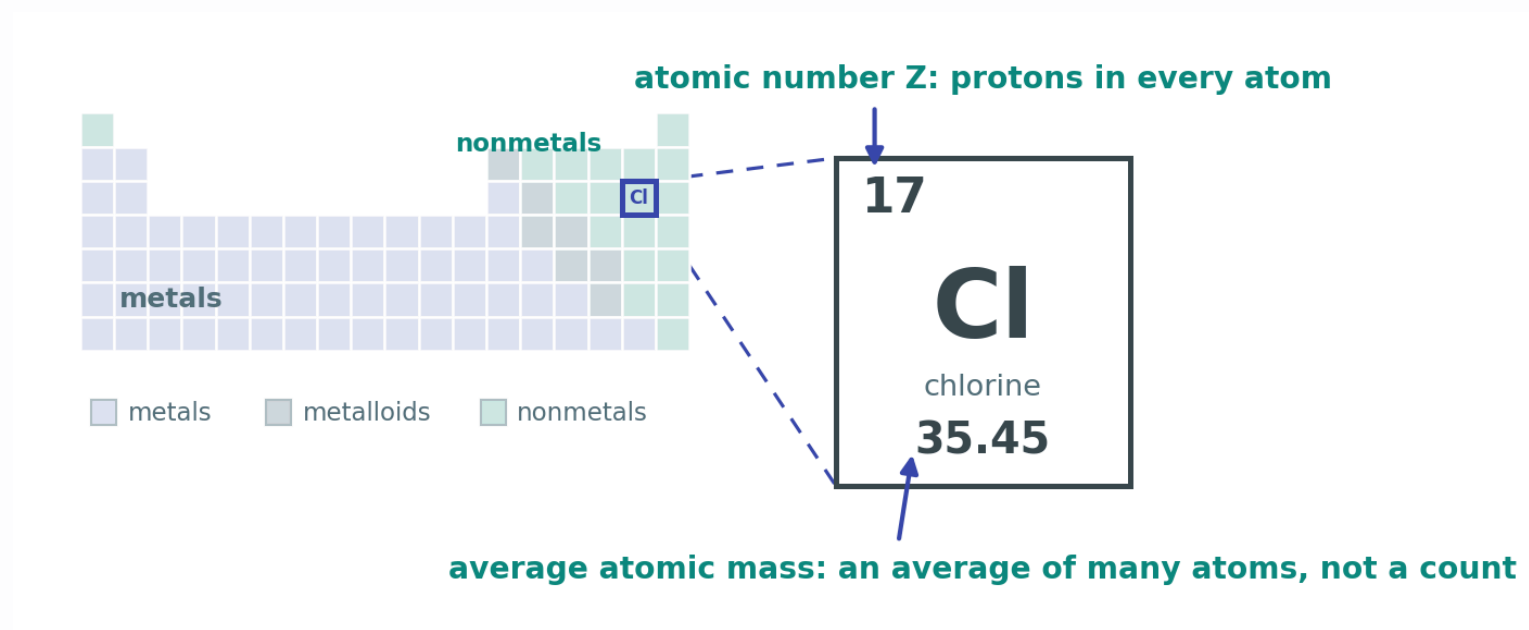
Z names the element: every carbon atom has $Z = 6$

mass number A = protons + neutrons

A counts the particles in the nucleus of one atom

Z is the same for every atom of an element. In a neutral atom, electrons match protons, so the charges cancel.

Reading the periodic table



The table lists the elements in order of Z. A tile carries the atomic number and the average mass of the element's atoms. Metals fill the left and center; nonmetals sit to the upper right.



The method

1. **Match protons and Z.** The atomic number is the proton count; it names the element.
2. **Use $A = \text{protons} + \text{neutrons}$.** Subtract to find whichever count is missing.
3. **Match electrons to protons.** A neutral atom holds equal numbers.



Worked example 1: silicon

silicon: $Z = 14$ · mass number $A = 29$

given: one neutral atom · wanted: protons, neutrons, electrons

A neutral silicon atom has mass number 29. Count its protons, neutrons, and electrons.

✓ Worked example 1: solution

silicon: $Z = 14$ · mass number $A = 29$

given: one neutral atom · wanted: protons, neutrons, electrons

Step 1 · Match protons and Z

Step 2 · Use $A = \text{protons} + \text{neutrons}$

Step 3 · Match electrons to protons

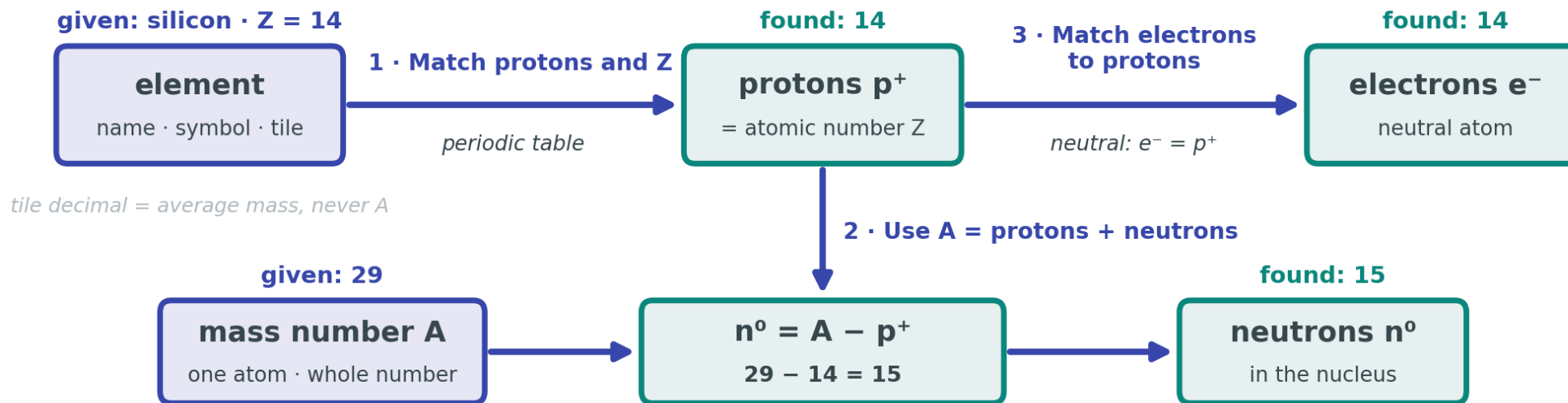
silicon $\rightarrow 14 \text{ p}^+ \cdot 15 \text{ n}^0 \cdot 14 \text{ e}^-$

protons = $Z = 14$ · neutrons = $29 - 14 = 15$ · electrons = 14 $\rightarrow$ neutral

🧠 **Sense check:** Rebuild the mass number: $14 + 15 = 29$, the given A . ✓

✓ Worked example 1: the route on the map

silicon: $Z = 14 \cdot A = 29 \rightarrow 14 \text{ p}^+ \cdot 15 \text{ n}^0 \cdot 14 \text{ e}^-$
 given: Z and A · found: protons, neutrons, electrons



🧠 **Sense check:** Protons first, from Z . Neutrons by subtraction, $29 - 14 = 15$. Electrons by matching the protons. ✓

Your turn: fluorine

fluorine: $Z = 9$ · mass number $A = 19$
one neutral atom

step	question	answer
1 · match protons and Z	protons?	_____
2 · use $A = \text{protons} + \text{neutrons}$	$19 - 9 = ?$	_____ neutrons
3 · match electrons to protons	electrons?	_____

Complete the three counts.

fluorine $\rightarrow 9 \text{ p}^+ \cdot 10 \text{ n}^0 \cdot 9 \text{ e}^-$
protons = $Z = 9$ · neutrons = $19 - 9 = 10$ · electrons = $9 \rightarrow \text{neutral}$

⚠ Where this goes wrong

Naming the element from the electron count. A neutral atom holds equal electrons and protons, so the two counts agree. Electrons are gained and lost in chemical changes; the proton count is the one that names the element.

Reading the tile's decimal as a mass number. Chlorine's 35.45 is an average over many atoms, not a count. A mass number is a whole number and belongs to one specific atom.

Taking the mass number as the neutron count. $A = 29$ does not mean 29 neutrons. The mass number counts protons and neutrons together: for silicon, neutrons = $29 - 14 = 15$.



Practice 1

zinc: $Z = 30$ · mass number $A = 66$
one neutral atom

A neutral zinc atom has mass number 66. Which row counts its particles?

- A. p^+ : 30 · n^0 : 36 · e^- : 30
- B. p^+ : 30 · n^0 : 96 · e^- : 30
- C. p^+ : 30 · n^0 : 66 · e^- : 30
- D. p^+ : 36 · n^0 : 30 · e^- : 36

✓ Practice 1 · answer: A

zinc, $Z = 30$, $A = 66 \rightarrow 30 \text{ p}^+ \cdot 36 \text{ n}^0 \cdot 30 \text{ e}^-$ (answer A)
protons = $Z = 30$ · neutrons = $66 - 30 = 36$ · electrons = $30 \rightarrow$ neutral

C read the mass number as the neutron count: 66. B added instead of subtracting: $66 + 30 = 96$. D swapped protons and neutrons: 36 protons is a different element: krypton, not zinc.

🧠 **Sense check:** 30 protons + 36 neutrons returns the mass number, 66. ✓



Worked example 3: the element from the counts

one neutral atom: $24 \text{ p}^+ \cdot 28 \text{ n}^0 \cdot 24 \text{ e}^-$

wanted: the element and its mass number

An atom holds 24 protons, 28 neutrons, and 24 electrons. Identify the element and give the mass number.

A common first attempt: $A = \text{protons} + \text{electrons} = 24 + 24 = 48$. Test it against what the mass number counts.

✓ Worked example 3: solution

A common first attempt

$24 \text{ p}^+ \cdot 28 \text{ n}^0 \cdot 24 \text{ e}^- \cdot \text{attempt: } A = 24 + 24 = 48?$

electrons sit outside the nucleus and weigh about 1/1840 of a proton ✗

Step 1 · Match protons and Z

Step 2 · Use $A = \text{protons} + \text{neutrons}$

Step 3 · Match electrons to protons

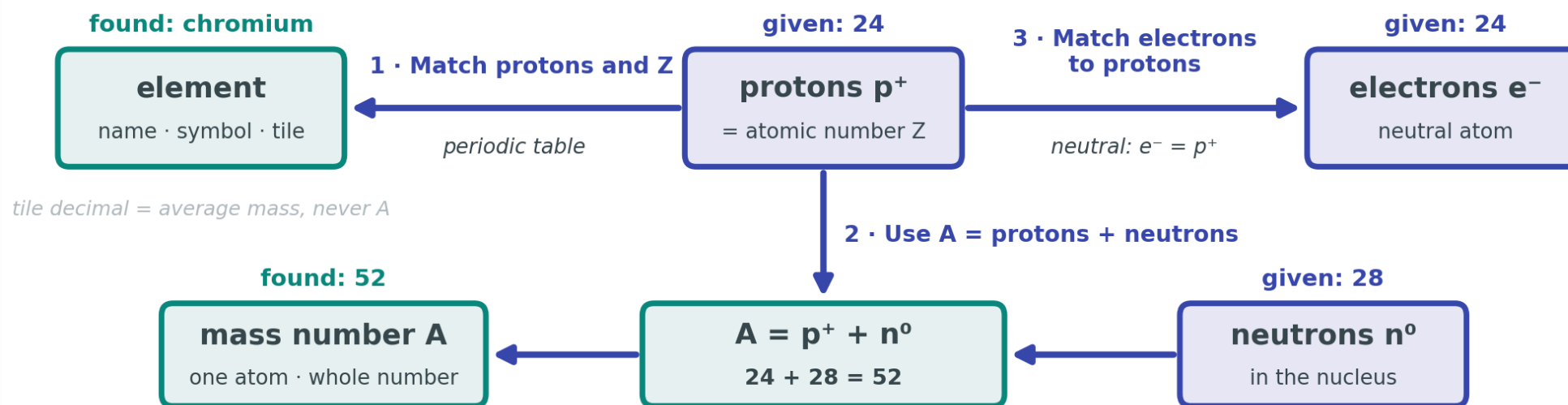
chromium: $Z = 24 \cdot A = 52$

$24 \text{ p}^+ \cdot 28 \text{ n}^0 \cdot 24 \text{ e}^- \cdot \text{electrons equal protons: neutral } \checkmark$

🧠 **Sense check:** A comes from the nucleus alone: $24 + 28 = 52$. The electrons never entered the sum.

✓ Worked example 3: the route on the map

$24 \text{ p}^+ \cdot 28 \text{ n}^0 \cdot 24 \text{ e}^- \rightarrow \text{chromium} \cdot A = 52$
 given: all three counts · found: the element and A



 **Sense check:** The links run the other way: protons out to the element, protons plus neutrons into A. The electrons only confirm neutral. ✓



Practice 2

$A = 27 \cdot 14 n^0 \cdot \text{no net charge}$
wanted: the element, its protons, its electrons

Which row identifies this atom?

- A. cobalt $\cdot 27 p^+ \cdot 27 e^-$
- B. silicon $\cdot 14 p^+ \cdot 14 e^-$
- C. aluminum $\cdot 13 p^+ \cdot 14 e^-$
- D. aluminum $\cdot 13 p^+ \cdot 13 e^-$

✓ Practice 2 · answer: D

protons = $A - \text{neutrons} = 27 - 14 = 13 \rightarrow \text{aluminum} \cdot 13 \text{ p}^+ \cdot 13 \text{ e}^-$ (answer D)

13 protons = Z = aluminum · neutral: electrons = protons = 13

A read the mass number as the atomic number: $Z = 27$ is cobalt, and 27 protons leave no room for 14 neutrons in a nucleus of 27. B read the neutron count as the proton count: $Z = 14$ is silicon, but neutrons never name the element. C matched the electrons to the neutrons; a neutral atom matches them to the protons, 13.

 **Sense check:** Rebuild the nucleus: $13 + 14 = 27$, the given mass number. ✓

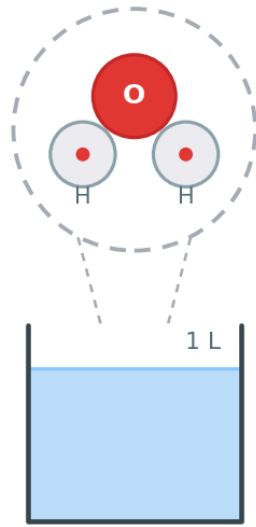
3 · Isotope Notation

Read and write isotope symbols in both notations and count the protons, neutrons, and electrons in a neutral atom of any isotope.

Heavy water

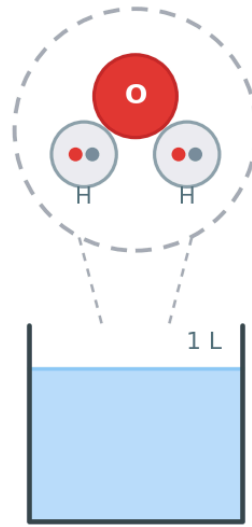
same look, same behavior: the heavier one has an extra particle in every hydrogen

inside each hydrogen: one particle



ordinary water
1 liter weighs 1.00 kg

inside each hydrogen: two particles

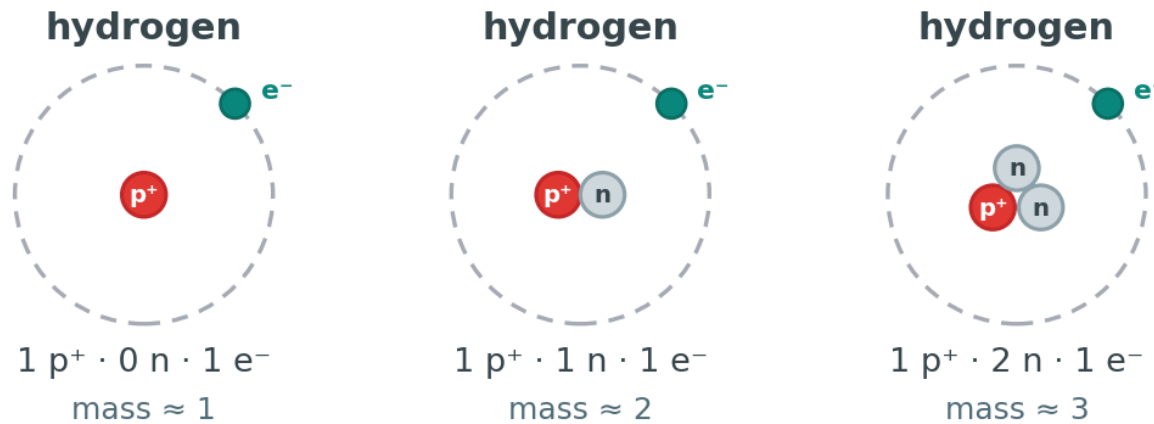


heavy water
1 liter weighs 1.11 kg

Heavy water looks, pours, and reacts like ordinary water, but a liter of it weighs about a tenth more. The extra mass sits inside its hydrogen atoms.

Same element, different mass

same proton count → all hydrogen · extra neutrons → extra mass, nothing else



The proton count fixes the element: one proton means hydrogen. Neutrons add mass and never change the element. Atoms with the same protons but different neutrons are **isotopes** of one element.

Two numbers label the nucleus

atomic number Z = protons

Z names the element: every chlorine atom has $Z = 17$

mass number A = protons + neutrons

a chlorine atom with 20 neutrons: $A = 17 + 20 = 37$

Both are whole-number counts of the particles in one atom. Rearranged, $A - Z$ isolates the neutrons.

Writing an isotope down

mass number A = protons + neutrons

37

17

Cl

= chlorine-37

hyphen notation: the name fixes Z ,
the number after it is A

$$\text{neutrons} = A - Z = 37 - 17 = 20$$

atomic number Z = protons

The nuclide symbol carries both counts: mass number upper left, atomic number lower left (though Z may be dropped, since the element symbol already fixes it). Hyphen notation writes the name, then A .

Isotopes of an element share chemistry



same electron count → same bonds · 18 vs 20 neutrons → different mass only

Electrons make the chemistry, and a neutral atom holds electrons equal to its protons. Isotopes share the proton count, so both chlorine isotopes form the same compounds.



The method

1. **Find Z.** The element and its atomic number fix each other on the periodic table.
2. **Apply $A = Z + N$.** Any two of the three counts give the third.
3. **Count electrons.** Neutral atom: electrons = protons.



Worked example 1: reading a symbol

$^{65}_{29}\text{Cu}$: one neutral atom

given: $A = 65$ · $Z = 29$ · wanted: protons, neutrons, electrons

About a third of natural copper atoms carry this symbol. Count the protons, neutrons, and electrons in one of them.

✓ Worked example 1: solution

$^{65}_{29}\text{Cu}$: one neutral atom

given: $A = 65$ · $Z = 29$ · wanted: protons, neutrons, electrons

Step 1 · Find Z

Step 2 · Apply $A = Z + N$

$$\text{neutrons} = A - Z = 65 - 29 = 36$$

$$65 \text{ heavy particles} - 29 \text{ protons} = 36 \text{ neutrons}$$

Step 3 · Count electrons



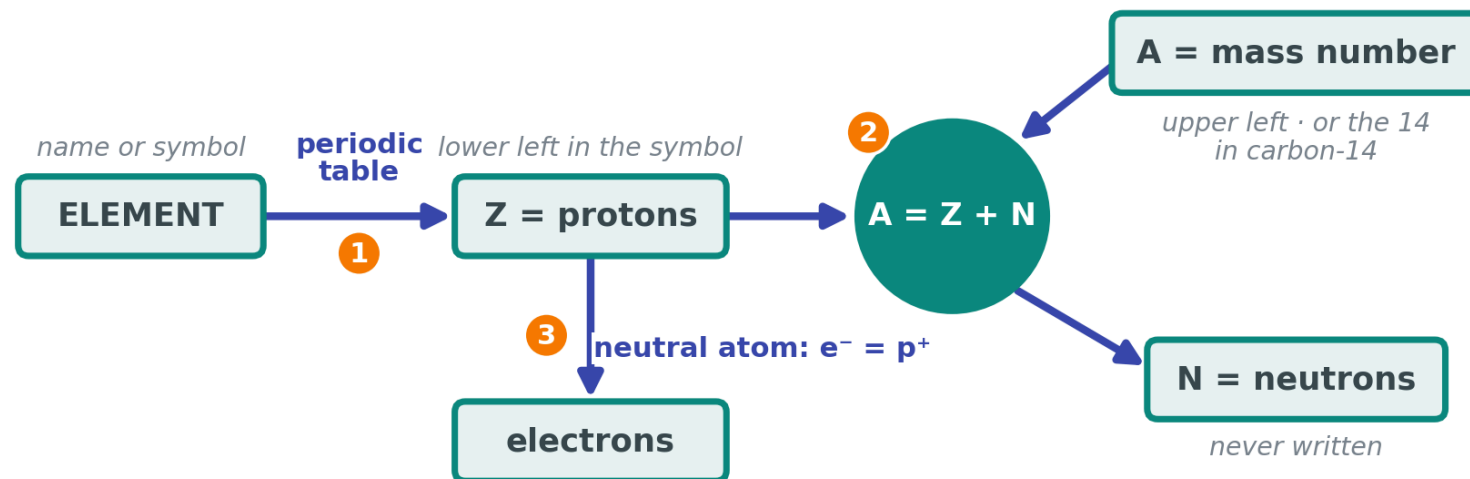
neutral atom: electrons = protons = 29 · check: $29 + 36 = 65 = A$ ✓

 **Sense check:** Neutrons outnumber protons, 36 to 29, typical beyond the lightest elements. The sum rebuilds A : $29 + 36 = 65$. ✓

✓ Worked example 1: the route on the map

$^{65}_{29}\text{Cu}$: one neutral atom

given: $A = 65 \cdot Z = 29 \cdot$ found: $29 \text{ p}^+ \cdot 36 \text{ n}^0 \cdot 29 \text{ e}^-$



- ① find Z ② apply $A = Z + N$: any two give the third ③ count electrons

🧠 **Sense check:** Step 1: $Z = 29 \rightarrow$ copper. Step 2: A and Z in, N out: $65 - 29 = 36$. Step 3: 29 protons $\rightarrow$ 29 electrons.





Worked example 2: hyphen notation

carbon-14: one neutral atom

given: the name carries $A = 14$ · wanted: protons, neutrons, electrons

Living wood holds a trace of carbon-14; the amount left in an artifact dates it. Count the particles in one neutral atom.

A common first attempt: carbon-14 holds 14 neutrons. Test it.

✓ Worked example 2: the first attempt

carbon-14: one neutral atom

given: $A = 14$ · Z not written: the periodic table supplies it

A common first attempt

carbon-14 → 14 neutrons?

14 counts protons and neutrons together; the protons are still inside ✕

The 14 is the mass number: every heavy particle in the nucleus. Some of those particles are protons, so the neutron count must be smaller than 14.

🧠 **Sense check:** A is a total; the protons take part of it. Finding neutrons needs a subtraction, not a copy of A .

✓ Worked example 2: solution

carbon-14: one neutral atom

given: $A = 14$ · Z not written: the periodic table supplies it

Step 1 · Find Z

Step 2 · Apply $A = Z + N$

$$\text{neutrons} = A - Z = 14 - 6 = 8$$

of the 14 heavy particles, 6 are protons and 8 are neutrons

Step 3 · Count electrons

$$\text{carbon-14} \rightarrow 6 \text{ p}^+ \cdot 8 \text{ n}^0 \cdot 6 \text{ e}^-$$

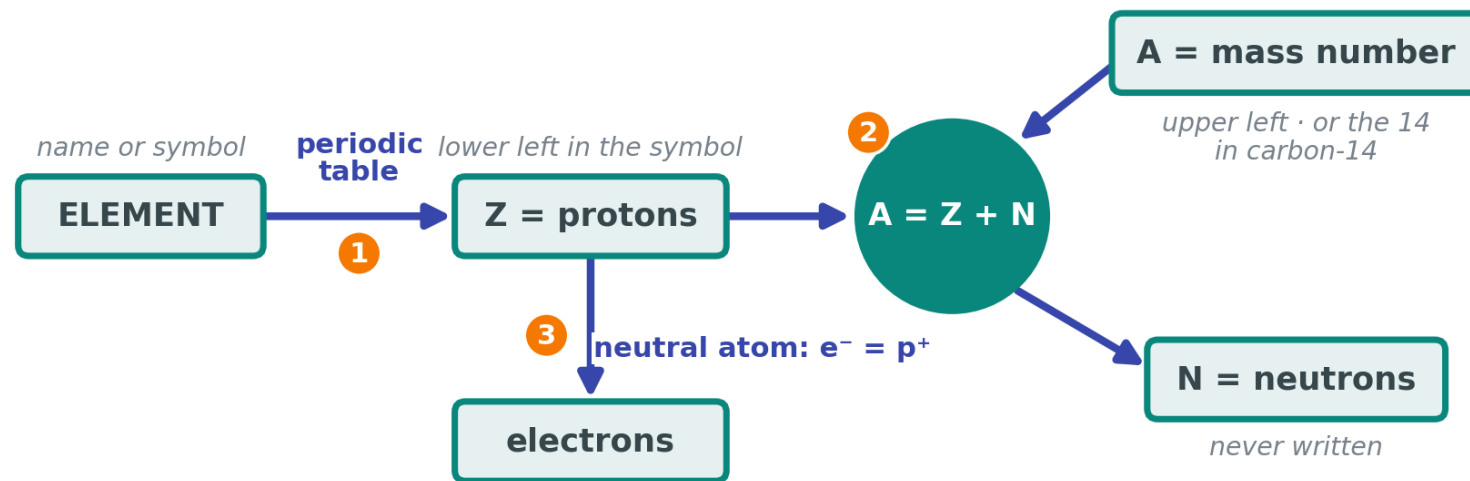
neutral atom: electrons = protons = 6 · check: $6 + 8 = 14$ ✓

🧠 **Sense check:** 8 of the 14 heavy particles are neutrons; the other 6 are the protons. The sum rebuilds A : $6 + 8 = 14$.

✓

✓ Worked example 2: the route on the map

carbon-14: one neutral atom
given: $A = 14 \cdot \text{found: } 6 \text{ p}^+ \cdot 8 \text{ n}^0 \cdot 6 \text{ e}^-$



- ① find Z ② apply $A = Z + N$: any two give the third ③ count electrons

Sense check: Step 1 starts at the name: carbon $\rightarrow Z = 6$. Step 2: A and Z in, N out: $14 - 6 = 8$. Step 3: 6 electrons. The 14 enters at $A = Z + N$, never as N. ✓

Your turn: sulfur-34

$^{34}_{16}\text{S}$: one neutral atom

$A = 34$ upper left · $Z = 16$ lower left

step	reading	count
1 · Find Z	lower left: $Z = 16$	protons = <u> </u>
2 · Apply $A = Z + N$	$N = 34 - 16$	neutrons = <u> </u>
3 · Count electrons	neutral atom	electrons = <u> </u>

Complete the three counts.



neutrons: $34 - 16 = 18$ · check: $16 + 18 = 34$ ✓

⚠ Where this goes wrong



$$A = 37 \cdot Z = 17 \cdot \text{neutrons} = 37 - 17 = 20$$

Reading A as the neutron count. "37 neutrons" reads a total as one of its parts. The 37 counts protons and neutrons together; subtract: $37 - 17 = 20$ neutrons.

Adding A and Z. $37 + 17 = 54$ counts the 17 protons twice: A already includes them. Neutrons = $A - Z$, never $A + Z$.

Reading Z as the neutron count. The 17 counts protons. The neutron count never appears in the symbol; only the subtraction produces it.

Expecting A on the periodic table. The table lists 35.45 for chlorine, and that is not a mass number. A is a whole-number count for one specific atom.

 Practice 1

strontium-88 = ^{88}Sr · atomic number 38
the most common strontium atom in nature

How many neutrons are in one atom of strontium-88?

- A. 88
- B. 50
- C. 126
- D. 38

✓ Practice 1 · answer: B

^{88}Sr : neutrons = $A - Z = 88 - 38 = 50$ (answer B)

$38 \text{ p}^+ \cdot 50 \text{ n}^0 \cdot 38 \text{ e}^- \cdot \text{check: } 38 + 50 = 88 \checkmark$

A read the mass number as the neutron count; 88 counts protons and neutrons together. C added the two numbers: $88 + 38 = 126$, counting the protons twice. D read the atomic number; 38 counts the protons.

🧠 **Sense check:** Beyond the lightest elements, neutrons outnumber protons: $50 > 38$ fits. ✓



Practice 2

cadmium-114 (hyphen notation)
the periodic table: cadmium is element 48

Cadmium-114 is the most common cadmium atom. How many neutrons does one neutral atom hold?

- A. 114
- B. 48
- C. 66
- D. 162

✓ Practice 2 · answer: C

cadmium-114: neutrons = $A - Z = 114 - 48 = 66$ (answer C)

$48 \text{ p}^+ \cdot 66 \text{ n}^0 \cdot 48 \text{ e}^- \cdot \text{check: } 48 + 66 = 114 \checkmark$

A read the mass number as the neutron count; 114 counts protons and neutrons together. B read the atomic number; 48 counts the protons. D added the two numbers: $114 + 48 = 162$, counting the protons twice.

🧠 **Sense check:** The neutron excess grows with heavier elements: 66 neutrons to 48 protons. ✓



Worked example 3: writing the symbol

a neutral gallium atom with 38 neutrons

given: the element · $N = 38$ · wanted: nuclide symbol and hyphen notation

This time the particle counts are given and the symbol is wanted. Write both notations for this atom. The same steps apply.

✓ Worked example 3: solution

a neutral gallium atom with 38 neutrons

given: the element · $N = 38$ · wanted: nuclide symbol and hyphen notation

Step 1 · Find Z

Step 2 · Apply $A = Z + N$

$$A = Z + N = 31 + 38 = 69$$

31 protons + 38 neutrons = 69 heavy particles

Assemble the notation

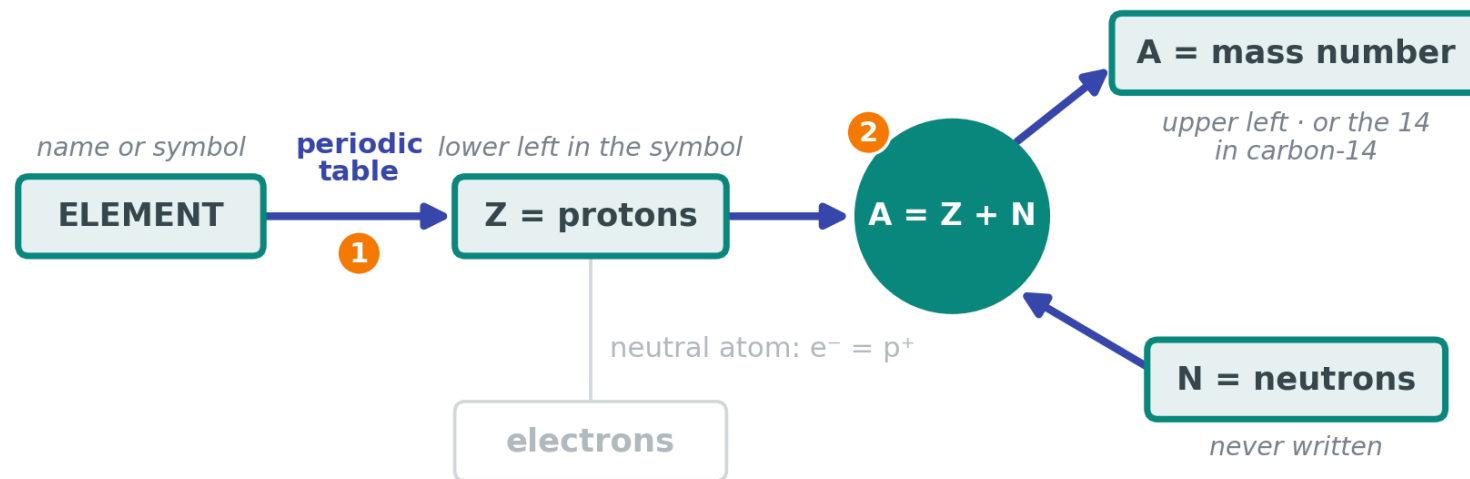


$A = 69$ upper left · $Z = 31$ lower left · the hyphen form keeps only A

🧠 **Sense check:** Subtraction runs the check in reverse: $69 - 31 = 38$, the given neutron count. ✓

✓ Worked example 3: the route on the map

a neutral gallium atom with 38 neutrons
given: gallium · N = 38 · found: $^{69}_{31}\text{Ga}$ = gallium-69



- ① find Z ② apply $A = Z + N$: any two give the third ③ count electrons

🧠 **Sense check:** The route crosses the junction the other way: Z and N in, A out: $31 + 38 = 69$. Step 3 stays off the route; no electron count was asked. ✓



Practice 3

atom 1: $26 \text{ p}^+ \cdot 32 \text{ n}^0$ · atom 2: $^{58}_{28}\text{Ni}$ · atom 3: $A = 56 \cdot 30 \text{ n}^0$
three neutral atoms

Which two of these atoms are isotopes of one element?

- A. Atoms 1 and 3
- B. Atoms 1 and 2
- C. Atoms 2 and 3
- D. No two: the three are different elements

✓ Practice 3 · answer: A

Z: atom 1 = 26 · atom 2 = 28 · atom 3 = 56 – 30 = 26 → atoms 1 and 3 (answer A)

atom 1: $A = 26 + 32 = 58$, iron-58 · atom 3: iron-56 · atom 2: $58 - 28 = 30$ n°, nickel-58

B matched the mass numbers: atom 1 has $A = 26 + 32 = 58$, like nickel-58, but 26 and 28 protons are two elements. C matched the neutron counts: nickel-58 holds $58 - 28 = 30$ neutrons, like atom 3, but neutrons never name the element. D read atom 3's 30 neutrons as its proton count, zinc; subtract instead: $56 - 30 = 26$.

 **Sense check:** Same protons, different neutrons: iron-58 and iron-56 are isotopes. ✓

4 • Average Atomic Mass

Calculate an element's average atomic mass from isotopic masses and percent abundances, and check that the answer lands between the isotope masses, closer to the more abundant one.

The number under every symbol

no single atom weighs 35.45 amu: the tile prints the average of the mixture

a sample of chlorine atoms



average
→

³⁵ Cl-35 · one atom weighs 34.97 amu
³⁷ Cl-37 · one atom weighs 36.97 amu

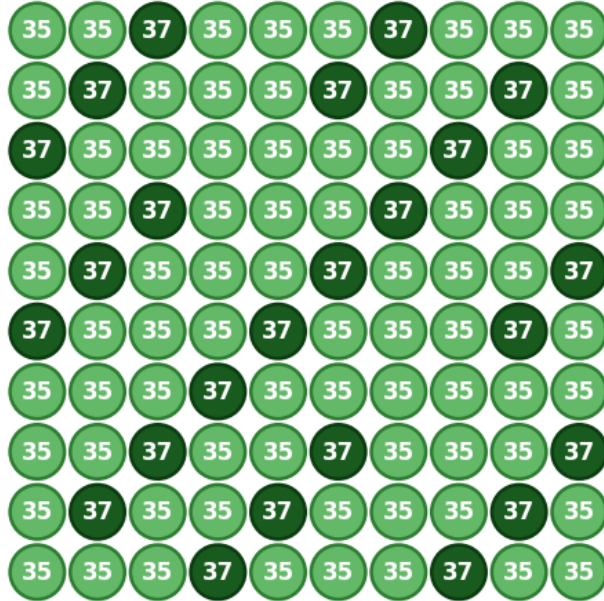


the periodic-table entry

A chlorine atom weighs 34.97 or 36.97 amu, never 35.45. Every periodic table lists 35.45: the average of the natural mix. That average, in g/mol, runs every mole calculation.

A natural sample is a fixed mix of isotopes

100 atoms of natural chlorine



35 Cl-35 · 75.76% → 76 atoms of the 100

37 Cl-37 · 24.24% → 24 atoms of the 100

**every natural sample keeps this split:
ocean salt, lab bottle, or star dust**

one fixed mixture → one average mass

Natural chlorine is always the same mixture: 75.76% Cl-35 and 24.24% Cl-37, in every bottle. The mass that describes chlorine is the sample's average, weighted by those fixed proportions.

The weighted average

$$\text{average atomic mass} = (\text{mass}_1 \times \text{fraction}_1) + (\text{mass}_2 \times \text{fraction}_2) + \dots$$

one term per isotope · fraction = percent ÷ 100 · masses in amu · 1 amu = 1/12 the mass of one carbon-12 atom

Each isotope contributes its mass in proportion to its share of the sample. Convert every percent to a fraction first: 75.76% → 0.7576. Mass spectrometry measures the masses and the abundances.

Mass number and atomic mass

mass number $A = 35$

a whole-number count: 17 protons + 18 neutrons in one Cl-35 atom

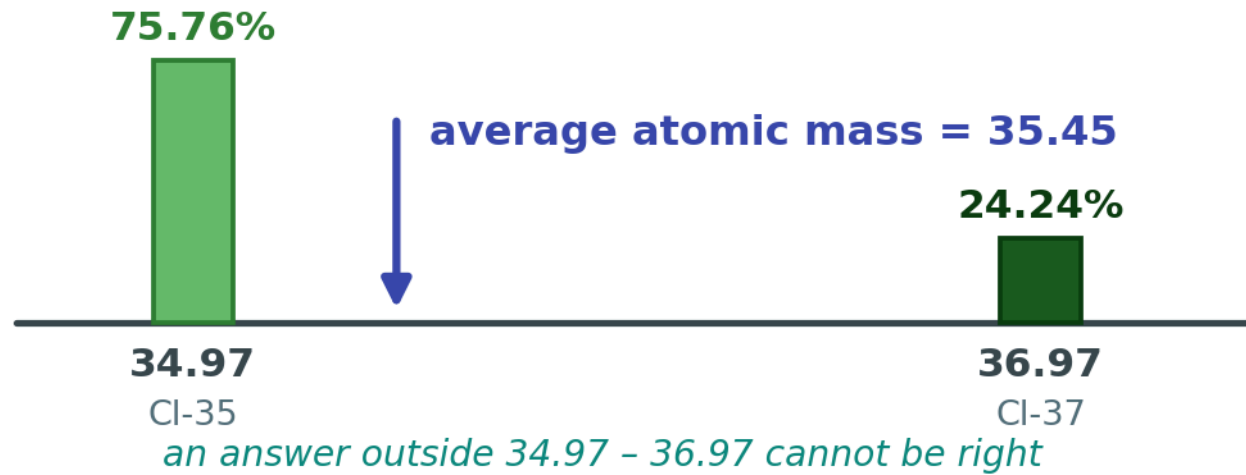
atomic mass = 35.45 amu

a weighted average over the natural sample, the periodic-table entry

A mass number counts particles in one atom, so it is whole. The periodic-table mass is an average over the sample; it is not whole, and it matches no single atom.

Where the average lands

the average lands between the two masses, closer to the abundant isotope



A weighted average lands between the lightest and heaviest masses, closer to the more abundant isotope. Check every answer against that range before trusting the arithmetic.



The method

1. **Percents → fractions:** divide each percent abundance by 100.
2. **Mass × fraction:** multiply each isotopic mass by its fraction of the sample.
3. **Add the contributions:** the sum is the average atomic mass.



Worked example 1: boron

B-10 · 10.0129 amu · 19.9% · B-11 · 11.0093 amu · 80.1%
given: two isotopic masses with abundances · wanted: average atomic mass

Natural boron is the two isotopes above. Calculate the average atomic mass of boron.

✓ Worked example 1: solution

B-10 · 10.0129 amu · 19.9% · B-11 · 11.0093 amu · 80.1%
 wanted: average atomic mass of boron

Step 1 · Percents → fractions

Step 2 · Mass × fraction

$10.0129 \times 0.199 = 1.9926$ · $11.0093 \times 0.801 = 8.8184$
 one contribution per isotope, in amu

Step 3 · Add the contributions

$1.9926 + 8.8184 = 10.81$ amu
 the periodic-table entry for boron

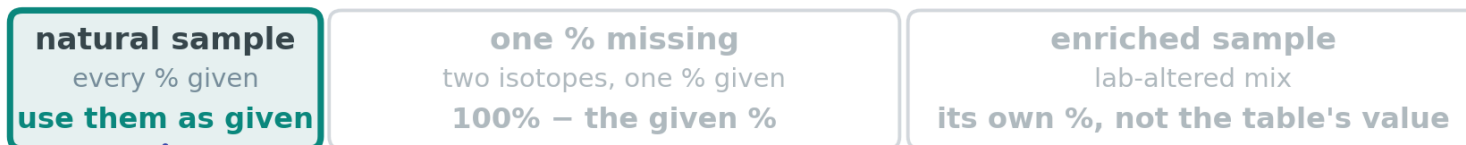
🧠 **Sense check:** 10.81 lies between 10.0129 and 11.0093, close to B-11, the isotope carrying 80.1% of the sample. ✓

✓ Worked example 1: the route on the map

$$\text{B-10} \cdot 10.0129 \text{ amu} \cdot 19.9\% \quad + \quad \text{B-11} \cdot 11.0093 \text{ amu} \cdot 80.1\%$$

found: 10.81 amu

SET UP the abundances



CALCULATE



WRONG TURNS X



🧠 **Sense check:** A natural sample, two terms, one sum, the range check. ✓



Worked example 2: chlorine

Cl-35 · 34.97 amu · 75.76% · Cl-37 · 36.97 amu · 24.24%
given: two isotopic masses with abundances · wanted: average atomic mass

Chlorine disinfects drinking water. Calculate its average atomic mass.

A common first attempt: add the two masses and divide by two. Test it.

✓ Worked example 2: solution

Cl-35 · 34.97 amu · 75.76% · Cl-37 · 36.97 amu · 24.24%

wanted: average atomic mass of chlorine

A common first attempt

$$(34.97 + 36.97) \div 2 = 35.97 \text{ amu}$$

every periodic table prints 35.45: the even split fails ✗

Step 1 · Percents → fractions

Step 2 · Mass × fraction

Step 3 · Add the contributions

$$34.97 \times 0.7576 + 36.97 \times 0.2424 = 26.4933 + 8.9616 = 35.45 \text{ amu}$$

two contributions, one sum: the periodic-table entry ✓

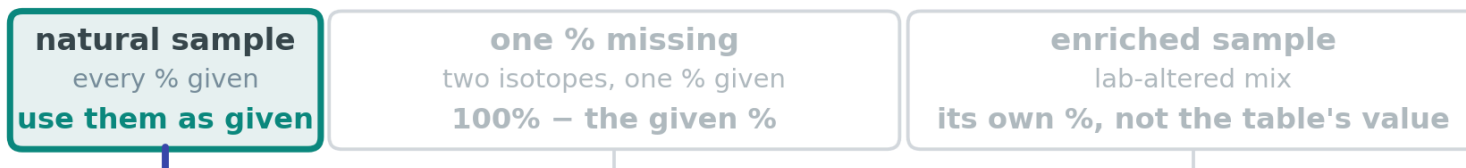
🧠 **Sense check:** 35.45 lies between 34.97 and 36.97, closer to Cl-35, the isotope in three quarters of the sample. The even split lands at 35.97 because it ignores which isotope is common. ✓

✓ Worked example 2: the route on the map

Cl-35 · 34.97 amu · 75.76% · Cl-37 · 36.97 amu · 24.24%

tested: 35.97 amu × · found: 35.45 amu ✓

SET UP the abundances



CALCULATE



WRONG TURNS ×



Sense check: The even split is a wrong turn: it holds only when the abundances are equal. The route weights each mass by its fraction. ✓

Your turn: copper

Cu-63 · 62.9296 amu · 69.17% · Cu-65 · 64.9278 amu · 30.83%

wanted: average atomic mass of copper

$62.9296 \times \underline{\hspace{1cm}} + 64.9278 \times 0.3083 = \underline{\hspace{1cm}} + 20.0172 = \underline{\hspace{1cm}}$ amu

fractions from 69.17% and 30.83% · one contribution per isotope · then the sum

Fill the missing fraction, then complete the first contribution and the sum.

$62.9296 \times 0.6917 + 64.9278 \times 0.3083 = 43.5284 + 20.0172 = 63.55$ amu

between 62.9296 and 64.9278, closer to Cu-63, 69.17% of the sample ✓

⚠ Where this goes wrong

Cu-63 · 62.9296 amu · 69.17% · Cu-65 · 64.9278 amu · 30.83%
average atomic mass: 63.55 amu

Using whole percents. $62.9296 \times 69.17 + 64.9278 \times 30.83 = 6354.6$ amu: one hundred times too heavy. A share of a sample is a fraction: divide each percent by 100 first. 0.6917 and 0.3083 give 63.55 amu.

Attaching the abundances to the wrong isotopes. $62.9296 \times 0.3083 + 64.9278 \times 0.6917 = 64.31$ amu: closer to Cu-65, the rarer isotope. The average must sit closer to the 69.17% isotope: 63.55 amu.

Weighting mass numbers instead of isotopic masses. $63 \times 0.6917 + 65 \times 0.3083 = 63.62$ amu, not 63.55. Mass numbers count protons and neutrons; the average takes the measured masses, 62.9296 and 64.9278.



Practice 1

Ga-69 · 68.9256 amu · 60.108% · Ga-71 · 70.9247 amu · 39.892%

wanted: average atomic mass of gallium

Gallium nitride makes the blue light in LED bulbs. Natural gallium is the two isotopes above.

What is the average atomic mass of gallium, in amu?

- A. 69.93
- B. 69.72
- C. 70.13
- D. 6972

✓ Practice 1 · answer: B

Ga-69 · 68.9256 amu · 60.108% · Ga-71 · 70.9247 amu · 39.892%
 wanted: average atomic mass of gallium

$$68.9256 \times 0.60108 + 70.9247 \times 0.39892 = 41.4298 + 28.2933 = 69.72 \text{ amu}$$

(answer B)

each mass weighted by its fraction of the sample

A averaged the masses equally: $(68.9256 + 70.9247) \div 2 = 69.93$. C attached the abundances to the wrong isotopes: $68.9256 \times 0.39892 + 70.9247 \times 0.60108 = 70.13$. D used whole percents: $68.9256 \times 60.108 + 70.9247 \times 39.892 = 6972$.

🧠 **Sense check:** D is one hundred times too heavy. A and C sit inside the range, but only 69.72 leans toward Ga-69, the isotope in 60.108% of the sample. ✓



Practice 2

Eu-151 · 150.9199 amu · 47.81% · Eu-153 · 152.9212 amu
the only two natural isotopes · wanted: average atomic mass of europium

Natural europium is these two isotopes and nothing else. What is the average atomic mass of europium, in amu?

- A. 151.92
- B. 72.15
- C. 151.88
- D. 151.96
- E. 145.27

✓ Practice 2 · answer: D

$$\text{Eu-151} \cdot 150.9199 \text{ amu} \cdot 47.81\% \quad \cdot \quad \text{Eu-153} \cdot 152.9212 \text{ amu}$$

$$\text{Eu-153: } 100 - 47.81 = 52.19\% \cdot \text{fractions } 0.4781 \text{ and } 0.5219$$

$$150.9199 \times 0.4781 + 152.9212 \times 0.5219 = 72.1548 + 79.8096 = 151.96 \text{ amu}$$

(answer D)

the missing abundance first, then one contribution per isotope

B stopped at the first contribution, 72.15. E skipped the missing abundance and reused 0.4781 for Eu-153: $72.1548 + 73.1114 = 145.27$, a sample only 95.62% complete. C attached 47.81% to the wrong isotope: $150.9199 \times 0.5219 + 152.9212 \times 0.4781 = 151.88$. A averaged the masses equally: 151.92.

🧠 **Sense check:** 151.96 sits just above the midpoint, 151.92, toward Eu-153, the 52.19% isotope. ✓

5 · Periodic Table Organization

Locate an element by period and group, name its family, classify it as a metal, nonmetal, or metalloid, and predict its bench behavior from its position.

Same column, same chemistry

group →

period

H: a nonmetal parked over group 1

the staircase

Legend:

- alkali metals · group 1
- alkaline earth metals · group 2
- transition metals · groups 3–12
- metalloids · the staircase
- halogens · group 17
- noble gases · group 18

period \ group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	57–71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	89–103	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

metals: left of the staircase

nonmetals: upper right

a row is a period · a column is a group · a named column is a family

Sodium explodes in water. Potassium does too, more violently. The periodic table seats them in one column: elements with matching behavior stack vertically, on purpose.

Order by atomic number, and behavior repeats

Li (3) · Na (11) · K (19): soft metals, violent in water
 $11 - 3 = 8$ · $19 - 11 = 8$: the behavior returns at regular intervals

one list, in order of atomic number

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca
cut									cut									cut	

behavior repeats
→ new row

the same tiles, one row per cut

1																	2								
H																	He								
3	4	5	6	7	8	9	10																		
Li	Be	B	C	N	O	F	Ne																		
11	12	13	14	15	16	17	18																		
Na	Mg	Al	Si	P	S	Cl	Ar																		
19	20																								
K	Ca																								

look-alikes stack

and stack

cut at each repeat, and the look-alikes stack into columns

The table lists elements in order of atomic number. Cut the list at each repeat, and the look-alikes stack into columns.

Rows are periods, columns are groups

groups: columns, 1 to 18

periods: rows, 1 to 7

	1															18		
1	H															He		
2	Li	Be										B	C	N	O	F	Ne	
3	Na	Mg										Al	Si	P	S	Cl	Ar	
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	57-71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	89-103	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

row 3 and column 17 cross at one element

the address: period 3, group 17 = Cl

Every element has an address: period, then group. Chlorine sits in row 3, column 17: period 3, group 17. Two numbers locate any element.

Five columns carry family names

group →

period

H: a nonmetal parked over group 1

the staircase

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	H																He	
2	Li	Be										B	C	N	O	F	Ne	
3	Na	Mg										Al	Si	P	S	Cl	Ar	
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	57-71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	89-103	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

alkali metals · group 1

alkaline earth metals · group 2

transition metals · groups 3-12

metalloids · the staircase

halogens · group 17

noble gases · group 18

metals: left of the staircase

nonmetals: upper right

a row is a period · a column is a group · a named column is a family

Group 1: alkali metals. Group 2: alkaline earth metals. Groups 3 to 12: transition metals. Group 17: halogens. Group 18: noble gases. A family name is a summary of shared behavior.

Metals, nonmetals, metalloids

H: a nonmetal parked over group 1

the staircase: B to Te

metals: left of the staircase
nonmetals: upper right, plus H
metalloids: B Si Ge As Sb Te, on the line

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	H											B	C	N	O	F	He	
2	Li	Be										Al	Si	P	S	Cl	Ar	
3	Na	Mg										Ga	Ge	As	Se	Br	Kr	
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	In	Sn	Sb	Te	I	Xe
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	57-71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	89-103	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

most of the table is metal · six elements on the line fit neither class cleanly

A stepped line runs from boron to tellurium. Metals sit to its left: most of the table. Nonmetals fill the upper right, plus hydrogen. The six elements on the line are metalloids: neither class fits cleanly.

What the classes mean at the bench

metals	metalloids	nonmetals
Cu · Fe · Al · Ca	B Si Ge As Sb Te	O · S · Br · Cl
 shiny (metallic luster)	metallic look, in-between behavior	 dull
 malleable and ductile: bend and draw, never shatter	 Si	 brittle as solids: shatter, never bend
 conduct heat and electricity	semiconductors: silicon runs electronics	 insulators: no current flows
all solid at room temp except mercury, a liquid		varied room-temp states: 5 solids · liquid Br · 11 gases
 e^- in reactions: lose electrons		 e^- in reactions: gain electrons

left of the staircase

the staircase

right of the staircase

The classes are bench descriptions. Metals are shiny, bend without shattering, and conduct heat and electricity. Nonmetals are dull, brittle as solids, and insulate. In reactions, metals lose electrons; nonmetals gain them.

Main group and transition block

main group: 1, 2, 13 to 18 · transition: 3 to 12
the tall columns at both edges · the block in the middle

Groups 1, 2, and 13 through 18 are the main group. Groups 3 through 12 are the transition metals. Family behavior runs cleanest in the main group; the transition block is all metals.

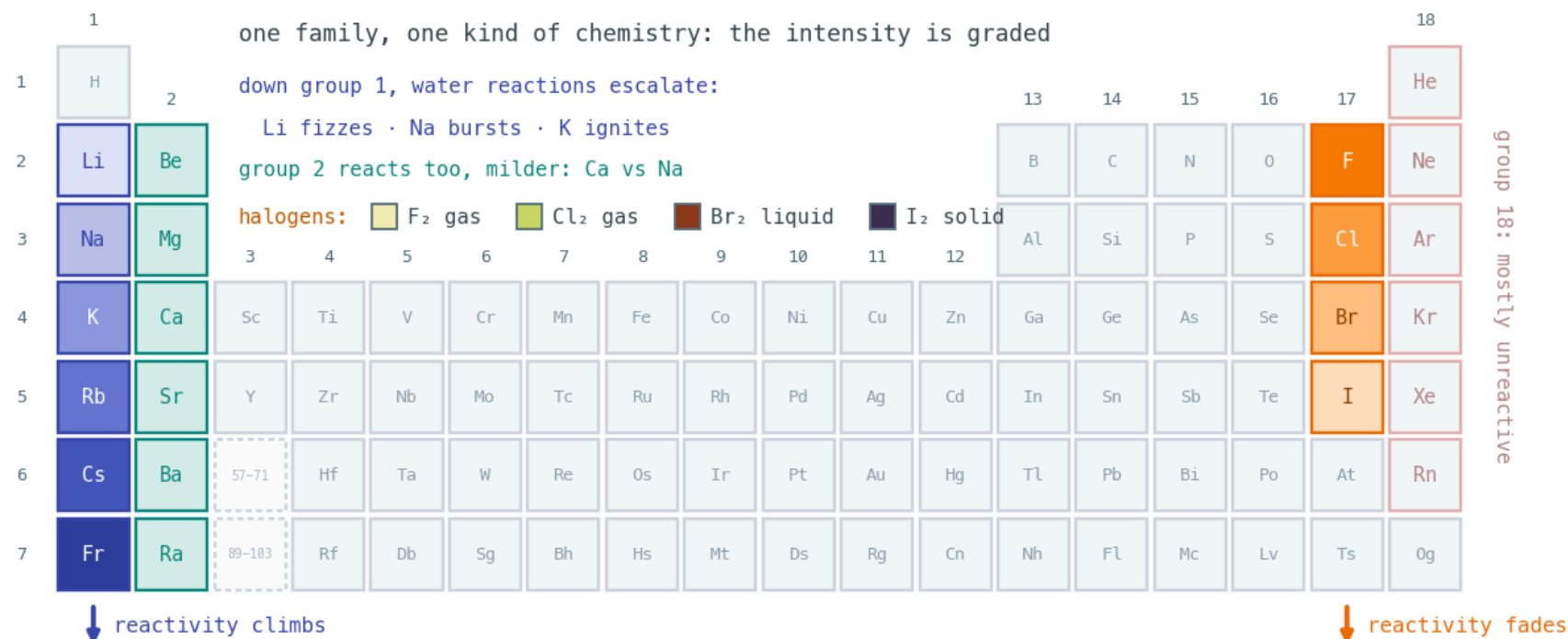
Why a family behaves alike

Li · Na · K: 1 outer electron each

F · Cl · Br · I: 7 outer electrons each, $8 - 7 = 1$ short of a full set

Elements in one column hold the same number of outer electrons, and outer electrons do the chemistry. Same count, same behavior. Row neighbors hold different counts, so they differ.

Reactivity is graded down a family



family members share behavior, not intensity: the gradation runs down the column

A family shares behavior, not intensity. Down group 1 the water reaction escalates: lithium fizzes, sodium bursts, potassium ignites. Down group 17 it fades, fluorine to iodine.

The table predicts missing elements

1871: a gap below silicon, named eka-silicon · predicted mass ≈ 72 , density ≈ 5.5 g/cm³

1886: germanium isolated · mass 72.6, density 5.32 g/cm³ · 1886 – 1871 = 15 years

Mendeleev left the space under silicon empty and forecast the missing element's properties from its neighbors. Germanium, found fifteen years later, matched. The table predicts chemistry; it does not just file elements.



The method

1. **Find the period.** Count rows down; hydrogen's row is period 1.
2. **Find the group.** Count columns 1 to 18.
3. **Name the family** if the column has one.
4. **Classify with the staircase.** Left: metal. Right: nonmetal. On it: metalloid.



Worked example 1: locating chlorine

Cl · atomic number 17

wanted: period, group, family, class

Find chlorine's period and group, name its family, and classify it: metal, nonmetal, or metalloid.

✓ Worked example 1: solution

Cl · atomic number 17
wanted: period, group, family, class

Step 1 · Find the period

Step 2 · Find the group

Step 3 · Name the family

Step 4 · Classify with the staircase

Cl: period 3, group 17 · halogen · nonmetal
right of the staircase: nonmetal

 **Sense check:** Chlorine's column-mates F, Br, and I are all reactive nonmetals. The address alone predicted the behavior. ✓

✓ Worked example 1: the route on the map

Cl · atomic number 17

given: Cl · found: period 3, group 17 (7A), halogen, nonmetal

group (A label for the main-group columns)

	1A																	8A
	1	2A											3A	4A	5A	6A	7A	18
1	H												B	C	N	O	F	He
2	Li	Be																Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

	Cl · Z = 17			given
1	period	period 3		found
2	group	group 17 = 7A		found
3	family	alkali metals · 1	alkaline earth · 2	found
		halogens · 17	noble gases · 18	
	class	metal left of the line	metalloid the six on it	found
			nonmetal right of it, + H	

 **Sense check:** Row 3 and column 17 cross at chlorine. The halogen column sits right of the staircase: F, Cl, Br, and I are all nonmetals. ✓

Worked example 2: predicting strontium

Sr · atomic number 38 · directly below Ca (20)

wanted: family, class, expected chemistry

Strontium sits directly below calcium. Name its family and class, and predict how its chemistry compares with calcium's.

A common first attempt: strontium holds nearly twice calcium's protons, so its chemistry should differ. Test it.

✓ Worked example 2: solution

Sr · atomic number 38 · directly below Ca (20)
wanted: family, class, expected chemistry

A common first attempt

Step 1 · Find the period

Step 2 · Find the group

Step 3 · Name the family

Step 4 · Classify with the staircase

Sr: period 5, group 2 · alkaline earth metal · metal
2 outer electrons, the same count as Ca: the same chemistry follows

 **Sense check:** The prediction is physical: bone takes up strontium because the body processes it like calcium.
Same family, same chemistry. ✓

✓ Worked example 2: the route on the map

Sr · atomic number 38 · directly below Ca (20)
 given: Sr · found: period 5, group 2 (2A), alkaline earth metal, metal

group (A label for the main-group columns)

	1A																	8A
	1																	18
1	H	2A																He
2	Li	Be																Ne
3	Na	Mg	3	4	5	6	7	8	9	10	11	12	Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

Sr · Z = 38		given
1 period	period 5	found
2 group	group 2 = 2A	found
3 family	alkali metals · 1 alkaline earth · 2 transition · 3-12 halogens · 17 noble gases · 18 no name · 13-16	found
4 class	metal left of the line metalloids the six on it nonmetals right of it, + H	found

 **Sense check:** One row below calcium, in the same column. The column carries the family, the class, and the chemistry down with it. ✓

Your turn: barium

Ba · atomic number 56 · directly below Sr (38)

$56 - 38 = 18$: one full row lower

step	answer
1 · find the period	one row below strontium's period 5: period _____
2 · find the group	the column of Be, Mg, Ca, Sr: group _____
3 · name the family	_____
4 · classify	left of the staircase: _____

Complete the four steps.

Ba: period 6, group 2 · alkaline earth metal · metal

2 outer electrons, like Mg, Ca, and Sr

⚠ Where this goes wrong

Swapping period and group. Period 3, group 17 names a row, then a column: chlorine. Reversed it names nothing: the table holds 7 periods, and no period 17 exists. Period counts rows; group counts columns.

Filing hydrogen with the alkali metals. Hydrogen sits over group 1, but it is a colorless nonmetal gas. The alkali family starts at lithium.

Stretching the staircase. The metalloids are exactly B, Si, Ge, As, Sb, Te. Aluminum touches the line and is still a metal: household foil, an excellent conductor. Membership is the list, not proximity.

Expecting row-mates to behave alike. Sodium and chlorine share period 3: a soft metal stored under oil, and a corrosive yellow-green gas. Alike runs down a column, never across a row.



Practice 1

wanted: the element at period 4, group 17
row 4 · column 17

Which element sits in period 4, group 17?

- A. Iodine
- B. Bromine
- C. Manganese
- D. Krypton

✓ Practice 1 · answer: B

period 4, group 17 → bromine (answer B)

period 4 spans $Z = 19$ to 36 : $36 - 19 + 1 = 18$ elements, ending at Kr

A counted rows inside the halogen column: fluorine's row is period 2, so the fourth halogen down is iodine, period 5. C read group 17 as group 7 and landed in the transition block: manganese sits in period 4, group 7. D overshoot by one column: krypton is group 18, a noble gas.

 **Sense check:** Bromine at this address is a halogen and a nonmetal: the only element in its column that is liquid at room temperature. ✓



Worked example 3: tellurium and iodine

Te: $Z = 52$, mass 127.6 · I: $Z = 53$, mass 126.9

wanted: which comes first, and each element's class

Tellurium outweighs iodine: $127.6 - 126.9 = 0.7$. State which element comes first on the table, then classify both.

✓ Worked example 3: solution

Te: $Z = 52$, mass 127.6 · I: $Z = 53$, mass 126.9

wanted: which comes first, and each element's class

The ordering rule

Classify with the staircase

Te: period 5, group 16 · on the staircase · metalloid

I: period 5, group 17 · halogen · nonmetal · order: $Z = 52$, then 53

 **Sense check:** One proton separates a semiconducting metalloid from a violet-vapor halogen. Position, and the chemistry it encodes, follows the proton count, not the mass. ✓

Te: $Z = 52$, mass 127.6 · I: $Z = 53$, mass 126.9

given: Te and I · found: Te: period 5, group 16 (6A), metalloid · I: group 17 (7A), halogen, nonmetal

group (A label for the main-group columns)

	1A	2A												3A	4A	5A	6A	7A	8A
	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																		He
2	Li	Be												B	C	N	O	F	Ne
3	Na	Mg												Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
6	Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
7	Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	

	Te · Z = 52 (then I · Z = 53)			given
1 period	period 5			found
2 group	group 16 = 6A			found
3 family	alkali metals · 1	alkaline earth · 2	transition · 3-12	found
	halogens · 17	noble gases · 18	no name · 13-16	
4 class	metal left of the line	metalloid the six on it	nonmetal right of it, + H	found

 **Sense check:** Tellurium's column, group 16, has no family name, and tellurium sits on the staircase. The next seat, $Z = 53$, is iodine: group 17, a halogen. ✓



Practice 2

Na · K: one column, group 1

Na: $Z = 11$ · K: $Z = 19$ · $19 - 11 = 8$

Sodium and potassium react with water the same violent way. Which statement explains why?

- A. They share a period, and elements in a period behave alike
- B. Their atomic masses are close, and mass sets chemical behavior
- C. They hold the same number of outer electrons: one each
- D. Both are transition metals, and that block reacts with water

✓ Practice 2 · answer: C

group 1: one outer electron per atom (answer C)

same outer count → same chemistry · $19 - 11 = 8$, one behavior repeat apart

A misreads the geometry: sodium and potassium share a group, a column; period-mates differ. B fails on its own numbers: $39.10 - 22.99 = 16.11$, the masses are not close, and mass does not set behavior. D misfiles them: group 1 is a main-group column; the transition block starts at group 3.

 **Sense check:** One easily lost outer electron is the alkali signature. Rubidium and cesium extend the column, and their water reactions escalate in order. ✓



Worked example 4: the address in reverse

wanted: the alkaline earth metal in period 3

given: a family name and a row · wanted: one element

A problem names no element, only a description: the alkaline earth metal in period 3.
Find the element.

✓ Worked example 4: solution

wanted: the alkaline earth metal in period 3

given: a family name and a row · wanted: one element

Family → group

Period → row

Read the intersection

group 2, period 3 → Mg, magnesium

row 3 opens at Na ($Z = 11$) in group 1 · the group-2 seat is next: $Z = 11 + 1 = 12$

 **Sense check:** Check the column: Be above, Ca below, all group 2. The address ran in reverse and still landed on a single element. ✓

✓ Worked example 4: the route on the map

wanted: the alkaline earth metal in period 3

given: alkaline earth metal, period 3 · found: group 2 (2A), Mg

group (A label for the main-group columns)

	1A 1																	8A 18
1	H	2A 2																He
2	Li	Be																Ne
3	Na	Mg	3	4	5	6	7	8	9	10	11	12	Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

	Mg · magnesium	found
1	period	period 3 given
2	group	group 2 = 2A found
3	family	alkali metals · 1 alkaline earth · 2 transition · 3-12 given
		halogens · 17 noble gases · 18 no name · 13-16
4	class	metal metalloid nonmetal found
		left of the line the six on it right of it, + H

 **Sense check:** The family fixed the column and the period fixed the row. The map ran from the steps up to the element. ✓



Practice 3

shiny · malleable · conducts electricity · loses two electrons
wanted: the one element fitting every observation

A sample is shiny, flattens under a hammer without shattering, and conducts electricity. Each of its atoms loses two electrons when it reacts. Which element fits?

- A. Potassium
- B. Silicon
- C. Calcium
- D. Sulfur

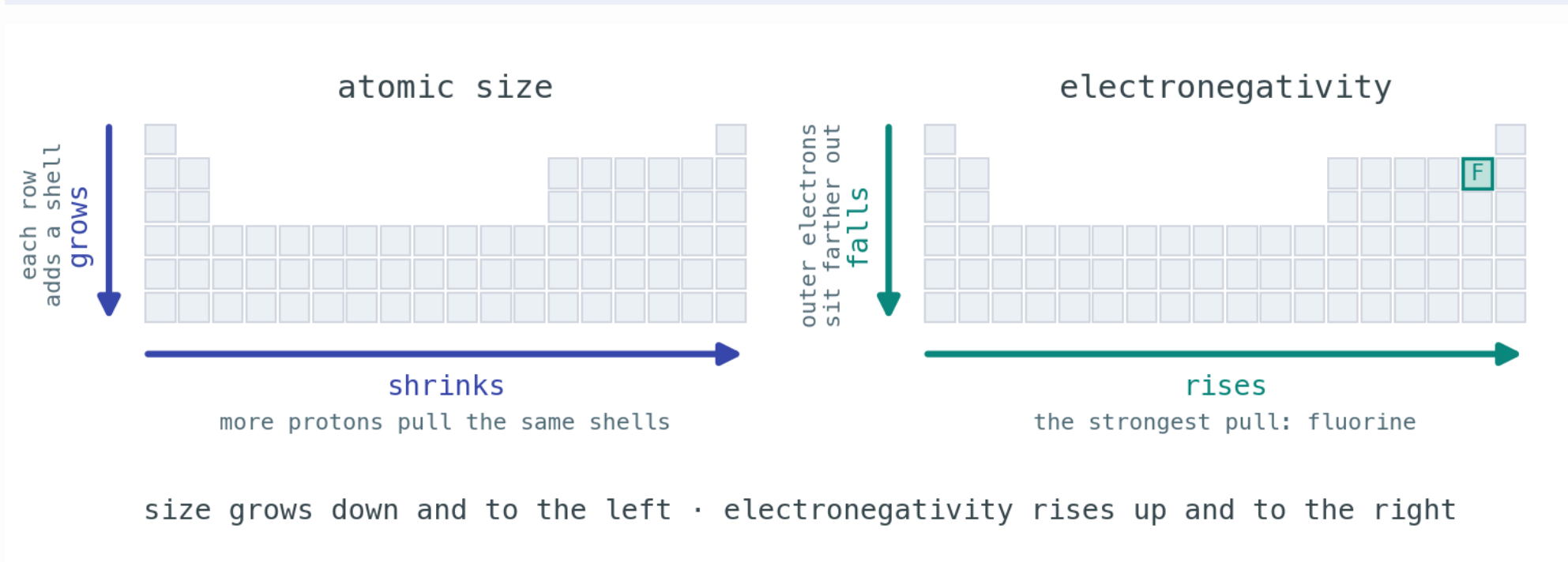
✓ Practice 3 · answer: C

metal properties + two electrons lost → calcium (answer C)
shiny, malleable, conducting: a metal, left of the staircase · 2 outer electrons: group 2

A fits the bench tests, but potassium sits in group 1: one outer electron, so it loses one, never two. B fails at the bench: silicon is a metalloid on the staircase, a semiconductor, not a full conductor. D reverses the electron move: sulfur is a brittle nonmetal, and nonmetals gain electrons.

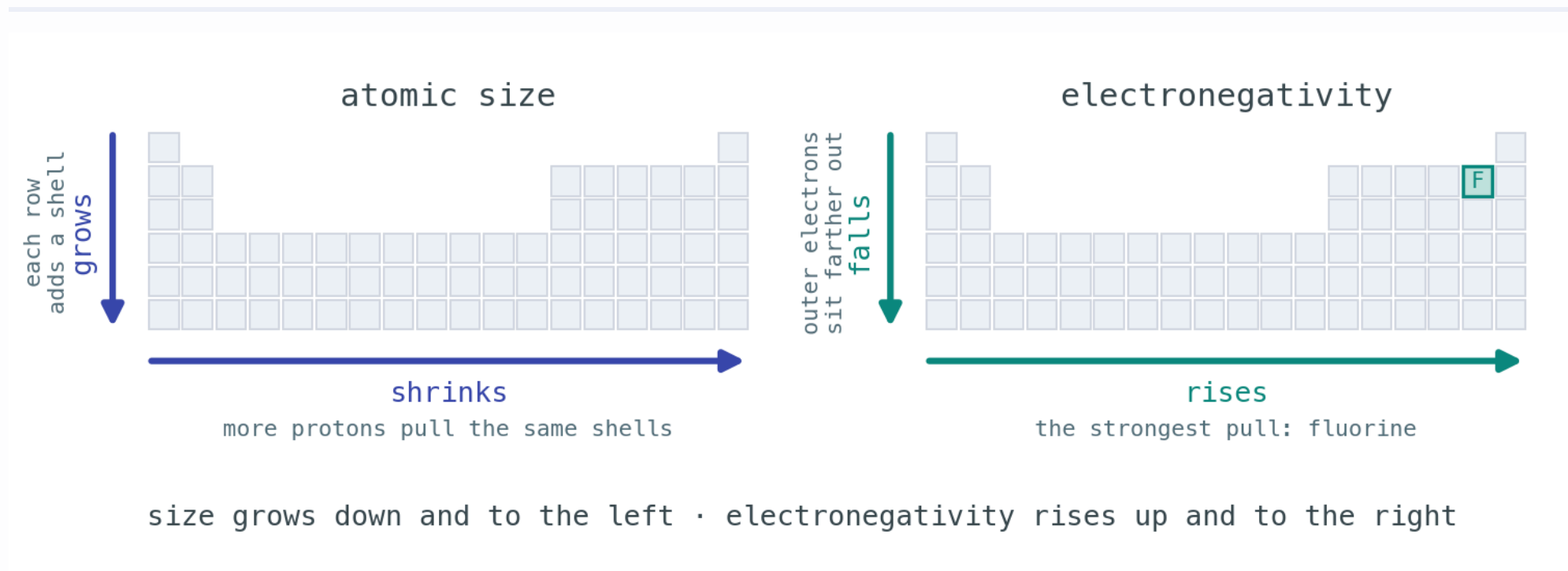
 **Sense check:** Bench properties place the region; the electron count picks the column. Magnesium and barium, calcium's family-mates, fit the same description. ✓

Atomic size follows the address



Down a group, atoms grow: each row adds a shell. Across a period, atoms shrink: protons are added while the shells stay the same, and the stronger pull draws every shell inward.

Electronegativity runs opposite to size



Electronegativity is how strongly a bonded atom pulls shared electrons toward itself. It rises across a period and falls down a group: the pull is strongest where atoms are smallest. Fluorine pulls hardest.



Practice 4

Na: period 3, group 1 · S: period 3, group 16 · O: period 2, group 16

Na and S share period 3 · S and O share group 16

Rank sodium, sulfur, and oxygen by atomic size, largest first, and pick the atom that pulls shared electrons hardest.

- A. Na, S, O · oxygen pulls hardest
- B. O, S, Na · oxygen pulls hardest
- C. Na, O, S · oxygen pulls hardest
- D. Na, S, O · sodium pulls hardest

✓ Practice 4 · answer: A

largest to smallest: Na, S, O · strongest pull: O (answer A)

across period 3: Na outsizes S · down group 16: S outsizes O · electronegativity peaks toward F

B ranked by pull instead of size: the atom that pulls hardest is the smallest, so the order came out reversed. C swapped sulfur and oxygen: each row down adds a shell, and sulfur's outer electrons sit one shell beyond oxygen's. D handed the strongest pull to the biggest atom: the biggest atom holds the bonding pair farthest from its nucleus and pulls it least.

 **Sense check:** Size grows down and to the left; the pull on shared electrons grows up and to the right. One address answers both questions.

Check yourself

1. Selenium sits in period 4, group 16. Classify it: metal, nonmetal, or metalloid. Is it a halogen?
2. Radium sits directly below barium. Name its family, predict its class, and state whether its reaction with water should be gentler or more violent than barium's.

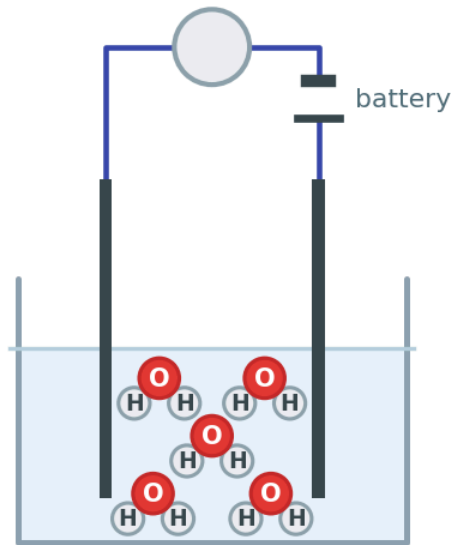
The two arrows give directions, not amounts. The pull on an outer electron can be measured, as the energy needed to remove it from the atom, and those measured values sharpen the arrows into exact rankings, deciding which atoms give up electrons and which take them when ions form.

6 • Ions

Predict the charge a main-group atom takes when it forms an ion, count the particles in the ion, and write its symbol.

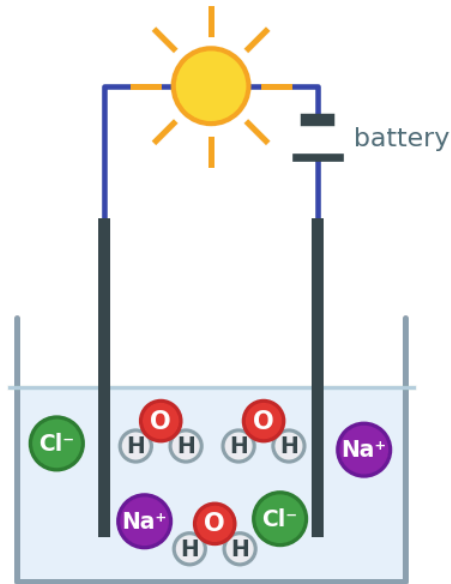
Salt water conducts electricity

pure water: the bulb stays dark



whole molecules: no charge carriers

salt water: the bulb lights

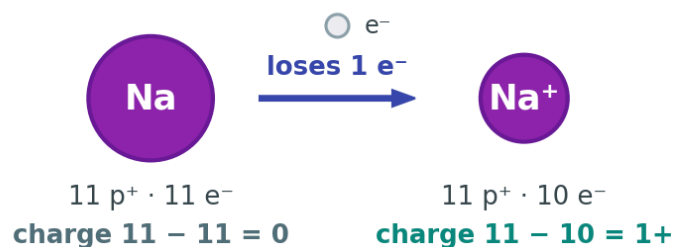


charged particles drift: a current

Pure water barely conducts electricity. Stir in table salt and the same water lights a bulb. Dissolved salt releases charged particles, and moving charges are an electric current.

Ions form by losing or gaining electrons

lose an electron → charge 1+

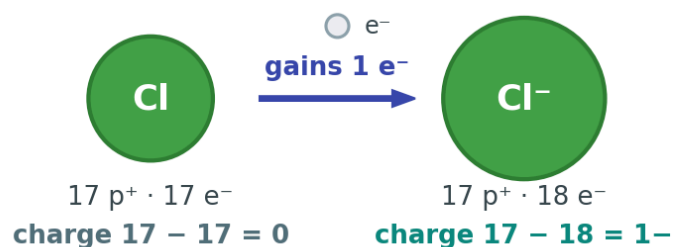


11 p⁺ before, 11 p⁺ after

still sodium ✓

smaller than the atom: the outer shell left

gain an electron → charge 1-



17 p⁺ before, 17 p⁺ after

still chlorine ✓

larger than the atom: one more electron, same pull

A neutral atom holds equal protons and electrons. Losing or gaining **electrons** makes an **ion**: charge = protons - electrons. Protons never change: they name the element. Cations shrink; anions swell.

Cation or anion



cation: $11 \text{ p}^+ \cdot 10 \text{ e}^- \rightarrow \text{charge } 11 - 10 = 1+$ · the t is a plus sign



anion: $17 \text{ p}^+ \cdot 18 \text{ e}^- \rightarrow \text{charge } 17 - 18 = 1-$ · A Negative ION

Losing electrons removes negative charge: a positive ion, a **cation**. Gaining electrons adds negative charge: a negative ion, an **anion**. Metals lose; nonmetals gain.

Predicting the charge

group 1	group 2							group 13	group 14	group 15	group 16	group 17	group 18
1+	2+							3+	none	3-	2-	1-	0
Li⁺	Be²⁺							B	C	N³⁻	O²⁻	F⁻	Ne
Na⁺	Mg²⁺							Al³⁺	Si	P³⁻	S²⁻	Cl⁻	Ar
K⁺	Ca²⁺							Ga³⁺	Ge	As³⁻	Se²⁻	Br⁻	Kr

groups 3-12

no simple ion

already stable

lose 1 · 2 · 3 e⁻ → cation

gain 3 · 2 · 1 e⁻ → anion

destination: the electron count of the nearest noble gas

Noble gases react with almost nothing: their electron counts are stable. Atoms lose or gain to reach the nearest one. Groups 1, 2, 13 lose: 1+, 2+, 3+. Groups 15, 16, 17 gain: 3-, 2-, 1-.

Writing the ion symbol



charge upper-right · number before sign: 2+, never +2

The charge sits at the upper right of the element symbol, number before sign. A charge of one shows the sign alone: Na^+ , Cl^- .



The method

1. **Count the protons.** The atomic number; it never changes.
2. **Count the electrons.** Neutral = protons; subtract lost, add gained.
3. **Compute the charge.** Charge = protons – electrons.
4. **Write the symbol.** Charge upper-right, number before sign.



Worked example 1: magnesium

^{24}Mg loses $2\text{ e}^- \rightarrow ?$

neutral atom: $12\text{ p}^+ \cdot 12\text{ n}^0 \cdot 12\text{ e}^-$ · wanted: particle counts and symbol

A magnesium atom loses two electrons. Count each particle in the ion and write its symbol.

✓ Worked example 1: solution

^{24}Mg loses $2\text{ e}^- \rightarrow ?$
 neutral atom: $12\text{ p}^+ \cdot 12\text{ n}^0 \cdot 12\text{ e}^-$

Step 1 • Count the protons

Step 2 • Count the electrons

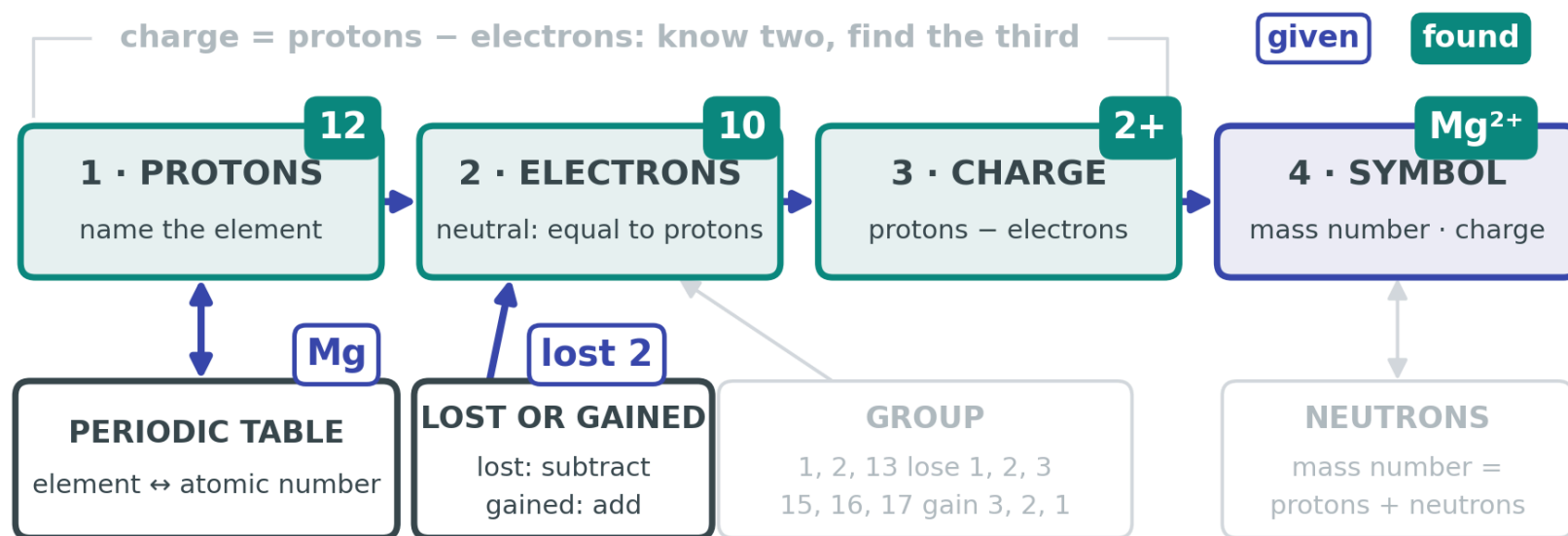
Step 3 • Compute the charge

Step 4 • Write the symbol

Mg^{2+}
 $12\text{ p}^+ \cdot 12\text{ n}^0 \cdot 10\text{ e}^- \rightarrow \text{charge } 12 - 10 = 2+$

 **Sense check:** Twelve positive protons against ten negative electrons: two positives are unmatched, so the ion carries 2+. ✓

✓ Worked example 1: the route on the map



Sense check: All four steps ran in order. The problem said how many electrons left, so the lost-or-gained card set the electron count. ✓

Worked example 2: sulfur



neutral atom: 16 p⁺ · 16 n⁰ · 16 e⁻ · group 16 · wanted: charge, counts, symbol

Sulfur forms an ion. Predict how many electrons move, count the particles, and write the symbol.

A common first attempt: an ion that gains electrons gains particles, so its charge comes out positive. Test it.

✓ Worked example 2: solution



neutral atom: $16 \text{ p}^+ \cdot 16 \text{ n}^0 \cdot 16 \text{ e}^- \cdot \text{group } 16$

A common first attempt

S gains $2 \text{ e}^- \rightarrow \text{S}^{2+}?$

$16 \text{ p}^+ \cdot 18 \text{ e}^- \rightarrow \text{charge } 16 - 18 = 2-, \text{ not } 2+ \times$

Step 1 · Count the protons

Step 2 · Count the electrons

Step 3 · Compute the charge

Step 4 · Write the symbol



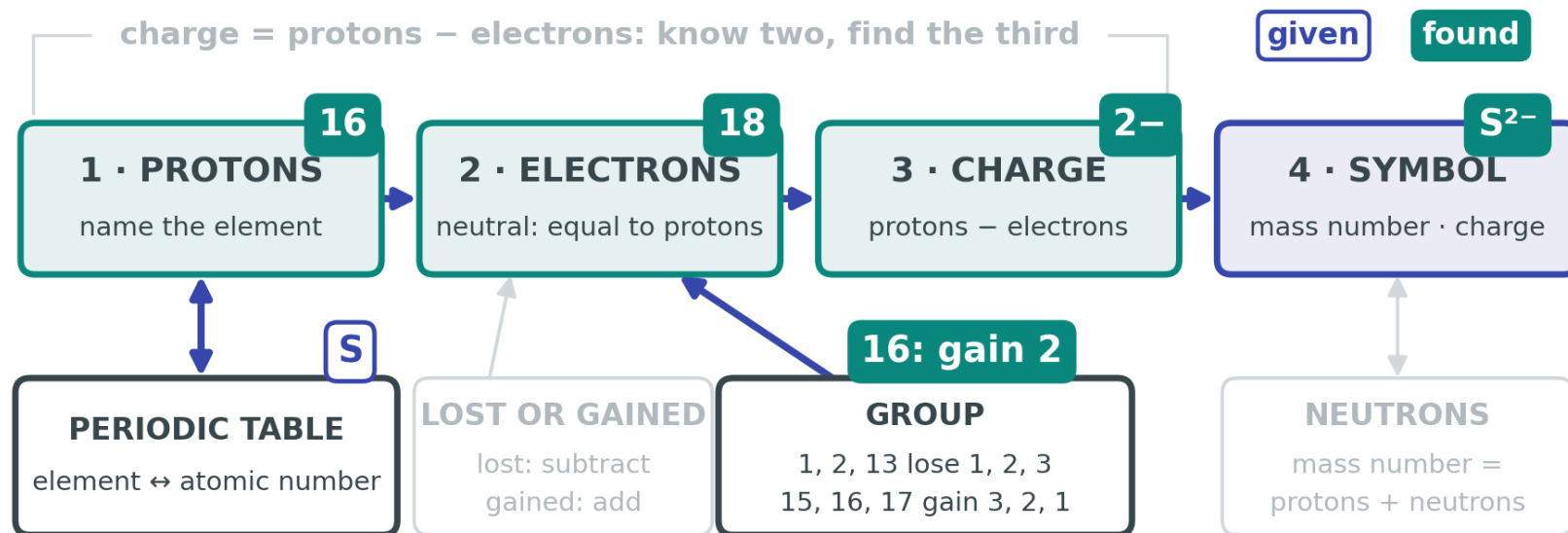
$16 \text{ p}^+ \cdot 16 \text{ n}^0 \cdot 18 \text{ e}^- \rightarrow \text{charge } 16 - 18 = 2-$

 **Sense check:** Two electrons beyond the protons, each carrying one negative charge: $2-$. Gained electrons always land the charge negative. ✓

✓ Worked example 2: the route on the map



found: group 16 gains 2 · 16 p⁺ · 18 e⁻ · charge 2-



🧠 **Sense check:** Nothing said how many electrons move. The group decided it: two short of argon, so gain two. ✓

Your turn: potassium



neutral atom: 19 p⁺ · 20 n⁰ · 19 e⁻ · group 1

step	count
1 · protons	19, unchanged
2 · electrons	argon holds 18, so one electron leaves: 19 – 1 = <u> </u>
3 · charge	19 – 18 = <u> </u>
4 · symbol	<u> </u>

Complete the counts and write the symbol.



19 p⁺ · 20 n⁰ · 18 e⁻ → charge 19 – 18 = 1+

⚠ Where this goes wrong

Reading "lost" as negative. Mg loses 2 e⁻, leaving 12 p⁺ and 10 e⁻: charge $12 - 10 = 2+$. The particles lost were the negative ones. Losing electrons always leaves a positive ion.

Charging the nucleus. A 2+ charge never comes from added protons: 12 protons is magnesium, 14 is silicon. Ion formation moves electrons only.

Naming the element from the electrons. Na⁺, Mg²⁺, and O²⁻ each hold 10 electrons, and none is neon. Protons identify the element.

Counting electrons into the mass number. Only nucleus particles count: ²⁴Mg²⁺ keeps mass number $12 + 12 = 24$, with 12 electrons or with 10.

 Practice 1

neutral atom: 56 p⁺ · 56 e⁻ · group 2

A neutral barium atom becomes a Ba²⁺ ion. Which statement describes what happens?

- A. The atom loses two electrons; with more protons than electrons left, it carries the 2+ charge
- B. The nucleus gains two protons, which makes the atom 2+
- C. The atom gains two electrons; the extra particles give it the 2+ charge
- D. The atom loses two protons from its nucleus, leaving a 2+ charge

✓ Practice 1 · answer: A



$$56 \text{ p}^{+} \cdot 54 \text{ e}^{-} \rightarrow \text{charge } 56 - 54 = 2+$$

B: 58 protons is no longer barium; protons never change in chemistry. C: gaining two electrons computes $56 - 58 = 2-$, an anion. D: losing two protons changes the element too, and 54 p^{+} against 56 e^{-} computes $54 - 56 = 2-$.

 **Sense check:** Barium sits in group 2: it loses two electrons, and 54 electrons is xenon's count, the nearest noble gas. ✓



Worked example 3: identifying an unknown ion

?: 34 p⁺ · 46 n⁰ · 36 e⁻

given: the particle counts · wanted: element, mass number, charge, full symbol

A particle holds 34 protons, 46 neutrons, and 36 electrons. Identify it and write its full symbol.

✓ Worked example 3: solution

?: $34 \text{ p}^+ \cdot 46 \text{ n}^0 \cdot 36 \text{ e}^-$

given: the particle counts · wanted: element, mass number, charge, full symbol

Step 1 · Count the protons

Step 2 · Count the electrons

Step 3 · Compute the charge

The mass number

Step 4 · Write the symbol

$^{80}\text{Se}^{2-}$

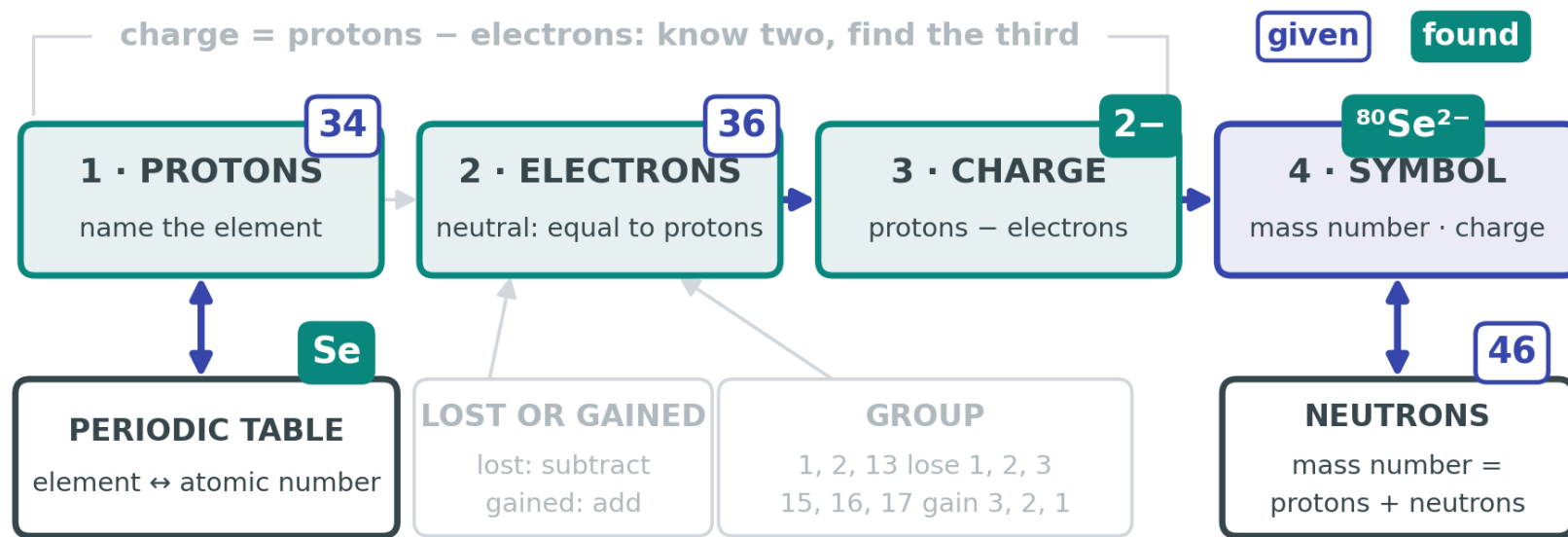
$34 \text{ p}^+ \cdot 46 \text{ n}^0 \cdot 36 \text{ e}^- \cdot \text{mass number } 34 + 46 = 80 \cdot \text{charge } 34 - 36 = 2-$

 **Sense check:** Selenium sits in group 16, two electrons short of krypton, and a $2-$ anion is exactly what the periodic table predicts. ✓

✓ Worked example 3: the route on the map



found: selenium · charge $34 - 36 = 2-$ · mass number $34 + 46 = 80$



Sense check: The counts came given. The table read 34 protons as selenium; the neutrons fed only the mass number. ✓



Practice 2

	decoded symbol
1	$^{40}\text{Ca}^{2+}$ has mass number 38, since it lost two electrons
2	$^{31}\text{P}^{3-}$ holds $15\text{ p}^+ \cdot 16\text{ n}^0 \cdot 18\text{ e}^-$
3	$^{85}\text{Rb}^+$ holds $37\text{ p}^+ \cdot 48\text{ n}^0 \cdot 36\text{ e}^-$

Three ion symbols, three decodings. Which statements are correct?

- A. Statements 1, 2 and 3
- B. Statement 3 only
- C. Statement 2 only
- D. Statements 2 and 3 only

✓ Practice 2 · answer: D

correct: 2 and 3 · false: 1 (answer D)

$$^{31}\text{P}^{3-}: 31 - 15 = 16 \text{ n}^0 \cdot 15 + 3 = 18 \text{ e}^- \cdot ^{85}\text{Rb}^+: 85 - 37 = 48 \text{ n}^0 \cdot 37 - 1 = 36 \text{ e}^- \cdot ^{40}\text{Ca}^{2+} \text{ keeps } A = 40$$

A accepted statement 1: electrons never enter the mass number, so $^{40}\text{Ca}^{2+}$ keeps $A = 20 + 20 = 40$, not $40 - 2 = 38$. B read $3-$ as three electrons lost, $15 - 3 = 12$, and rejected statement 2; a negative ion gained them. C found neutrons by subtracting electrons, $85 - 36 = 49$, and rejected statement 3; neutrons = $A - \text{protons} = 48$.

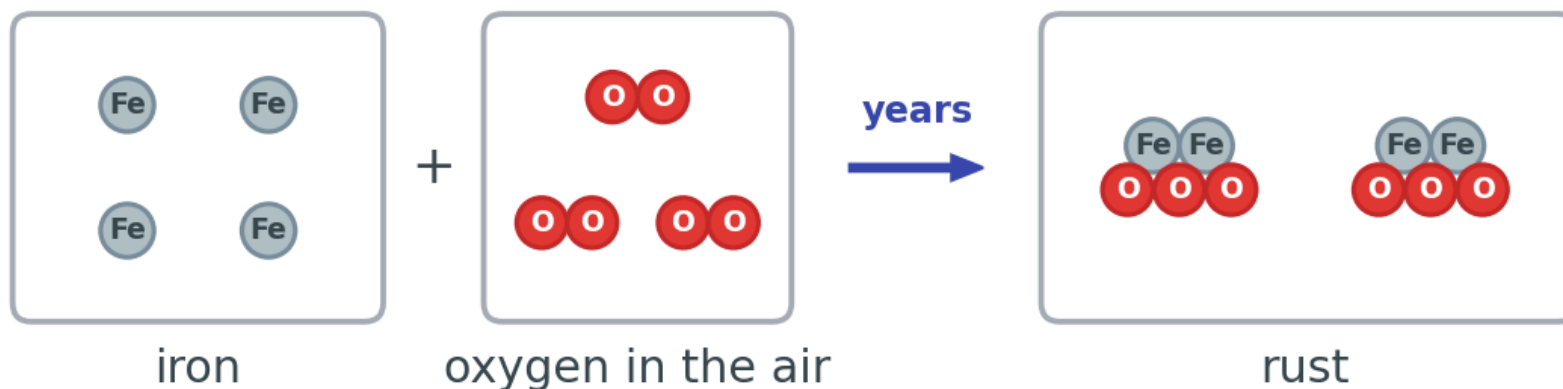
🧠 **Sense check:** A charge moves electrons only. Protons, neutrons, and the mass number stay put. ✓

7 • Naming Ionic Compounds

Name any binary ionic compound from its formula and write its formula from its name, letting charge balance set every subscript and every Roman numeral.

What a chemical name is for

iron left in the air turns to rust



iron : oxygen = 2 : 3, in every flake

Rust is iron combined with oxygen from the air: two iron for every three oxygen, in every flake. A chemical name reports exactly what a compound contains.

Reading a chemical formula



read aloud: K-three-P-O-four · a symbol with no subscript counts one atom



the 2 outside the parentheses multiplies everything inside

A subscript counts atoms of the symbol just before it. A subscript after parentheses multiplies the whole group inside them.

Your turn: count the atoms



wanted: the number of atoms of each element

element	count
Ca	_____
N	_____
O	_____

Count every atom. The subscript 2 sits outside the parentheses.



N: $2 \times 1 = 2$ · O: $2 \times 3 = 6$ · the outside 2 multiplies the whole group

Every ionic compound is neutral

equal and opposite charges cancel one for one



$$1(+1) + 1(-1) = 0 \cdot \text{neutral}$$

formula unit
NaCl

Cations and anions carry charge; the compound carries none. Total positive cancels total negative. Na^+ meets Cl^- one for one: the charges already cancel, so the formula is NaCl.

Unequal charges: the counts adjust

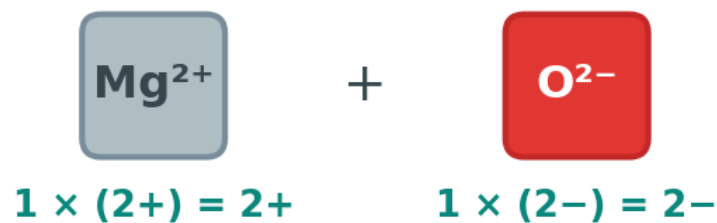
a 2+ cation needs two 1- anions



$$1(+2) + 2(-1) = 0$$



2+ meets 2-: one of each



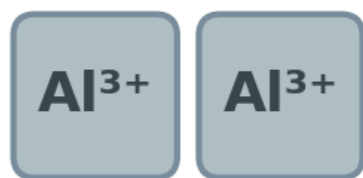
$$1(+2) + 1(-2) = 0$$



Ca^{2+} carries twice the charge of Cl^- , so two chlorides are needed: CaCl_2 . Mg^{2+} meets O^{2-} , equal and opposite, so MgO stays one for one. The ion counts change; the zero total never does.

When neither charge cancels the other

the smallest group of ions that adds to zero charge



$$2 \times (3+) = 6+$$

+



$$3 \times (2-) = 6-$$

$$2(+3) + 3(-2) = 0 \cdot \text{neutral}$$

formula unit
 Al_2O_3

Al^{3+} and O^{2-} cannot cancel one for one. The smallest totals that cancel are +6 and -6: two aluminums with three oxides, Al_2O_3 . Charge balance alone fixes both subscripts.

Recognizing an ionic compound

metal + nonmetal → ionic

1+	2+	varies	3+	none	3−	2−	1−	none
Li Na K	Mg Ca Ba	Fe · Cu · Sn · Pb · Cr more than one possible charge fixed anyway: Zn ²⁺ · Ag ⁺	Al	C Si	N P	O S	F Cl Br I	He Ne Ar
1A	2A	transition metals	3A	4A	5A	6A	7A	8A

metals lose electrons → cations (+) **nonmetals gain electrons → anions (−)**

A metal with a nonmetal is ionic: the metal's atoms become cations, the nonmetal's become anions. Periodic position gives each ion its charge.

nonmetal charge = 8 − A-number

sulfur: Group 6A = IUPAC group 16 → 8 − 6 = 2 → 2− · 18-column: 18 − group, 18 − 16 = 2

The name: cation, then anion

NaCl → sodium chloride

$1(+1) + 1(-1) = 0 \checkmark$ · the cation keeps its element name

MgBr₂ → magnesium bromide

$1(+2) + 2(-1) = 0 \checkmark$ · brom- + -ide · the subscript is never spoken

The cation is named first, unchanged. The anion takes its element's stem plus **-ide**. Subscripts come from charge balance, so the name does not repeat them.

The -ide names

chlorine → chloride · oxygen → oxide · sulfur → sulfide

chlor- + -ide · ox- + -ide · sulf- + -ide

nitrogen → nitride · phosphorus → phosphide

nitr- + -ide · phosph- + -ide

The stem is the element name's opening syllables, and it can shorten the word: nitride, not nitrogenide. These five cover most binary ionic compounds.

Your turn: name the anions



wanted: each anion's name

anion	name
Br^-	_____
I^-	_____
Se^{2-}	_____

Attach -ide to each element's stem.

bromide · iodide · selenide

brom- + -ide · iod- + -ide · selen- + -ide

Fixed-charge and variable-charge metals

one possible charge: Group 1 $\rightarrow$ 1+ $\cdot$ Group 2 $\rightarrow$ 2+ $\cdot$ Ag⁺ $\cdot$ Zn²⁺ $\cdot$ Al³⁺

the name never carries a numeral $\cdot$ the three loners count up: Ag 1+, Zn 2+, Al 3+

more than one: Fe²⁺/Fe³⁺ $\cdot$ Cu⁺/Cu²⁺ $\cdot$ Sn²⁺/Sn⁴⁺ $\cdot$ Pb²⁺/Pb⁴⁺

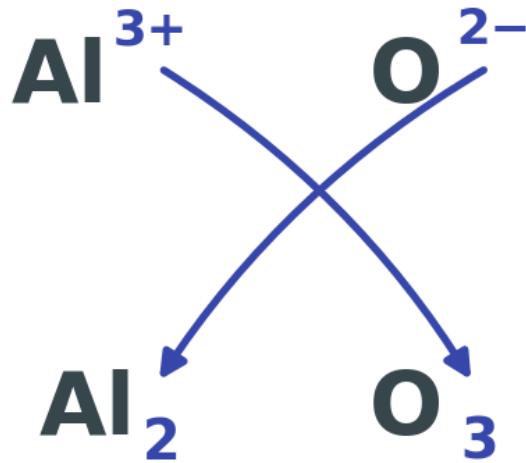
iron(II) = Fe²⁺ $\cdot$ iron(III) = Fe³⁺ $\cdot$ the Roman numeral states the cation's charge

older labels: ferrous = iron(II) $\cdot$ ferric = iron(III)

-ous marks the lower charge, -ic the higher $\cdot$ recognize them; write the numeral form

A fixed-charge metal forms one cation; its name needs no numeral. A variable-charge metal forms more than one, so its name carries a Roman numeral stating the cation's charge.

The criss-cross shortcut



each charge becomes the other ion's subscript

check the sum

$$2 \text{ Al}^{3+} \rightarrow +6 \quad 3 \text{ O}^{2-} \rightarrow -6$$

$$+6 - 6 = 0 \quad \checkmark$$

the crossed counts are the smallest totals that cancel

check the ratio

2 : 3 shares no factor, already smallest

Each charge number becomes the other ion's subscript, because those counts make the totals cancel. The shortcut is bookkeeping for charge balance, so finish with its two checks: the sum is zero, the ratio is smallest.



The method

1. **Classify the compound.** Metal + nonmetal: ionic.
2. **Identify the ions.** Fixed: periodic position. Variable: numeral or anion total.
3. **Balance the charges to zero.** Criss-cross, check, reduce.
4. **Assemble the answer.** Name: cation, numeral if variable, -ide. Formula: smallest ratio.



Worked example 1: K_2S

Step 1 · Classify the compound



potassium, a metal · sulfur, a nonmetal → ionic · wanted: the name

Black powder burns to a residue containing K_2S . Name the compound.

✓ Worked example 1: solution



potassium, a metal · sulfur, a nonmetal → ionic · wanted: the name

Step 2 · Identify the ions



K: Group 1 → 1+, fixed · S: Group 6A → 8 – 6 = 2 → 2–

Step 3 · Balance the charges to zero

Step 4 · Assemble the answer



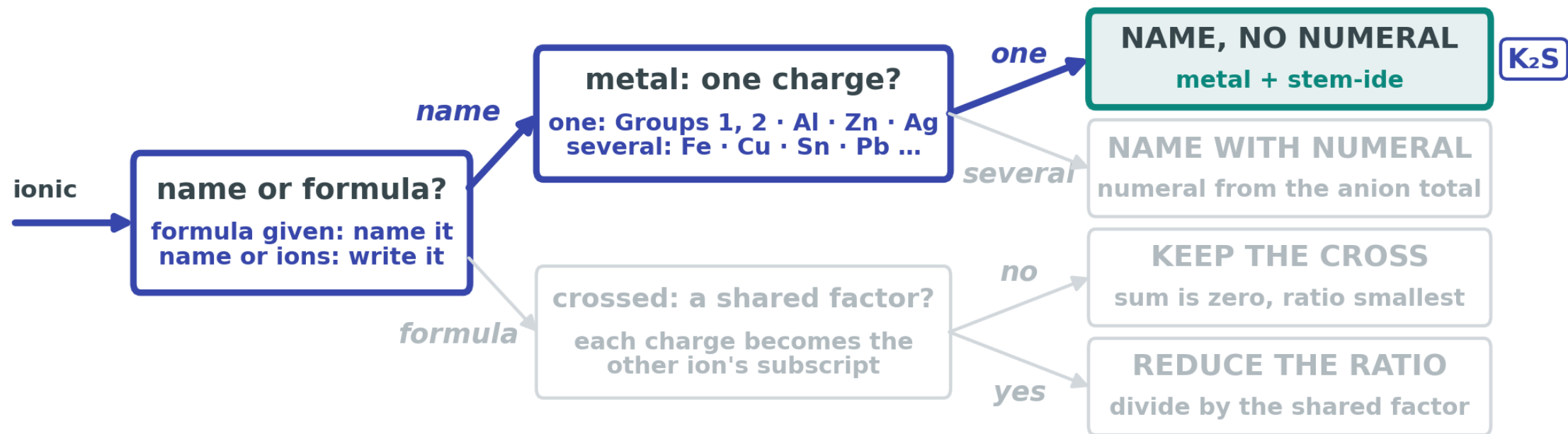
$2(+1) + 1(-2) = 0$ ✓ · sulf- + -ide · the 2 is not spoken

 **Sense check:** No numbers appear in the name, and none are needed: K^+ and S^{2-} reach zero charge only in a 2 : 1 ratio.

✓ Worked example 1: the route on the map

K_2S : potassium sulfide

name wanted · potassium: Group 1, one possible charge → no numeral



 **Sense check:** A fixed-charge metal takes the top exit: the element name, then the anion stem plus -ide. ✓



Worked example 2: magnesium nitride

Step 1 • Classify the compound

magnesium nitride

magnesium, a metal • nitride, a nonmetal anion → ionic • wanted: the formula

Magnesium burning in air combines with nitrogen as well as oxygen. Write the formula for magnesium nitride.

✓ Worked example 2: solution

magnesium nitride

a metal with a nonmetal → ionic · wanted: the formula

Step 2 · Identify the ions

Mg^{2+} and N^{3-}

Mg: Group 2 → $2+$ · N: Group 5A → $8 - 5 = 3 \rightarrow 3-$

Step 3 · Balance the charges to zero

Step 4 · Assemble the answer

magnesium nitride → Mg_3N_2

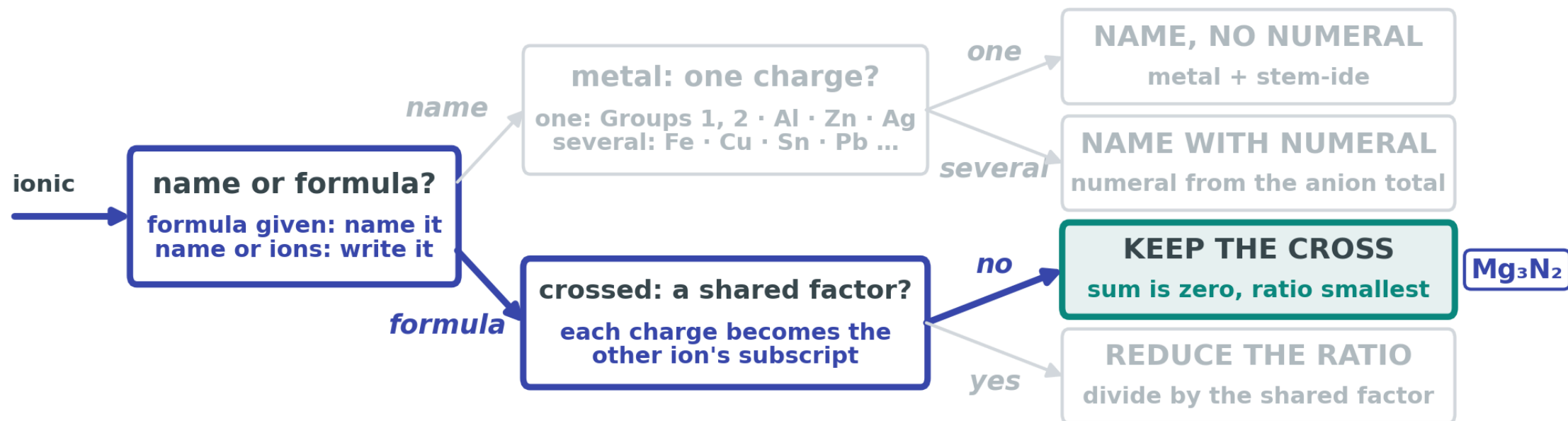
$3(+2) + 2(-3) = +6 - 6 = 0 \checkmark$ · 3 and 2 share no common factor

 **Sense check:** The formula sums to zero charge, in the smallest whole numbers that do it.

✓ Worked example 2: the route on the map

magnesium nitride: Mg_3N_2

formula wanted · Mg^{2+} and N^{3-} cross to 3 and 2 · no shared factor → keep



🧠 **Sense check:** Unequal charges, no shared factor: the crossed subscripts are already the smallest ratio. ✓

Your turn: calcium sulfide

calcium sulfide
wanted: the formula

step	question	answer
1 · classify the compound	metal + nonmetal?	ionic
2 · identify the ions	both fixed: charges from periodic position	Ca_____ and S_____
3 · balance the charges to zero	the criss-cross gives Ca_2S_2 : is that the smallest ratio?	_____
4 · assemble the answer		_____

Complete the formula.

calcium sulfide → CaS

$1(+2) + 1(-2) = 0 \checkmark$ · Ca_2S_2 reduces: a formula unit is the smallest ratio of ions, not a molecule

Where this goes wrong

Greek prefixes on an ionic compound. CaCl_2 is calcium chloride, never calcium dichloride. Prefixes count atoms in molecular compounds. An ionic subscript comes from charge balance and is not spoken.

A Roman numeral on a fixed-charge metal. Sodium(I) chloride and calcium(II) bromide are never written. The numeral appears only when the metal has more than one possible charge.

Writing each ion's own charge as its own subscript. Al^{3+} with Cl^- is not Al_3Cl : $3(+3) + 1(-1) = +8$, not neutral. Cross the charges instead: AlCl_3 , $1(+3) + 3(-1) = 0$.

Stopping before the smallest ratio. The criss-cross on Mg^{2+} and O^{2-} gives Mg_2O_2 , and $2(+2) + 2(-2) = 0$ balances. A formula unit is the smallest whole-number ratio: MgO .



Practice 1



sodium, a metal · oxygen, a nonmetal → ionic

Window glass is made from a melt containing Na_2O . What is the correct name for Na_2O ?

- A. sodium(II) oxide
- B. disodium monoxide
- C. sodium oxide
- D. sodium(I) oxide

✓ Practice 1 · answer: C

$\text{Na}_2\text{O} \rightarrow$ sodium oxide (answer C)

$2(+1) + 1(-2) = 0$ ✓ · Na: Group 1 $\rightarrow$ 1+, fixed

A read the subscript as a charge: sodium 2+ would give $2(+2) + 1(-2) = +2$, not neutral; the 2 counts Na^+ ions. B counts atoms with Greek prefixes, the naming system for molecular compounds. D writes a numeral for a metal with only one possible charge; numerals mark variable-charge metals only.

🧠 **Sense check:** Na^+ and O^{2-} reach zero charge only as 2 : 1, so the name needs no number.



Worked example 3: Cu_2O

Step 1 • Classify the compound



copper, a metal • oxygen, a nonmetal → ionic • wanted: the name

Cu_2O is the red pigment in antifouling boat paint. Copper is a variable-charge metal, so the name needs a Roman numeral.

A common first attempt: read the subscript 2 as copper's charge: copper(II) oxide. Test it.

✓ Worked example 3: testing the first attempt



copper, a variable-charge metal · oxygen, a nonmetal → ionic · wanted: the name

A common first attempt

copper(II) oxide → each Cu would be 2+

$$2(+2) + 1(-2) = +2 \times, \text{ not neutral}$$

The subscript 2 counts copper ions. It is not a charge.

 **Sense check:** Cu_2O is neutral, so any name for it must balance to zero.

✓ Worked example 3: solution



copper, a variable-charge metal · oxygen, a nonmetal → ionic · wanted: the name

Step 2 · Identify the ions

Step 3 · Balance the charges to zero

$$\text{each Cu} = +2 \div 2 = 1+$$

$$2(+1) + 1(-2) = 0 \checkmark$$

Step 4 · Assemble the answer



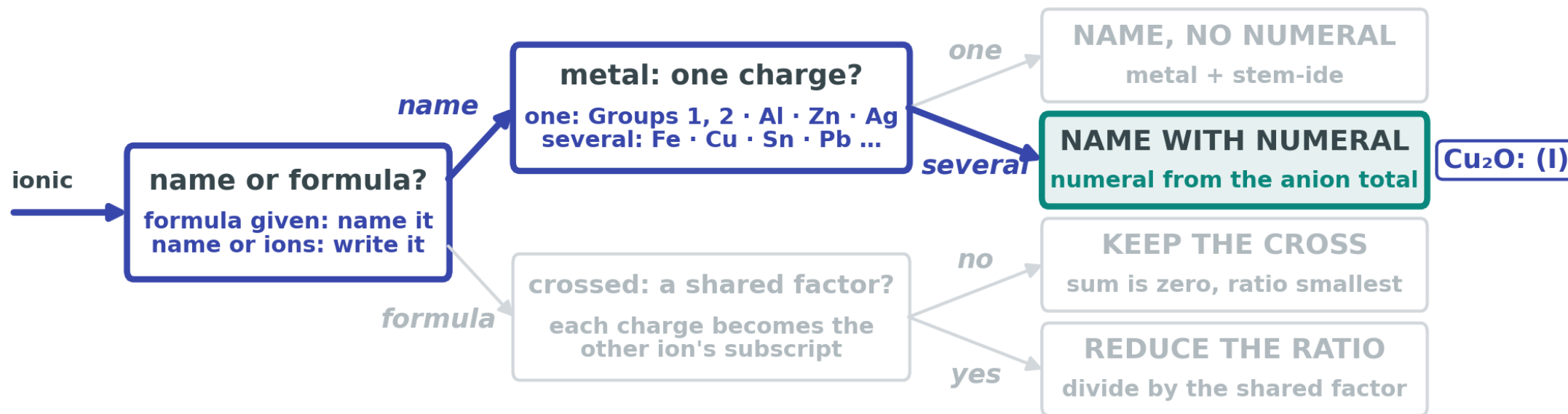
the numeral reports the charge on each Cu, 1+ · the subscript already counts the ions

 **Sense check:** Copper(II) oxide exists, and it is a different compound: CuO, where $1(+2) + 1(-2) = 0$. One numeral, one formula.

✓ Worked example 3: the route on the map

Cu₂O: copper(I) oxide

name wanted · copper: several possible charges → numeral · O²⁻ total 2- ÷ 2 Cu = 1+ each



 **Sense check:** A variable-charge metal takes the second exit. The numeral comes from the anion total, never from a subscript. ✓



Practice 2



iron, a variable-charge metal · oxygen, a nonmetal → ionic

FeO gives green bottle glass its tint. What is the correct name for FeO?

- A. iron(II) oxide
- B. iron(III) oxide
- C. iron oxide
- D. iron monoxide

✓ Practice 2 · answer: A

FeO → iron(II) oxide (answer A)

$1(+2) + 1(-2) = 0$ ✓ · one O^{2-} demands 2+ from one Fe

B recycles the 3+ from rust: here $1(+3) + 1(-2) = +1$, not neutral; the numeral must balance this formula. C omits the numeral: iron has more than one possible charge, so "iron oxide" cannot separate FeO from Fe_2O_3 . D counts atoms with a Greek prefix, the system for molecular compounds.

 **Sense check:** The numeral is settled one compound at a time: FeO holds Fe^{2+} , and Fe_2O_3 holds Fe^{3+} .



Worked example 4: tin(IV) oxide

Step 1 · Classify the compound

tin(IV) oxide

tin, a metal · oxide, a nonmetal anion → ionic · wanted: the formula

Tin(IV) oxide is the polishing powder sold as putty powder. The Roman numeral hands over the cation's charge. Write the formula.

✓ Worked example 4: solution

tin(IV) oxide

a metal with a nonmetal → ionic · wanted: the formula

Step 2 · Identify the ions

Step 3 · Balance the charges to zero

criss-cross: $\text{Sn}_2\text{O}_4 \cdot 2(+4) + 4(-2) = 0 \checkmark$ · 2 and 4 share a factor of 2

a formula unit is a ratio of ions, not a molecule → divide both subscripts by 2

Step 4 · Assemble the answer

tin(IV) oxide → SnO_2

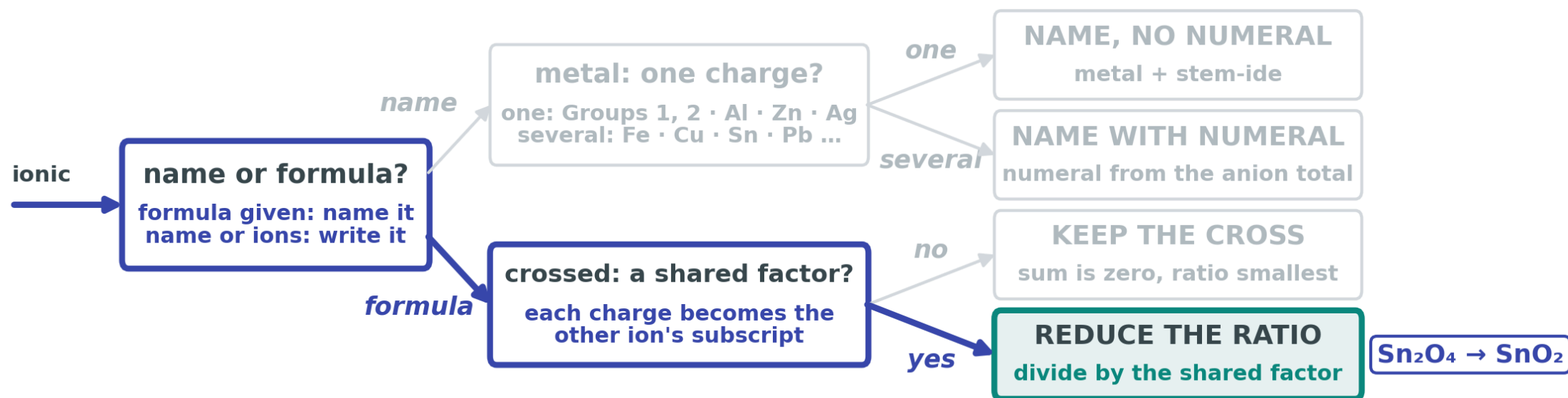
$1(+4) + 2(-2) = 0 \checkmark$ · smallest whole-number ratio

 **Sense check:** The numeral gave Sn^{4+} directly, and one 4+ cation balances exactly two 2– anions.

✓ Worked example 4: the route on the map

tin(IV) oxide: Sn_2O_4 reduces to SnO_2

formula wanted · Sn^{4+} from the numeral, O^{2-} · crossed 2 and 4 share a factor of 2 → reduce



🧠 **Sense check:** The bottom exit: crossing balances the charge, and reducing makes the ratio smallest. ✓

Take-home: when a formula reduces

ionic: $\text{Sn}_2\text{O}_4 \rightarrow \text{SnO}_2 \cdot \text{Mg}_2\text{O}_2 \rightarrow \text{MgO}$

a formula unit is the smallest ratio of ions $\rightarrow$ always reduce

molecular: N_2O_4 stays N_2O_4 · polyatomic groups: SO_4^{2-} never changes

a molecular formula counts the atoms in one real molecule · a polyatomic ion is one fixed unit

Reduce an ionic formula unit to the smallest ratio. Never reduce a molecular formula, and never change the subscripts inside a polyatomic group.



Practice 3

tin(IV) fluoride

tin, a metal · fluoride, F^- · wanted: the formula

Tin burns in fluorine gas to give tin(IV) fluoride, a white solid. Write the formula.

- A. Sn_4F
- B. SnF_2
- C. SnF
- D. SnF_4

✓ Practice 3 · answer: D

tin(IV) fluoride → SnF_4 (answer D)

$1(+4) + 4(-1) = 0$ ✓ · the numeral gives Sn^{4+} · 4 and 1 share no factor

B balances a different cation: $1(+2) + 2(-1) = 0$ holds for Sn^{2+} , so SnF_2 is tin(II) fluoride, the stannous fluoride on toothpaste labels. C pairs one of each ion: $1(+4) + 1(-1) = +3$, not neutral. A writes the numeral as a count of tin atoms: $4(+4) + 1(-1) = +15$.

🧠 **Sense check:** The numeral is the charge on one Sn. Four 1– anions cancel it, so the 4 lands on fluorine.



Practice 4



four binary ionic compounds, each with a name

Which formula and name pair has an error?

- A. CuBr_2 , copper(I) bromide
- B. Fe_2S_3 , iron(III) sulfide
- C. AlN , aluminum nitride
- D. SrI_2 , strontium iodide

✓ Practice 4 · answer: A

CuBr₂: two Br[−] carry $2(-1) = -2 \rightarrow$ one Cu is 2+ $\rightarrow$ copper(II) bromide (answer A)
 $1(+2) + 2(-1) = 0$ ✓ · copper(I) fails: $1(+1) + 2(-1) = -1$ ✕

B is correct: three S^{2−} carry $3(-2) = -6$, split over two Fe, $6 \div 2 = 3+$ each; reading the subscript 2 as the charge gives the wrong numeral. C is correct: aluminum is fixed at 3+, $1(+3) + 1(-3) = 0$, so no numeral. D is correct: $1(+2) + 2(-1) = 0$, and strontium diiodide would borrow molecular prefixes.

 **Sense check:** A numeral reports each cation's charge, found from the anion total, never read off a subscript.

8 • Polyatomic Ions

Recognize the common polyatomic ions, name compounds that contain them, and build formulas with parentheses wherever a group is multiplied.

The names on the shelf



Baking soda's ingredient label reads sodium hydrogen carbonate. Household bleach lists sodium hypochlorite. Garden fertilizer lists ammonium nitrate. Everyday products; the labels name the chemistry inside.

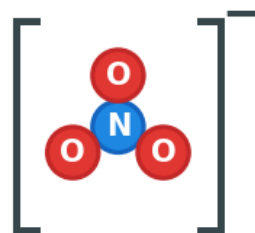
One group, one charge

the charge belongs to everything inside the bracket



Cl⁻ chloride

one atom, one 1- charge



NO₃⁻ nitrate

four bonded atoms, one 1- charge

A **polyatomic ion** is a bonded group of atoms with one overall charge. Nitrate holds one electron more than its atoms brought: that extra electron is the 1-. The group travels as one unit.

The common polyatomic ions

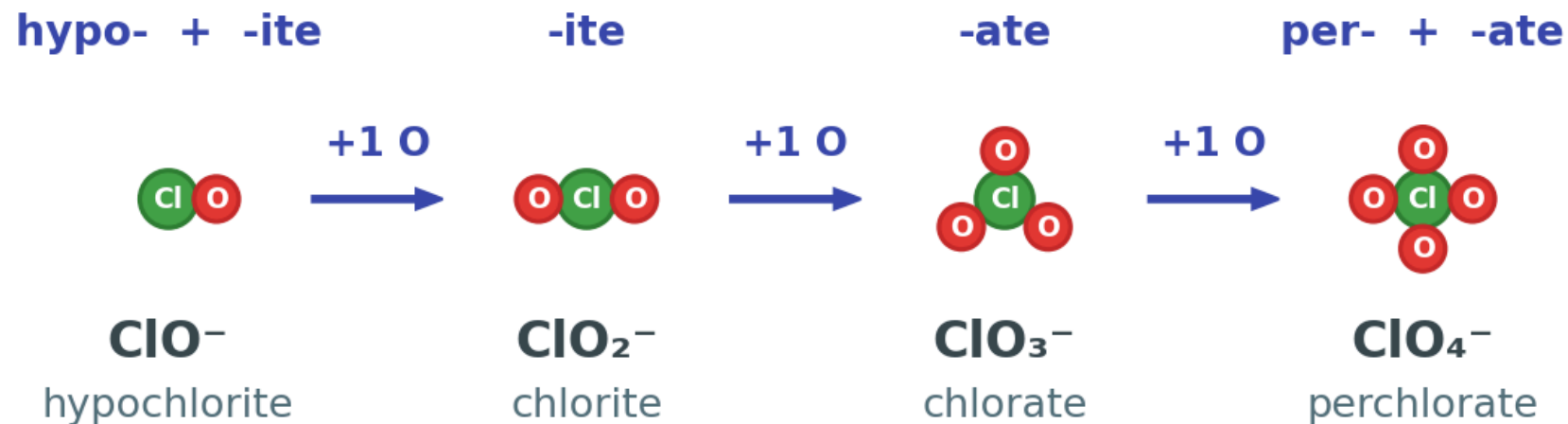
Each formula is memorized with its charge. Together they are the ion's identity.

OH^- hydroxide · NO_3^- nitrate · NO_2^- nitrite · ClO_3^- chlorate · HCO_3^- hydrogen carbonate
charge 1– · the largest family

SO_4^{2-} sulfate · SO_3^{2-} sulfite · CO_3^{2-} carbonate · CrO_4^{2-} chromate
charge 2–

PO_4^{3-} phosphate · NH_4^+ ammonium
phosphate: charge 3– · ammonium: 1+, the one common polyatomic cation

-ate and -ite: the oxygen count



the oxygen count changes · the 1– charge never does

Suffixes and prefixes report oxygen count, never charge. **-ate** marks the higher count, **-ite** one fewer; **per-** (over) sits one above -ate, **hypo-** (under: hypodermic) one below -ite. The whole chlorine series carries 1–.

Two patterns carry the list

the "7" shape

B	C	N	O	F
Al	Si	P	S	Cl
Ga	Ge	As	Se	Br
In	Sn	Sb	Te	I

on the 7: -ate holds 3 O

$\text{CO}_3^{2-} \cdot \text{NO}_3^- \cdot \text{ClO}_3^- \cdot \text{BrO}_3^- \cdot \text{IO}_3^-$

inside the bend: -ate holds 4 O

$\text{PO}_4^{3-} \cdot \text{SO}_4^{2-} \cdot \text{AsO}_4^{3-} \cdot \text{SeO}_4^{2-}$

two regions, two oxygen counts: the table carries half the memorizing

$\text{Cl}^- \text{ 1-} \rightarrow \text{ClO}_3^- \text{ 1-} \cdot \text{S}^{2-} \text{ 2-} \rightarrow \text{SO}_4^{2-} \text{ 2-} \cdot \text{P}^{3-} \text{ 3-} \rightarrow \text{PO}_4^{3-} \text{ 3-}$

the -ate ion keeps the monatomic anion's charge · exception: nitrate NO_3^- carries 1–

Table position sets the oxygen count; the -ate charge usually matches the monatomic anion. Nitrogen is the exception. Labels write bicarbonate for hydrogen carbonate.



The method

1. **Identify the ions.** Recall each ion's atoms and charge from the memorized list.
2. **Balance the charges to zero.** Smallest counts that sum to zero.
3. **Write the formula or the name.** Cation first; parentheses around a repeated polyatomic; no prefixes.



Worked example 1: naming K_2CO_3

K_2CO_3 : potash, a traditional glassmaking ingredient
given: the formula · wanted: the name

Potash lowers the melting point of the sand in a glass furnace. Name the compound.

✓ Worked example 1: solution



given: the formula · wanted: the name

Step 1 · Identify the ions

Step 2 · Balance the charges to zero



charge: $2(+1) + 1(-2) = 0$ ✓ · the split is consistent

Step 3 · Write the formula or the name



not "dipotassium carbonate": charge balance already fixes the counts

 **Sense check:** The name carries no numbers. The memorized charges rebuild them: reaching zero requires two K^+ for one CO_3^{2-} .

✓ Worked example 1: the route on the map



given: the formula · found: the name

1 · Identify the ions

METAL ION

K^+ · Group 1

MEMORIZED LIST

CO_3^{2-} carbonate

2 · Balance the charges to zero

BALANCE TO ZERO

$$2(+1) + 1(-2) = 0$$

3 · Write the formula or the name

NAME

potassium carbonate

PARENTHESES

a group taken 2 or more times

NO PARENTHESES

every group taken once



Sense check: Carbonate comes from the memorized list. The name exit carries no numbers. ✓



Worked example 2: magnesium nitrate

magnesium nitrate: a nitrogen source in fertilizers

given: the name · wanted: the formula

Write the formula. A common first attempt: MgNO_{32} . Test it.

✓ Worked example 2: balancing the charges

magnesium nitrate

given: the name · wanted: the formula

A common first attempt



reads as one N and one O_{32} : a 32-oxygen subscript, no nitrate group left ✗

Step 1 · Identify the ions

Step 2 · Balance the charges to zero

$$1(+2) + 1(-1) = +1 \text{ ✗} \quad \cdot \quad 1(+2) + 2(-1) = 0 \text{ ✓}$$

one nitrate leaves +1 → one Mg^{2+} needs two NO_3^-

 **Sense check:** The count of each ion may change; the charge on each ion may not. Two nitrates cancel one Mg^{2+} .

✓ Worked example 2: writing the formula

magnesium nitrate = Mg^{2+} with two NO_3^-

charge: $1(+2) + 2(-1) = 0$ ✓

Step 3 • Write the formula or the name



atoms: 1 Mg · 2 N · 2 × 3 = 6 O · the 2 multiplies everything inside

🧠 **Sense check:** The charges sum to zero, and each nitrate stays whole inside its parentheses.

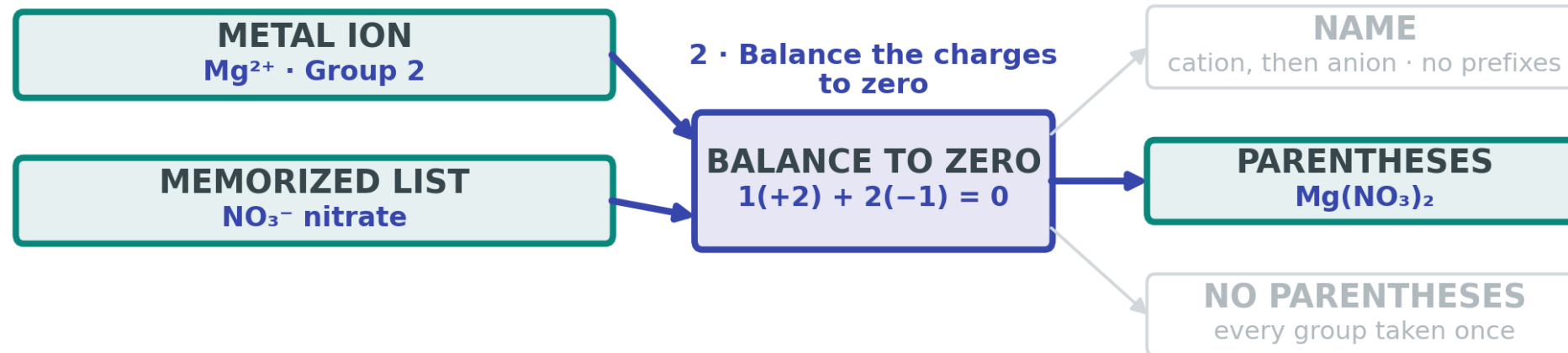
✓ Worked example 2: the route on the map

magnesium nitrate $\rightarrow \text{Mg}^{2+} + 2 \text{NO}_3^- \rightarrow \text{Mg}(\text{NO}_3)_2$

given: the name · found: the formula

1 · Identify the ions

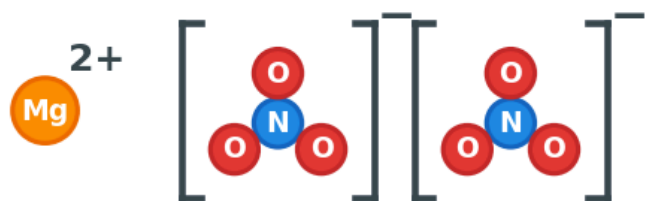
3 · Write the formula or the name



🧠 **Sense check:** Nitrate is taken twice, so the route ends at the parentheses. ✓

Take-home: parentheses keep the group whole

the outside subscript multiplies the whole group



1 Mg · 2 N · 6 O

✓ two complete nitrate units



the subscripts run together:

one N, thirty-two O

no nitrate group in sight

✗ not magnesium nitrate

A subscript outside parentheses multiplies everything inside. $\text{Mg}(\text{NO}_3)_2$ holds 1 Mg, 2 N, and 6 O. A polyatomic ion taken more than once is always written in parentheses.

Your turn: calcium hydroxide

calcium hydroxide: slaked lime, the base in mortar and plaster

given: the name · wanted: the formula

step	question	answer
1 · identify the ions	cation and anion?	Ca^{2+} and _____
2 · balance the charges to zero	$1(+2) + \text{_____}(-1) = 0$	_____ hydroxides
3 · write the formula or the name	parentheses needed?	_____

Complete the three steps.



charge: $1(+2) + 2(-1) = 0 \checkmark$ · atoms: 1 Ca · 2 O · 2 H

 **Sense check:** Hydroxide is 1−, so two groups balance one Ca^{2+} . The parentheses keep each OH whole.

⚠ Where this goes wrong

Reading -ite as a different charge. Sulfate SO_4^{2-} and sulfite SO_3^{2-} both carry 2-. The suffix changes the oxygen count, never the charge.

Borrowing another ion's charge. Nitrate is NO_3^- , never NO_3^{2-} : the 2- belongs to carbonate and sulfate. The charge is part of each ion's memorized identity.

Dropping the parentheses. CaOH_2 shows 1 O and 2 H. Calcium hydroxide holds two whole OH^- groups: $\text{Ca}(\text{OH})_2$, with 2 O and 2 H.

Adding counting prefixes to the name. $\text{Mg}(\text{NO}_3)_2$ is magnesium nitrate, never magnesium dinitrate. Charge balance already fixes the counts; counting prefixes belong to molecular compounds, the next section.



Practice 1

KClO_4 : K^+ with one ion from the chlorine series
given: the formula · wanted: the name

Fireworks carry KClO_4 as their oxygen supply. Name the compound.

- A. potassium chlorite
- B. potassium chloride
- C. potassium chlorate
- D. potassium perchlorate

✓ Practice 1 · answer: D

$\text{KClO}_4 \rightarrow$ potassium perchlorate (answer D)

K^+ and ClO_4^- · one oxygen above chlorate, ClO_3^- · charge: $1(+1) + 1(-1) = 0$ ✓

Four oxygens is one above the -ate member of the chlorine series: per- + chlorate. C, chlorate, is ClO_3^- , one oxygen fewer. A, chlorite, is ClO_2^- , two fewer. B, chloride, is Cl^- , a monatomic ion with no oxygen at all.

 **Sense check:** Only the oxygen count separates these four names. Every choice pairs one K^+ with one 1- anion, so the charge test cannot pick the name; the memorized series does.

Worked example 3: ammonium phosphate

ammonium phosphate: a fertilizer supplying nitrogen and phosphorus at once
given: the name · wanted: the formula · both ions polyatomic

Write the formula. Both ions come from the memorized list.

✓ Worked example 3: solution

ammonium phosphate

given: the name · wanted: the formula

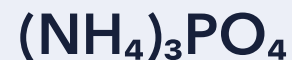
Step 1 · Identify the ions

Step 2 · Balance the charges to zero

$$1(+1) + 1(-3) = -2 \times \cdot 3(+1) + 1(-3) = 0 \checkmark$$

one PO_4^{3-} needs three NH_4^+

Step 3 · Write the formula or the name



atoms: $3 \times 1 = 3 \text{ N} \cdot 3 \times 4 = 12 \text{ H} \cdot 1 \text{ P} \cdot 1 \times 4 = 4 \text{ O}$

 **Sense check:** The charges sum to zero, and both groups stay intact on the page: three whole ammoniums, one whole phosphate.

✓ Worked example 3: the route on the map

ammonium phosphate $\rightarrow 3 \text{NH}_4^+ + \text{PO}_4^{3-} \rightarrow (\text{NH}_4)_3\text{PO}_4$

given: the name · found: the formula

1 · Identify the ions

METAL ION

group charge, or the Roman numeral

MEMORIZED LIST

NH_4^+ ammonium · PO_4^{3-} phosphate

2 · Balance the charges to zero

BALANCE TO ZERO

$$3(+1) + 1(-3) = 0$$

3 · Write the formula or the name

NAME

cation, then anion · no prefixes

PARENTHESES

$(\text{NH}_4)_3\text{PO}_4$

NO PARENTHESES

every group taken once

🧠 **Sense check:** No metal: both ions come from the memorized list. Three ammoniums put NH_4 in parentheses. ✓



Practice 2

ammonium sulfate: a lawn fertilizer

NH_4^+ , charge 1+ · SO_4^{2-} , charge 2– · wanted: the formula

Write the formula for ammonium sulfate.

- A. NH_4SO_4
- B. $(\text{NH}_4)_2\text{SO}_4$
- C. $(\text{NH}_4)_2\text{SO}_3$
- D. $\text{NH}_4(\text{SO}_4)_2$

✓ Practice 2 · answer: B



$$\text{charge: } 2(+1) + 1(-2) = 0 \checkmark \cdot \text{atoms: } 2 \text{ N} \cdot 2 \times 4 = 8 \text{ H} \cdot 1 \text{ S} \cdot 4 \text{ O}$$

A stops at one of each: $1(+1) + 1(-2) = -1$, not zero. C balances its charges, $2(+1) + 1(-2) = 0$, but holds sulfite, SO_3^{2-} (the -ite ion, one oxygen fewer). D doubles the wrong ion: $1(+1) + 2(-2) = -3$.

 **Sense check:** Two 1+ cations cancel one 2– anion, and the repeated polyatomic, ammonium, takes the parentheses.



Worked example 4: aluminum sulfate

aluminum sulfate: the coagulant that clears drinking water

given: the name · wanted: the formula · Al^{3+} with a polyatomic anion

Write the formula. A common first attempt criss-crosses the 3 into the group itself: $\text{Al}_2\text{SO}_{12}$.
Test it.

✓ Worked example 4: testing the first attempt

aluminum sulfate

given: the name · wanted: the formula

A common first attempt



the 3 crossed into the group: $3 \times 4 = 12$ O on one S · SO_{12} is not sulfate ×

Crossing into the group destroys it. Sulfate is one fixed unit: SO_4^{2-} , four O, charge 2–.

 **Sense check:** A criss-crossed number may never change the inside of a polyatomic group.

✓ Worked example 4: solution

aluminum sulfate

given: the name · wanted: the formula

Step 1 · Identify the ions

Step 2 · Balance the charges to zero

$$2(+3) + 3(-2) = 0 \checkmark$$

criss-cross: the 2 counts Al^{3+} , the 3 counts SO_4^{2-} groups

Step 3 · Write the formula or the name



atoms: 2 Al · 3 S · 3 × 4 = 12 O · 2 and 3 share no factor

 **Sense check:** Three 2– groups cancel two 3+ ions, and each sulfate rides along whole inside its parentheses.

✓ Worked example 4: the route on the map



given: the name · found: the formula

1 · Identify the ions

METAL ION

Al^{3+} · Group 13

MEMORIZED LIST

SO_4^{2-} sulfate

2 · Balance the charges to zero

BALANCE TO ZERO

$$2(+3) + 3(-2) = 0$$

3 · Write the formula or the name

NAME

cation, then anion · no prefixes

PARENTHESES

$\text{Al}_2(\text{SO}_4)_3$

NO PARENTHESES

every group taken once

 **Sense check:** The criss-cross lives in Step 2. The parentheses keep the 4 inside sulfate untouched. ✓



Practice 4

iron(III) sulfite

iron, a variable-charge metal · wanted: the formula

Write the formula for iron(III) sulfite.

- A. $\text{Fe}_2(\text{SO}_4)_3$
- B. FeSO_3
- C. $\text{Fe}_3(\text{SO}_3)_2$
- D. $\text{Fe}_2(\text{SO}_3)_3$
- E. $\text{Fe}_2\text{S}_3\text{O}_9$

✓ Practice 4 · answer: D

Fe^{3+} and $\text{SO}_3^{2-} \cdot 2(+3) + 3(-2) = 0 \checkmark \rightarrow \text{Fe}_2(\text{SO}_3)_3$ (answer D)

(III) $\rightarrow \text{Fe}^{3+}$ · sulfite: one O fewer than sulfate, same 2- · atoms: 2 Fe · 3 S · 3 × 3 = 9 O

A kept the -ate: $\text{Fe}_2(\text{SO}_4)_3$ is iron(III) sulfate. B pairs one of each: $1(+3) + 1(-2) = +1$; FeSO_3 balances only with Fe^{2+} , iron(II) sulfite. C writes each ion's own charge as its own subscript: $3(+3) + 2(-2) = +5$. E multiplies the 3 through: $\text{Fe}_2\text{S}_3\text{O}_9$ has the atoms but no sulfite group left.

 **Sense check:** Three 2- groups cancel two 3+ ions, and each sulfite stays whole inside its parentheses.

9 • Naming Molecular Compounds and Acids

Decide whether a compound is ionic, molecular, or an acid, then build its name with that system's rules, or rebuild the formula from the name.

One atom apart

the furnace gas



deadly: an alarm in every home

the soda gas



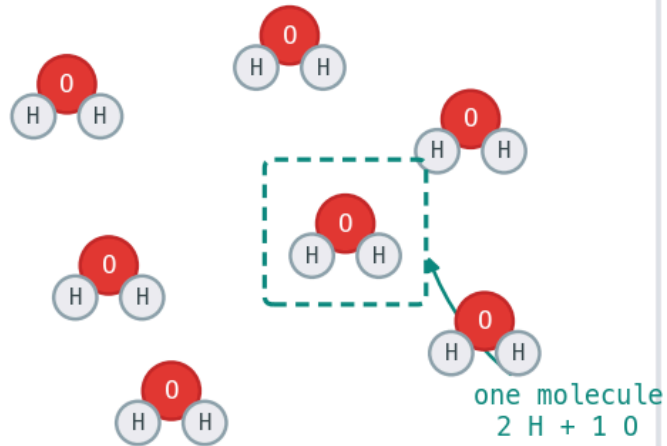
harmless: the fizz in every soda

the same two elements, one oxygen atom apart

A faulty furnace releases a deadly gas; homes carry an alarm for it. The fizz in soda is a different gas made of the same two elements.

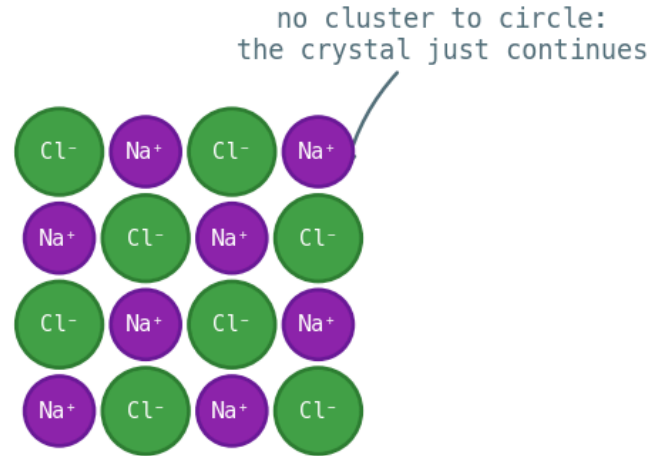
What a molecule is

water · H_2O



discrete clusters: each one complete on its own

table salt · NaCl



formula unit NaCl : the 1 : 1 ratio of ions

A molecule is a discrete cluster of nonmetal atoms held together by covalent bonds: shared pairs of electrons. An ionic compound contains no molecules; its formula unit is the smallest ratio of ions.

Seven elements are molecules of two

hydrogen, off on its own

the seven diatomic elements

$H_2 \cdot N_2 \cdot O_2 \cdot F_2 \cdot Cl_2 \cdot Br_2 \cdot I_2$

every name ends in -gen or -ine:

hydroGEN · nitroGEN · oxyGEN
fluorINE · chlorINE · bromINE · iodINE

six draw a 7 on the table

1	2												13	14	15	16	17	18
1	H_2																	He
2	Li	Be											B	C	N_2	O_2	F_2	Ne
3	Na	Mg											Al	Si	P_4	S_8	Cl_2	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br_2	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I_2	Xe
6	Cs	Ba	57-71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	89-103	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

a sample of the pure element holds molecules of two

phosphorus and sulfur go larger: $P_4 \cdot S_8$

Free hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine, and iodine each occur as two-atom molecules; the names all end in -gen or -ine. One word holds all seven:

BrINClHOF.

The element alone vs the element in a compound

oxygen, by itself $\rightarrow \text{O}_2$

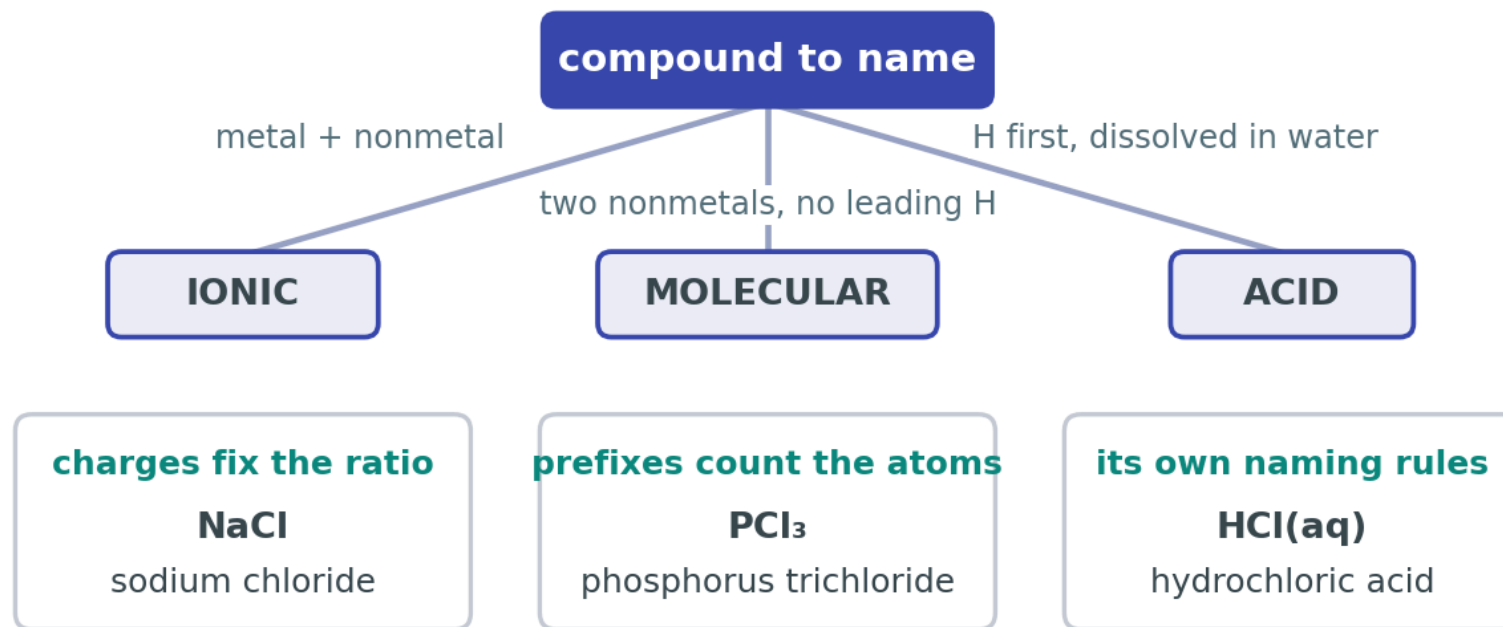
a sample of the pure element: every molecule is a pair

the oxygen in water $\rightarrow \text{H}_2\text{O}$

2 H + 1 O per molecule: no O_2 anywhere inside

A diatomic formula describes the free element only. Inside a compound, the compound's subscripts set every count. In a reaction equation, free oxygen enters as O_2 , never O.

The compound's type decides the name



Chemistry has three naming systems: ionic, molecular, acid. The type decides which applies; they never mix. A polyatomic ion makes a compound ionic even with no metal: NH4Cl is ammonium chloride, no counting prefixes.

Molecular compounds: prefixes count atoms

1 mono- · 2 di- · 3 tri- · 4 tetra- · 5 penta- · 6 hexa- · 7 hepta- · 8 octa- · 9 nona- · 10
deca-

mono- is dropped on the first element only · a prefix's final a or o drops before oxide: mono- + oxide →
monoxide

Two nonmetals form a molecular compound, and several ratios are often possible. The name carries the formula: a Greek prefix counts each element's atoms.

Acids: a category of their own

HCl(g) = hydrogen chloride, a gas · HCl(aq) = an acid
the same molecule; dissolved in water it releases H⁺

An acid is a compound that releases H⁺ when dissolved in water. Its formula starts with H and carries (aq). Acids get their own names, under their own rules.



The method

1. **Classify the compound.** H first, dissolved in water → acid. Metal present → ionic. Two nonmetals → molecular.
2. **Apply that system's rules.** One system per compound; rules never mix.
3. **Read the name back.** A correct name rebuilds the formula.



Worked example 1: CO and CO₂



the furnace gas: 1 C + 1 O · the soda gas: 1 C + 2 O

Both gases pair carbon with oxygen, one oxygen atom apart. Name each compound.

A common first attempt: name the elements and stop: carbon oxide. Test it.

✓ Worked example 1: solution



the furnace gas: 1 C + 1 O · the soda gas: 1 C + 2 O

A common first attempt

carbon oxide

fits CO and CO₂ equally: the name cannot rebuild either formula ✕

Step 1 · Classify the compound

Step 2 · Apply that system's rules

CO → carbon monoxide · CO₂ → carbon dioxide

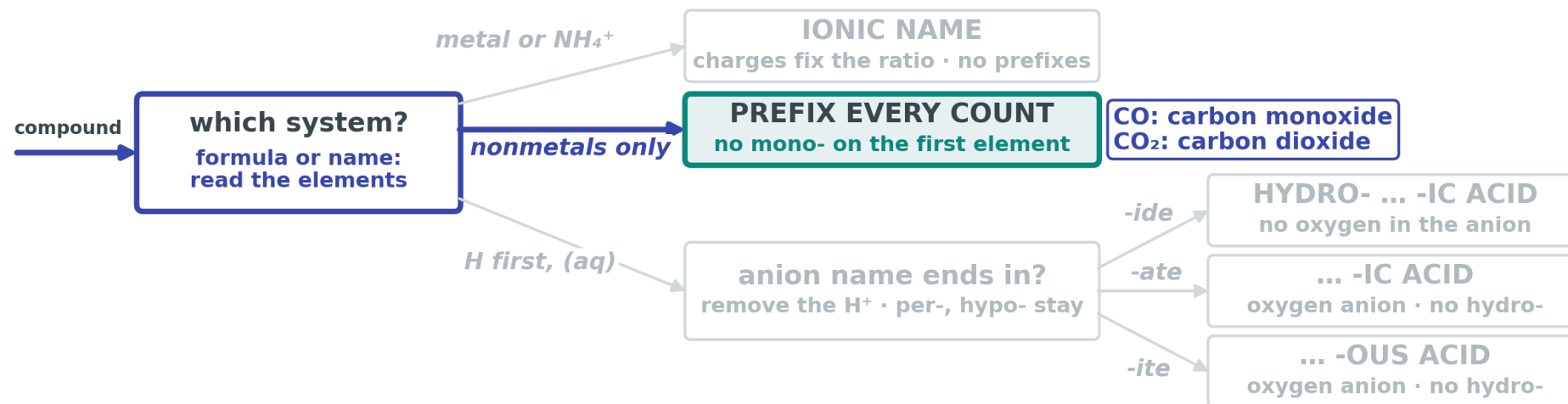
1 C: mono- dropped on the first element · mono- + oxide → monoxide · 2 O → dioxide

Step 3 · Read the name back

 **Sense check:** Two different gases, two different names. The prefix is the part of the name that keeps them apart.

✓ Worked example 1: the route on the map

CO → carbon monoxide · CO₂ → carbon dioxide
given: two formulas · found: two names



🧠 **Sense check:** Same branch, same rule, two counts: the prefix is the only part of the name that changes. ✓

Take-home: prefixes carry the formula

nitrogen + oxygen: $\text{NO} \cdot \text{NO}_2 \cdot \text{N}_2\text{O} \cdot \text{N}_2\text{O}_4$

four different compounds: "nitrogen oxide" fits every one X

Two nonmetals often combine in several ratios. A molecular name without prefixes loses the formula. Ionic names never need prefixes; molecular names always do.



Worked example 2: formula from the name

tetraphosphorus decoxide

given: the name · wanted: the formula

Tetraphosphorus decoxide is a laboratory drying agent, sold as a white powder. Write its formula.

✓ Worked example 2: solution

tetraphosphorus decoxide

given: the name · wanted: the formula

Step 1 · Classify the compound

Step 2 · Apply that system's rules

tetraphosphorus decoxide → P_4O_{10}

tetra- → 4 P · dec(a)- → 10 O, the a dropped before oxide

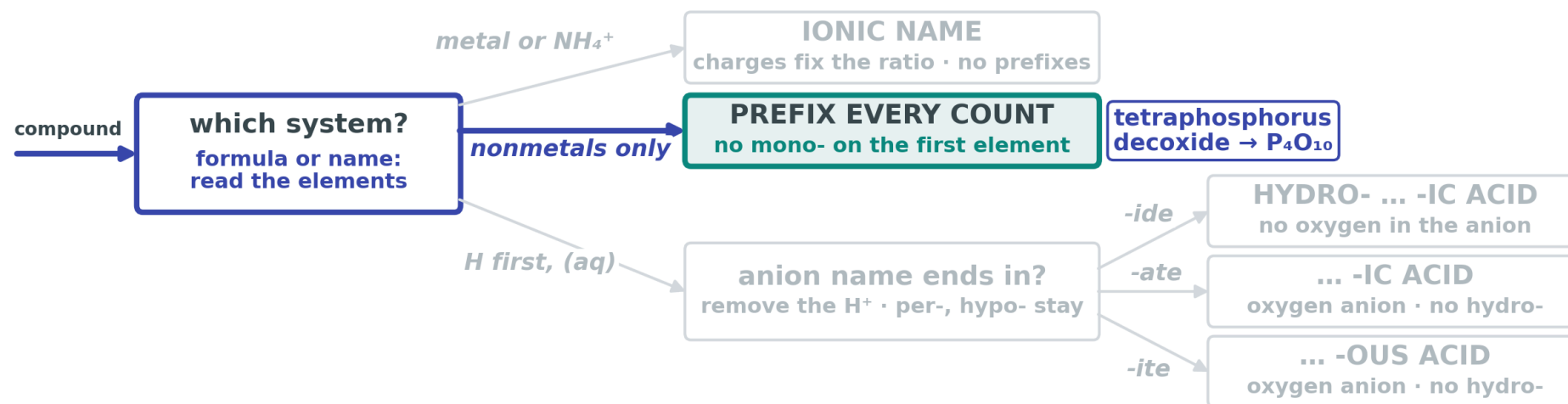
Step 3 · Read the name back

🧠 **Sense check:** Ten O for four P: the name counted every atom, so the formula keeps exactly those counts.

✓ Worked example 2: the route on the map

tetraphosphorus decoxide → P_4O_{10}

given: the name · found: the formula



 **Sense check:** The prefixes alone placed it on the molecular branch. Run backward, each prefix becomes a subscript. ✓

Your turn: Cl_2O_7



chlorine and oxygen: two nonmetals, no leading H

step	question	answer
1 · classify	acid, ionic, or molecular?	molecular → prefixes
2 · apply	2 Cl · 7 O: which prefixes?	_____chlorine _____oxide
3 · read back	does the name rebuild Cl_2O_7 ?	_____

Complete the name.

$\text{Cl}_2\text{O}_7 \rightarrow$ dichlorine heptoxide

di- → 2 Cl · hept(a)- → 7 O, the a drops before oxide · reads back to Cl_2O_7 ✓



Practice 1



nitrogen and oxygen: two nonmetals, no leading H

N_2O_3 is one of several oxides of nitrogen found in polluted air. What is the correct name for N_2O_3 ?

- A. nitrogen oxide
- B. dinitrogen trioxide
- C. trinitrogen dioxide
- D. nitrous acid

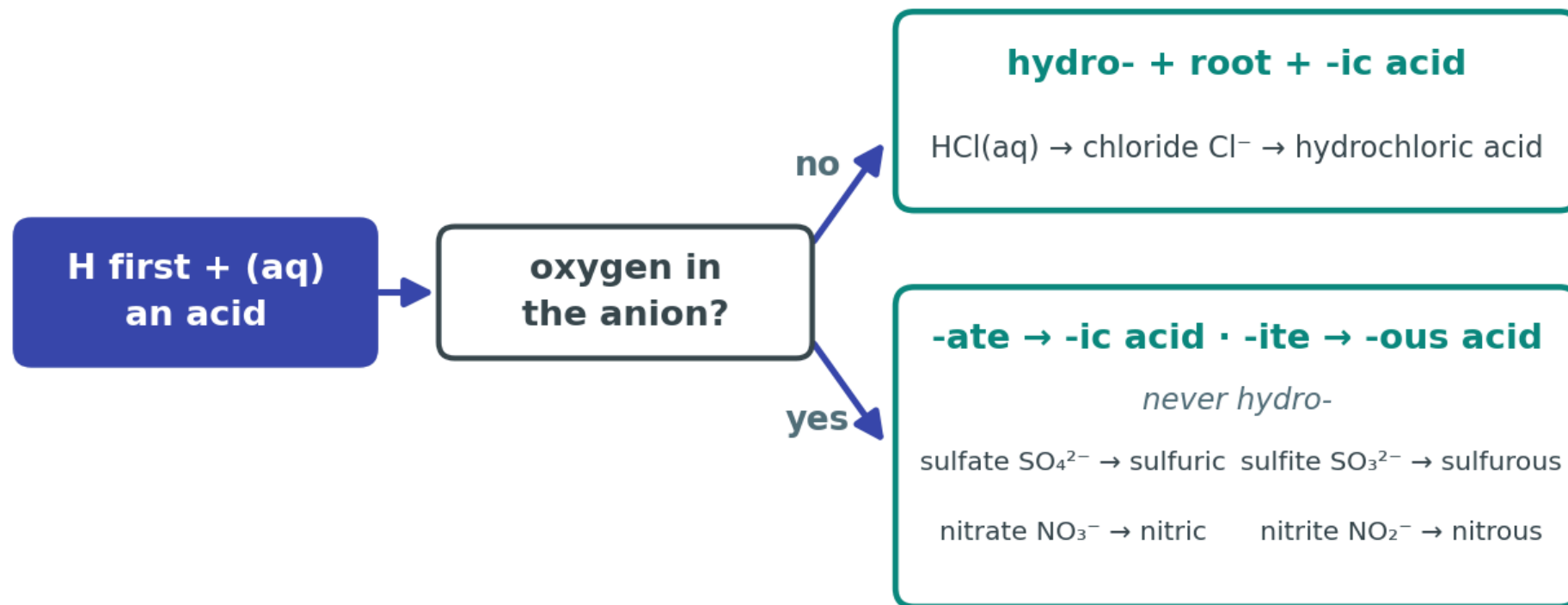
✓ Practice 1 · answer: B

$\text{N}_2\text{O}_3 \rightarrow$ dinitrogen trioxide (answer B)
two nonmetals $\rightarrow$ molecular · di- $\rightarrow$ 2 N · tri- $\rightarrow$ 3 O

A drops the prefixes, and NO, NO₂, N₂O, and N₂O₃ would all share that name: the formula is lost. C swaps the prefixes: trinitrogen dioxide rebuilds N₃O₂, a different compound. D uses an acid name, but nitrous acid is HNO₂ dissolved in water, and N₂O₃ contains no hydrogen.

 **Sense check:** Read the name back: di- and tri- rebuild N₂O₃ ✓. Each prefix counts its own element.

Acid names come from the anion



Remove the H and look at the anion. No oxygen: hydro- + root + -ic acid. Oxygen present: the anion's -ate becomes -ic, -ite becomes -ous, and hydro- never appears.



Worked example 3: two acids



both start with H · both dissolved in water

HCl(aq) cleans concrete; HNO₃(aq) is used to make fertilizer. Name each compound.

A common first attempt: hydro- on both: hydrochloric acid and hydronitric acid. Test it.

✓ Worked example 3: HCl(aq)



both start with H · both dissolved in water

Step 1 · Classify the compound

Step 2 · Apply that system's rules



anion: chloride, no oxygen $\rightarrow$ hydro- + chlor- + -ic acid

 **Sense check:** Without the water it is hydrogen chloride, a gas. The (aq) is what the acid name records.

✓ Worked example 3: $\text{HNO}_3(\text{aq})$



an acid · anion: NO_3^- , called nitrate; it holds three O

A common first attempt

hydronitric acid?

hydro- reads back to an anion with no oxygen; NO_3^- holds three X

Step 2 · Apply that system's rules



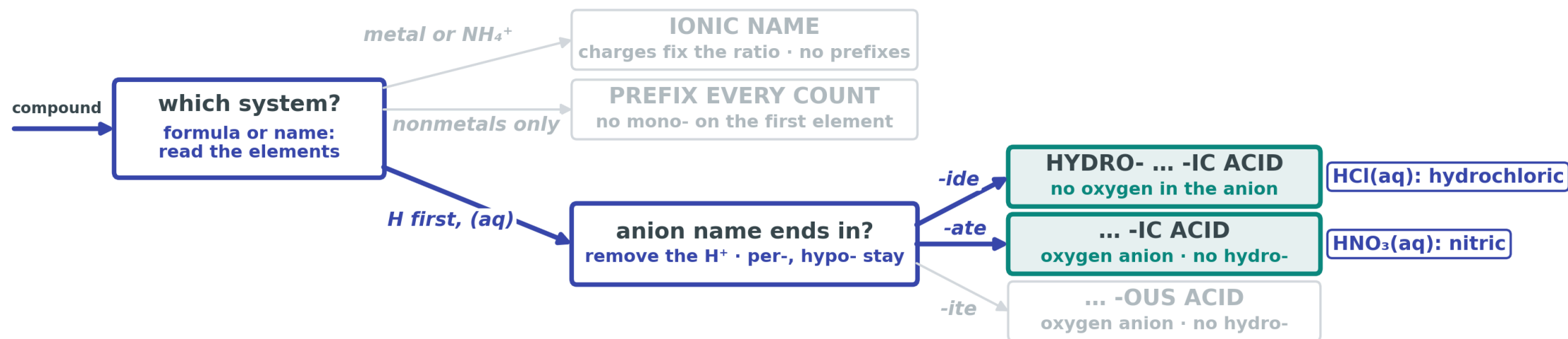
anion: nitrate → -ate becomes -ic · no hydro-

Step 3 · Read the name back

 **Sense check:** Oxygen in the anion picks the rule. Nitrate holds three O, so the name takes no hydro-.

✓ Worked example 3: the route on the map

$\text{HCl(aq)} \rightarrow \text{hydrochloric acid} \cdot \text{HNO}_3(\text{aq}) \rightarrow \text{nitric acid}$
 given: two acids · found: two names



🧠 **Sense check:** Both took the acid branch. The anion's ending split them: chloride $\rightarrow$ hydro-...-ic, nitrate $\rightarrow$...-ic. ✓

Take-home: hydro- means no oxygen

$\text{H}_2\text{S}(\text{aq}) \rightarrow$ hydrosulfuric acid

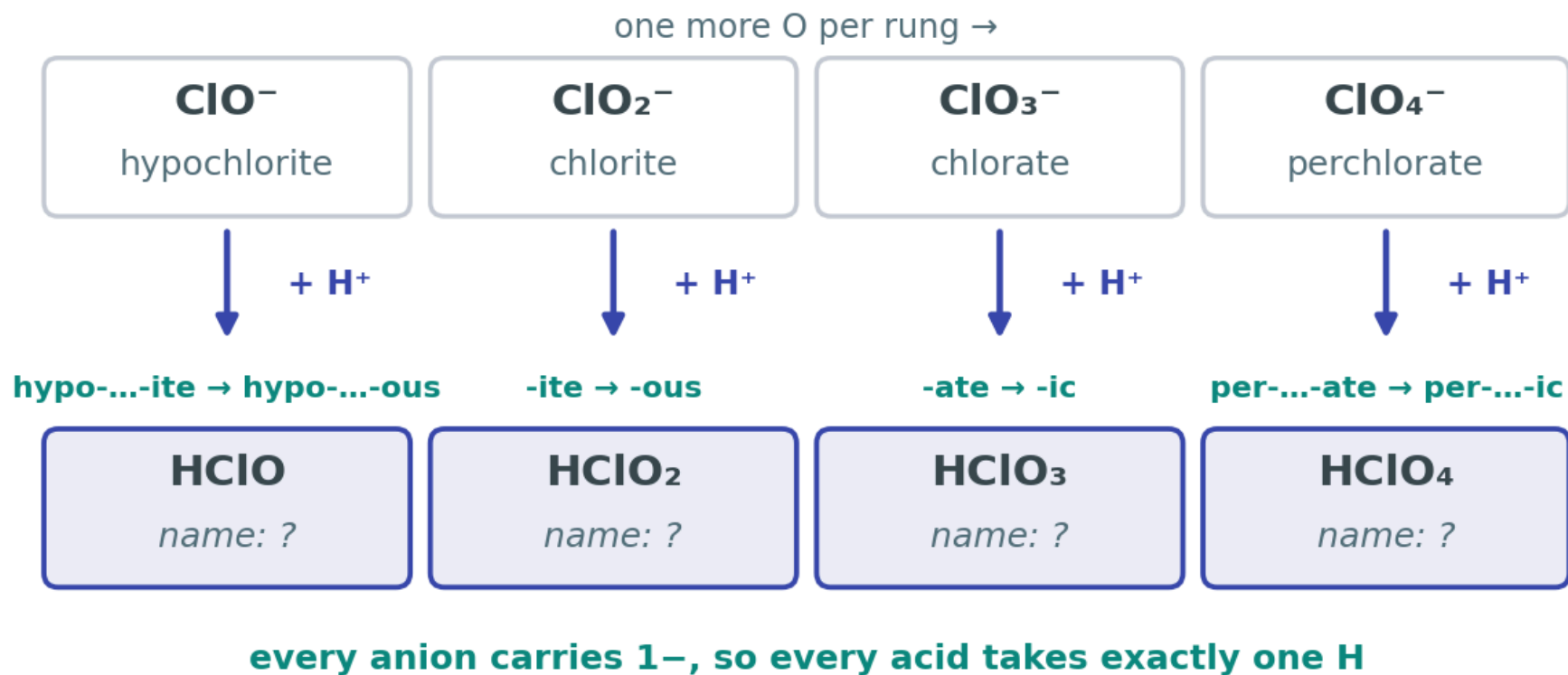
anion: sulfide, S^{2-} · no oxygen $\rightarrow$ hydro- + -ic

$\text{H}_2\text{SO}_4(\text{aq}) \rightarrow$ sulfuric acid · $\text{H}_2\text{SO}_3(\text{aq}) \rightarrow$ sulfurous acid

sulfate $\text{SO}_4^{2-} \rightarrow$ -ic · sulfite $\text{SO}_3^{2-} \rightarrow$ -ous · no hydro- on either

Hydro- appears only when the anion has no oxygen. With oxygen, the anion's suffix sets the acid's suffix: -ate $\rightarrow$ -ic, -ite $\rightarrow$ -ous. I ATE something ICky; spr-ITE is delici-OUS.

The oxyacid ladder



Every rung of the oxyanion ladder makes an acid. Per- and hypo- pass into the acid name unchanged; only the tail maps: -ate becomes -ic, -ite becomes -ous.

⚠ Where this goes wrong

Prefixes on an ionic compound. MgCl_2 is magnesium chloride, never magnesium dichloride. A metal is present, so charges fix the ratio; prefixes belong to molecular names.

Swapped prefixes. Each prefix counts its own element's atoms. Tetranitrogen dioxide rebuilds N_4O_2 ; the compound N_2O_4 is dinitrogen tetroxide.

An acid name without hydrogen. SO_3 is not sulfuric acid: sulfuric acid is $\text{H}_2\text{SO}_4(\text{aq})$. No leading H and no water: SO_3 is the molecular compound sulfur trioxide.

-ate mapped to -ous. Sulfate $\rightarrow$ sulfuric, sulfite $\rightarrow$ sulfurous. Naming $\text{H}_2\text{SO}_4(\text{aq})$ "sulfurous acid" points at the wrong compound: sulfurous acid is $\text{H}_2\text{SO}_3(\text{aq})$, built on sulfite.

 Practice 2

H first · dissolved in water

HF dissolved in water etches patterns into glass. What is the correct name for HF(aq)?

- A. hydrogen fluoride
- B. fluoric acid
- C. hydrofluoric acid
- D. hydrogen monofluoride

✓ Practice 2 · answer: C

HF(aq) → hydrofluoric acid (answer C)

an acid · anion: fluoride, F^- · no oxygen → hydro- + fluor- + -ic acid

A names the pure gas, HF(g); the (aq) marks a dissolved acid with its own name. B drops hydro-: without it the name reads as an oxyacid, and fluoride holds no oxygen. D uses counting prefixes, and prefixes never appear in acid names.

 **Sense check:** Read the name back: hydro- marks a no-oxygen anion, fluoride ✓. The name rebuilds HF(aq).



Worked example 4: sulfurous acid

sulfurous acid

given: the name · wanted: the formula

Sulfurous acid forms wherever sulfur dioxide meets water, including in acid rain. Write the formula.

✓ Worked example 4: solution

sulfurous acid

given: the name · wanted: the formula

Step 1 · Classify the compound

Step 2 · Apply that system's rules



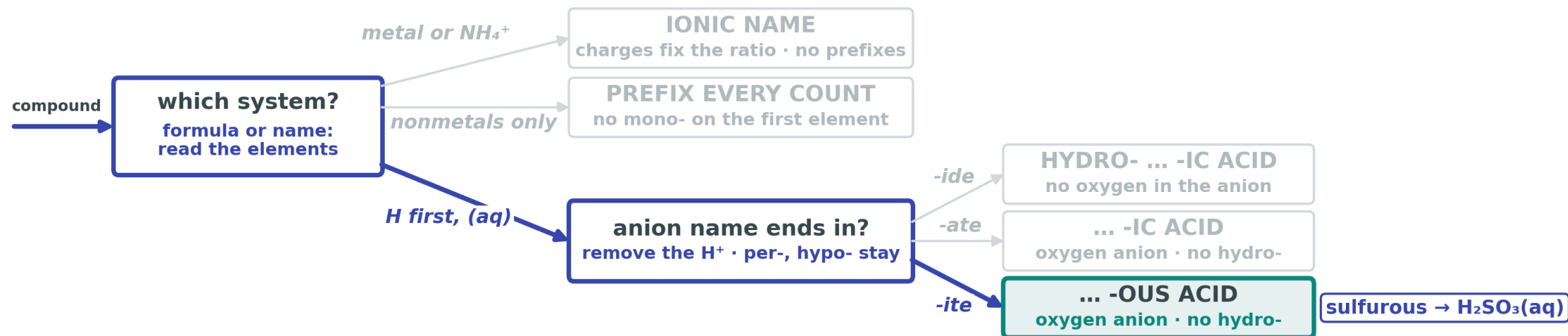
a 2– anion takes exactly two H^+ · the name never states the 2; balance rebuilds it

Step 3 · Read the name back

 **Sense check:** The H count was never memorized. The anion's charge fixes it, the same balance that fixes every ionic subscript.

✓ Worked example 4: the route on the map

sulfurous acid → $\text{H}_2\text{SO}_3(\text{aq})$
given: the name · found: the formula



🧠 **Sense check:** Run backward: -ous came from -ite. Sulfite, SO_3^{2-} , holds one O fewer than sulfate; its 2- sets two H.





Practice 3

phosphoric acid

an oxyacid · phosphate PO_4^{3-} , charge 3– · wanted: the formula

Phosphoric acid gives cola its bite. Write the formula.

- A. $\text{H}_3\text{PO}_3(\text{aq})$
- B. $\text{HPO}_4(\text{aq})$
- C. $\text{H}_2\text{PO}_4(\text{aq})$
- D. $\text{H}_3\text{PO}_4(\text{aq})$

✓ Practice 3 · answer: D

phosphoric acid $\rightarrow$ $\text{H}_3\text{PO}_4(\text{aq})$ (answer D)
-ic came from -ate: phosphate, $\text{PO}_4^{3-} \cdot 3(+1) + 1(-3) = 0$ ✓

B writes one H: $1(+1) + 1(-3) = -2$, not neutral. C writes two: $2(+1) + 1(-3) = -1$. A balances three H on the wrong rung: PO_3^{3-} is phosphite, and its acid is phosphorous acid, one rung down the ladder.

🧠 **Sense check:** A $3-$ anion takes exactly three H^+ . Wrong H counts fail the charge check on sight.

Hydrates: water inside the crystal

$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$: copper(II) sulfate pentahydrate

the dot attaches 5 water molecules to each formula unit · penta- counts them

heat drives the water off → CuSO_4 , anhydrous

anhydrous: the same salt with no attached water

Some ionic solids hold a fixed count of loosely attached water molecules. The name is the ionic name plus a counting prefix and hydrate.

 Worked example 5: $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$

$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$: Epsom salt, sold in every drugstore

given: the formula · wanted: the name

The dot carries seven water molecules per formula unit. Name the compound.

✓ Worked example 5: solution



given: the formula · wanted: the name

Step 1 · Classify the compound

Step 2 · Apply that system's rules

$\text{MgSO}_4 \rightarrow$ magnesium sulfate · $7 \text{H}_2\text{O} \rightarrow$ heptahydrate

$1(+2) + 1(-2) = 0 \checkmark$ · no numeral: Mg is fixed at 2+ · hepta- = 7

Step 3 · Read the name back

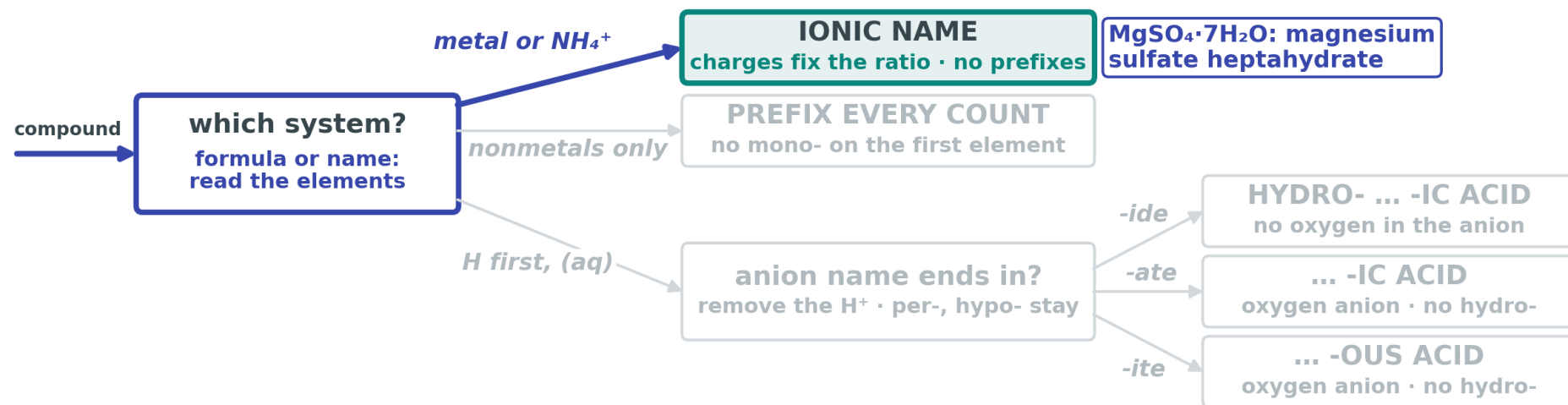
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O} \rightarrow$ magnesium sulfate heptahydrate

heptahydrate rebuilds exactly $\cdot 7\text{H}_2\text{O} \checkmark$

 **Sense check:** One name, two jobs: charge balance rebuilds the salt, and the prefix rebuilds the water count.

✓ Worked example 5: the route on the map

$\text{MgSO}_4 \cdot 7\text{H}_2\text{O} \rightarrow$ magnesium sulfate heptahydrate
given: the formula · found: the name



 **Sense check:** A metal is present: the ionic branch. The waters carry the only prefix in the name. ✓



Practice 5



four compounds, each with a name

Which formula and name pair has an error?

- A. N_2O_5 , dinitrogen pentoxide
- B. $\text{HI}(\text{aq})$, hydroiodic acid
- C. $\text{HClO}_3(\text{aq})$, chlorous acid
- D. $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, iron(III) chloride hexahydrate

✓ Practice 5 · answer: C

$\text{HClO}_3(\text{aq})$: anion ClO_3^- , chlorate $\rightarrow$ -ate becomes -ic $\rightarrow$ chloric acid (answer C)
chlorous acid is $\text{HClO}_2(\text{aq})$, built on chlorite $\cdot 1(+1) + 1(-1) = 0 \rightarrow$ one H ✓

A is correct: two nonmetals take prefixes, di- $\rightarrow$ 2 N, pent(a)- $\rightarrow$ 5 O; nitrogen(V) oxide would borrow the ionic numeral. B is correct: iodide holds no oxygen, so hydro- + iod- + -ic. D is correct: three Cl^- demand Fe^{3+} , $1(+3) + 3(-1) = 0$, and hexa- counts the 6 waters.

🧠 **Sense check:** The anion's suffix sets the acid's: chlorate $\rightarrow$ chloric, chlorite $\rightarrow$ chlorous.

10 · Organic Nomenclature Basics

Read a straight-chain alkane's name off its carbon count (and back again), write its molecular formula C_nH_{2n+2} , and recognize the common functional groups that set a molecule's family.

Carbon builds a whole language

three fuels · one carbon chain each

natural gas stove	1 CH₄	1 carbon
camp fuel	1 2 3 CH₃—CH₂—CH₃	3 carbons
gasoline	1 2 3 4 5 6 7 8 CH₃—CH₂—CH₂—CH₂—CH₂—CH₂—CH₂—CH₃	8 carbons

each unit holds one carbon: the name counts them

The fuels we burn, the plastics we mold, and the molecules of life are nearly all built on carbon. Their names follow one rule: count the carbons.

Hydrocarbon names count carbons

$\text{CO}_2 \rightarrow \text{carbon dioxide}$ · $\text{C}_3\text{H}_8 \rightarrow \text{propane}$

molecular name: a prefix counts each element's atoms · hydrocarbon name: one prefix counts the carbons, never tricarbon octahydride

Molecular names count atoms with mono- through deca-. Hydrocarbons use one prefix, for the carbons only; the hydrogens follow from that count. From five carbons up, the roots match: penta-/pent-, hexa-/hex-.

Carbon forms four bonds

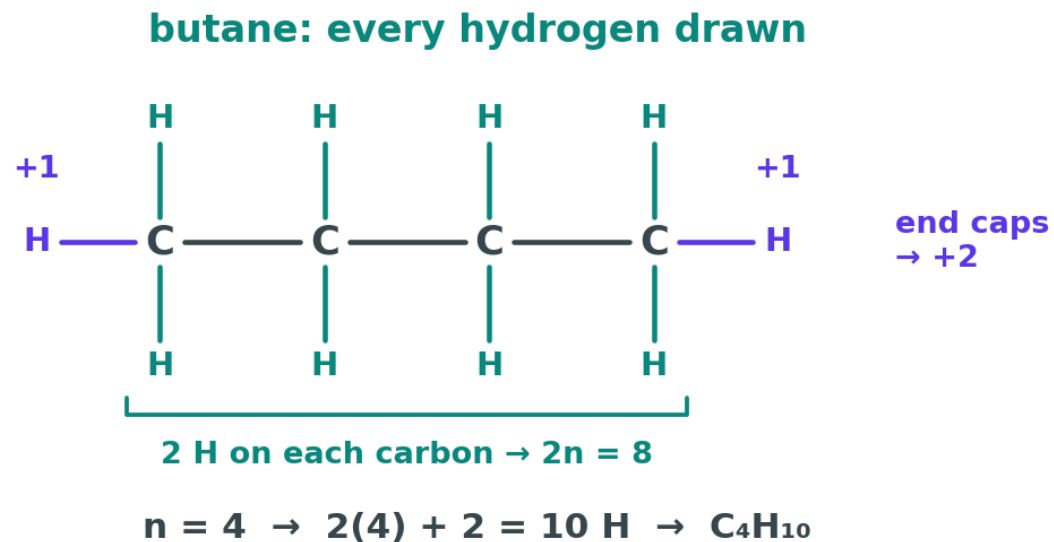
A carbon atom holds **four** valence electrons (the outermost ones) and shares four more to reach a full octet of eight: **four covalent bonds**. **Organic** compounds are carbon-based; **hydrocarbons** contain only carbon and hydrogen.

C: 4 valence e^- + 4 shared e^- = octet of 8 $\rightarrow$ 4 covalent bonds

those four bonds let carbon chain and branch into the skeletons of fuels, plastics, and tissue

Alkanes: all single bonds

An **alkane** is the simplest hydrocarbon: every bond is a single bond. Each carbon carries two hydrogens, and the two chain ends carry one extra cap each.



alkane: C_nH_{2n+2}

n carbons $\rightarrow 2n + 2$ hydrogens · methane CH_4 ($2 \times 1 + 2 = 4$), ethane C_2H_6 ($2 \times 2 + 2 = 6$)

The naming ladder

The first eight alkanes · general formula C_nH_{2n+2}

the prefix counts the carbons · every alkane has $H = 2n + 2$

C atoms	prefix	name	formula	condensed structure
1	meth-	methane	CH₄	CH ₄
2	eth-	ethane	C₂H₆	CH ₃ CH ₃
3	prop-	propane	C₃H₈	CH ₃ CH ₂ CH ₃
4	but-	butane	C₄H₁₀	CH ₃ CH ₂ CH ₂ CH ₃
5	pent-	pentane	C₅H₁₂	CH ₃ (CH ₂) ₃ CH ₃
6	hex-	hexane	C₆H₁₄	CH ₃ (CH ₂) ₄ CH ₃
7	hept-	heptane	C₇H₁₆	CH ₃ (CH ₂) ₅ CH ₃
8	oct-	octane	C₈H₁₈	CH ₃ (CH ₂) ₆ CH ₃

meth-but are historical names; pent- onward use the Greek/Latin number roots

A name has two parts: a **prefix** that counts the carbons and the ending **-ane** for a single-bonded alkane. meth-, eth-, prop-, but- (1-4) are historical; pent- (5) onward use the Greek/Latin number roots.



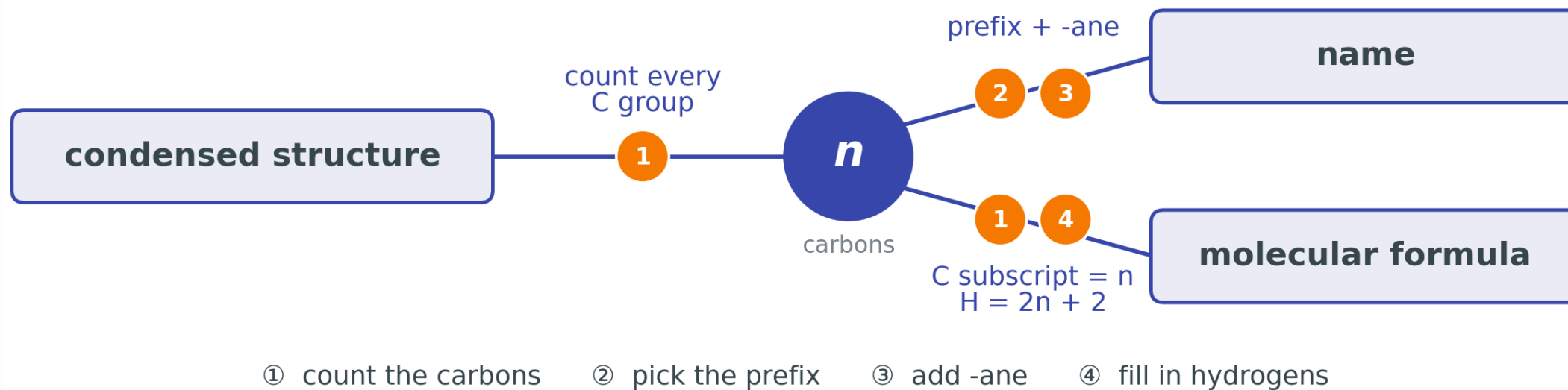
The method

1. **Count the carbons:** the count is n .
2. **Pick the prefix** for n from the ladder.
3. **Add -ane:** prefix + -ane is the name.
4. **Fill in hydrogens:** $H = 2n + 2$.

meth 1 · eth 2 · prop 3 · but 4 · pent 5 · hex 6 · hept 7 · oct 8 · non 9 · dec 10

Monkeys Eat Peanut Butter carries the first four · pent onward reuses the Greek counting prefixes ·
prefix + -ane → the name · n carbons → C_nH_{2n+2}

The method on the map



Every route runs through n , the carbon count. Step 1 reads n from whatever is given. Steps 2 and 3 turn n into the name. Step 4 turns n into the formula.



Worked example 1: a 7-carbon alkane

a straight-chain alkane with 7 carbon atoms

wanted: its name and its molecular formula

Everything you need is the carbon count. Read off the prefix, tack on the ending, then let $H = 2n + 2$ finish the formula.

✓ Worked example 1: solution

a straight-chain alkane with 7 carbon atoms
wanted: its name and its molecular formula

Step 1 · Count the carbons

Step 2 · Pick the prefix

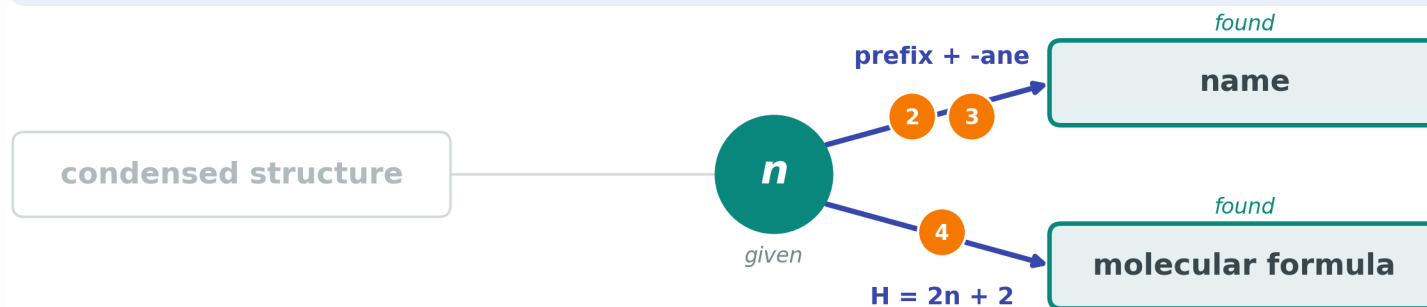
Step 3 · Add -ane

Step 4 · Fill in hydrogens

heptane = C_7H_{16}

7 carbons · $2 \times 7 + 2 = 16$ hydrogens · matches C_nH_{2n+2}

🧠 **Sense check:** The prefix carried the carbon count and the formula carried the hydrogens: no memorizing needed once you know $2n + 2$.



Worked example 2: the name from the formula

C_4H_{10} , a straight-chain alkane

given: the molecular formula · wanted: its name

Lighter fluid is C_4H_{10} . The naming runs in reverse: read n off the formula, then check that the hydrogens agree.

✓ Worked example 2: solution

C_4H_{10} , a straight-chain alkane

given: the molecular formula · wanted: its name

Step 1 · Count the carbons

Step 2 · Pick the prefix

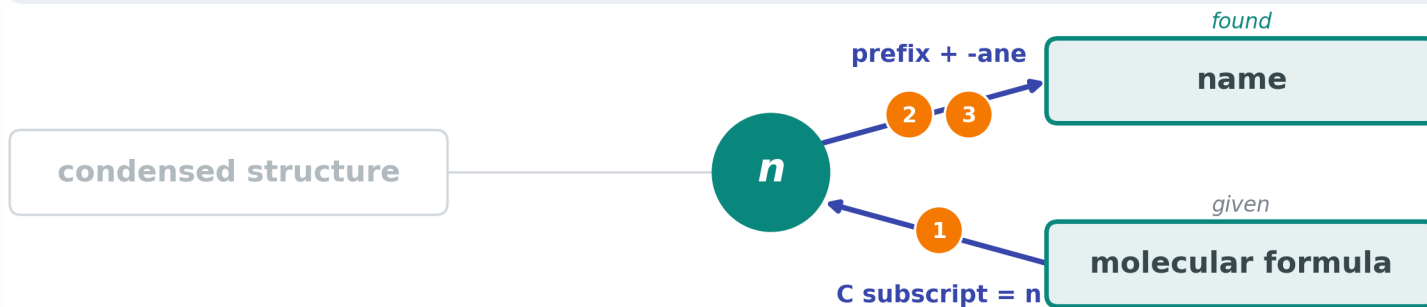
Step 3 · Add -ane

Step 4 · Fill in hydrogens

butane = C_4H_{10}

$2 \times 4 + 2 = 10$ hydrogens: the given formula agrees ✓

 **Sense check:** The hydrogen count confirms the family: 10 matches $2n + 2$, so every bond is single and -ane is the right ending.



Your turn: a 9-carbon alkane

a straight-chain alkane with 9 carbon atoms
wanted: its name and its molecular formula

step	question	answer
1 · count the carbons	$n = ?$	9
2 · pick the prefix	the ladder at 9	_____
3 · add -ane	the name	_____
4 · fill in hydrogens	$2 \times 9 + 2 = ?$	_____

Complete the name and the formula.

nonane = C_9H_{20}
non- + -ane · $2 \times 9 + 2 = 20$ hydrogens

Condensed vs. structural formulas

A **structural** formula draws every bond; a **condensed** formula groups each carbon with its hydrogens and drops the C-H lines. Same molecule, shorter notation.

propane: $\text{CH}_3\text{CH}_2\text{CH}_3 = \text{C}_3\text{H}_8$

three carbons written left to right $\cdot 3 + 3 + 2 = 8$ hydrogens

Long runs of CH_2 collapse further: pentane is $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$, or $\text{CH}_3(\text{CH}_2)_3\text{CH}_3$.



Guided example: a condensed structure



one unbranched chain, single bonds only · wanted: its name and molecular formula

This chain is one of the hydrocarbons in gasoline. Name it and give its molecular formula.

On the map, enter at the condensed structure. Every route runs through n.

✓ Guided example: solution



one unbranched chain, single bonds only · wanted: its name and molecular formula

Step 1 · Count the carbons

$$1 + 1 + 4 + 1 + 1 = 8 \text{ carbons}$$



Step 2 · Pick the prefix

Step 3 · Add -ane

Step 4 · Fill in hydrogens



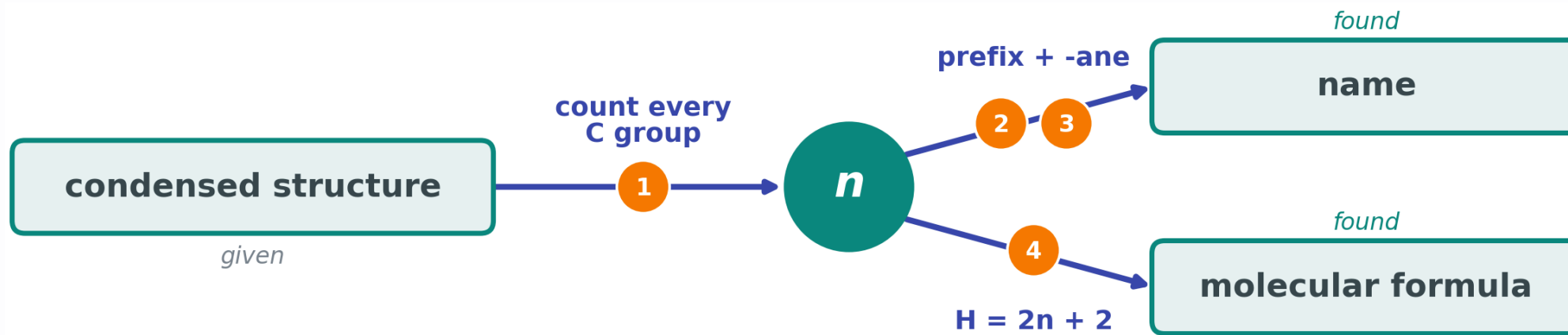
$$2 \times 8 + 2 = 18 \text{ H} \cdot \text{by groups: } 3 + 2 + 4(2) + 2 + 3 = 18 \checkmark$$

 **Sense check:** The count by groups agrees with $2n + 2$: 18 hydrogens both ways, so octane is C_8H_{18} . ✓

✓ Guided example: the route on the map



given: the condensed structure · found: $n = 8$, the name, and the formula



🧠 **Sense check:** Collapsed fully, the same chain is $\text{CH}_3(\text{CH}_2)_6\text{CH}_3$: two CH_3 ends plus $8 - 2 = 6$ CH_2 units.

Functional groups: a molecule's family

Common functional groups · the family is set by its group

Alcohol -OH ethanol $\text{CH}_3\text{CH}_2\text{OH}$	Carboxylic acid -COOH acetic acid CH_3COOH	Aldehyde -CHO acetaldehyde CH_3CHO	Ketone C=O acetone CH_3COCH_3
Amine -NH₂ methylamine CH_3NH_2	Ether C-O-C dimethyl ether CH_3OCH_3	Alkene C=C ethene $\text{CH}_2=\text{CH}_2$	Alkyne C≡C ethyne $\text{HC}\equiv\text{CH}$

Trade a hydrogen for a small cluster of atoms (a **functional group**) and the molecule joins a new family with new chemistry. Recognize each group and the family it marks.

⚠ Where this goes wrong

Off-by-one prefix. but- is 4 carbons, not 5: pent- is 5; miscounting the chain misnames the whole compound.

Using C_nH_{2n} for an alkane. That count is two H short of $2n + 2$; a single-bonded alkane always has $2n + 2$ H: propane is C_3H_8 , not C_3H_6 .

-OH vs. -COOH. A bare -OH is an alcohol, but the full -COOH (a C=O and an -OH on the same carbon) is a carboxylic acid.

Aldehyde vs. ketone. Both hold C=O, but an aldehyde's carbonyl sits at a chain end (-CHO) while a ketone's is between two carbons.



Practice 1

pentane: a straight-chain alkane with 5 carbon atoms
wanted: its molecular formula

Which is the molecular formula of pentane?



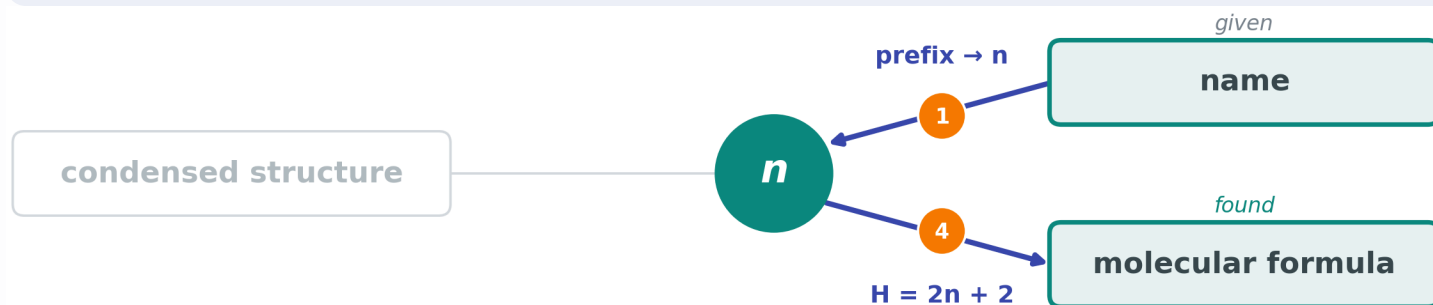
✓ Practice 1 · answer: B

pentane: $n = 5 \rightarrow 2 \times 5 + 2 = 12 \rightarrow \text{C}_5\text{H}_{12}$

answer B: five carbons, twelve hydrogens

A (C_5H_{10}) stops at $2n$ hydrogens, two H short of the $2n + 2$ count. C (C_6H_{14}) is the six-carbon alkane, hexane: one carbon too many. D (C_5H_{11}) has an odd H count no neutral alkane can have. Only **B** obeys $\text{C}_n\text{H}_{2n+2}$.

 **Sense check:** Every straight-chain alkane has an even number of hydrogens: an odd count is impossible for a neutral alkane.



 Practice 2

a condensed structure, one unbranched chain, single bonds only · wanted: name and molecular formula

Name this compound and give its carbon and hydrogen totals.

- A. decane, $\text{C}_{10}\text{H}_{22}$
- B. decane, $\text{C}_{10}\text{H}_{20}$
- C. octane, C_8H_{18}
- D. octane, C_8H_{16}
- E. carbon hydride, $\text{C}_{10}\text{H}_{22}$

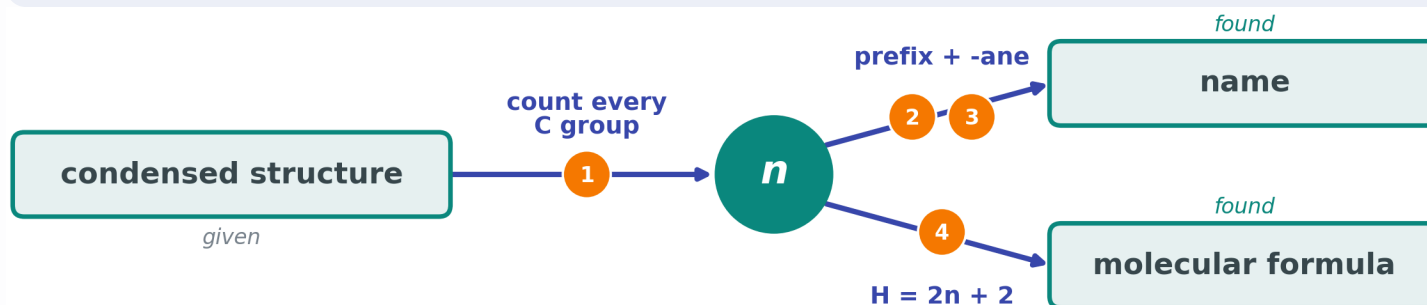
✓ Practice 2 · answer: A

$\text{CH}_3\text{CH}_2(\text{CH}_2)_6\text{CH}_2\text{CH}_3$: $1 + 1 + 6 + 1 + 1 = 10 \text{ C} \rightarrow \text{decane, C}_{10}\text{H}_{22}$ (answer A)

dec- + -ane · $2 \times 10 + 2 = 22 \text{ H}$ · by groups: $3 + 2 + 6(2) + 2 + 3 = 22 \checkmark$

B is the C_nH_{2n} count, $2 \times 10 = 20$, two H short of an alkane. C counted the two ends and the run but missed the two CH_2 written outside the parentheses: $1 + 6 + 1 = 8$, octane. D makes both slips: eight carbons and $2 \times 8 = 16 \text{ H}$. E has the right formula but the binary name with no prefixes; hydrocarbons take the alkane ladder.

 **Sense check:** Every written group holds one carbon; the subscript 6 counts only the CH_2 units inside the parentheses.





Practice 3

nonane

a straight-chain alkane, single bonds only · wanted: its condensed structure

Nonane is one of the hydrocarbons in jet fuel. Which condensed structure is nonane?

- A. $\text{CH}_3(\text{CH}_2)_8\text{CH}_3$
- B. $\text{CH}_3(\text{CH}_2)_9\text{CH}_3$
- C. $\text{CH}_3(\text{CH}_2)_7\text{CH}_3$
- D. $\text{CH}_3(\text{CH}_2)_7\text{CH}_2$
- E. $\text{CH}_2(\text{CH}_2)_7\text{CH}_2$

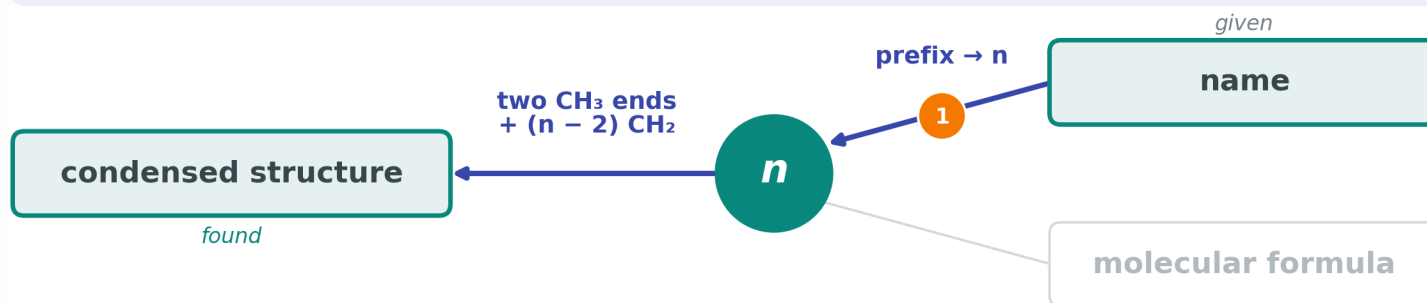
✓ Practice 3 · answer: C

nonane: $n = 9 \rightarrow$ two CH_3 ends + $9 - 2 = 7$ $\text{CH}_2 \rightarrow \text{CH}_3(\text{CH}_2)_7\text{CH}_3$ (answer C)

count back: $1 + 7 + 1 = 9$ C · H: $3 + 7(2) + 3 = 20 = 2 \times 9 + 2$ ✓

A subtracted only one end: $1 + 8 + 1 = 10$ C, decane. B put all nine inside the parentheses: $1 + 9 + 1 = 11$ C. D ends on CH_2 : $3 + 7(2) + 2 = 19$ H, an odd count. E dropped both CH_3 caps: $2 + 7(2) + 2 = 18$ H, the C_nH_{2n} count, two short.

 **Sense check:** Count back what you wrote: the two ends plus the subscript must return the 9 that non- promised.





Check yourself

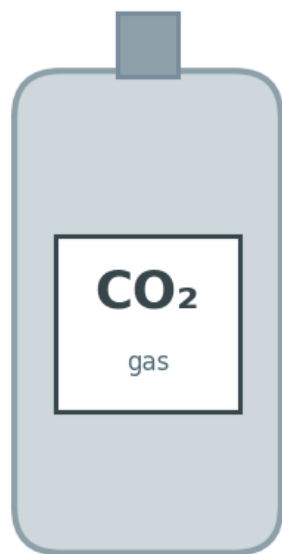
1. Name the alkane with formula C_6H_{14} and write its condensed structure.
2. A molecule contains a -COOH group: which family is it, and how does that group differ from a plain -OH ?

Naming branched chains and ranking how these families react is the work of a full organic-chemistry course. For now you can already read a straight-chain alkane's name straight off its carbon count and spot the functional group that sets a molecule's family.

11 · Choosing the Naming System

Decide which naming system a compound uses before applying any rule, so ionic, molecular, and acid names never mix.

One gas, two labels



carbon dioxide

molecular rules: a prefix counts the two oxygens

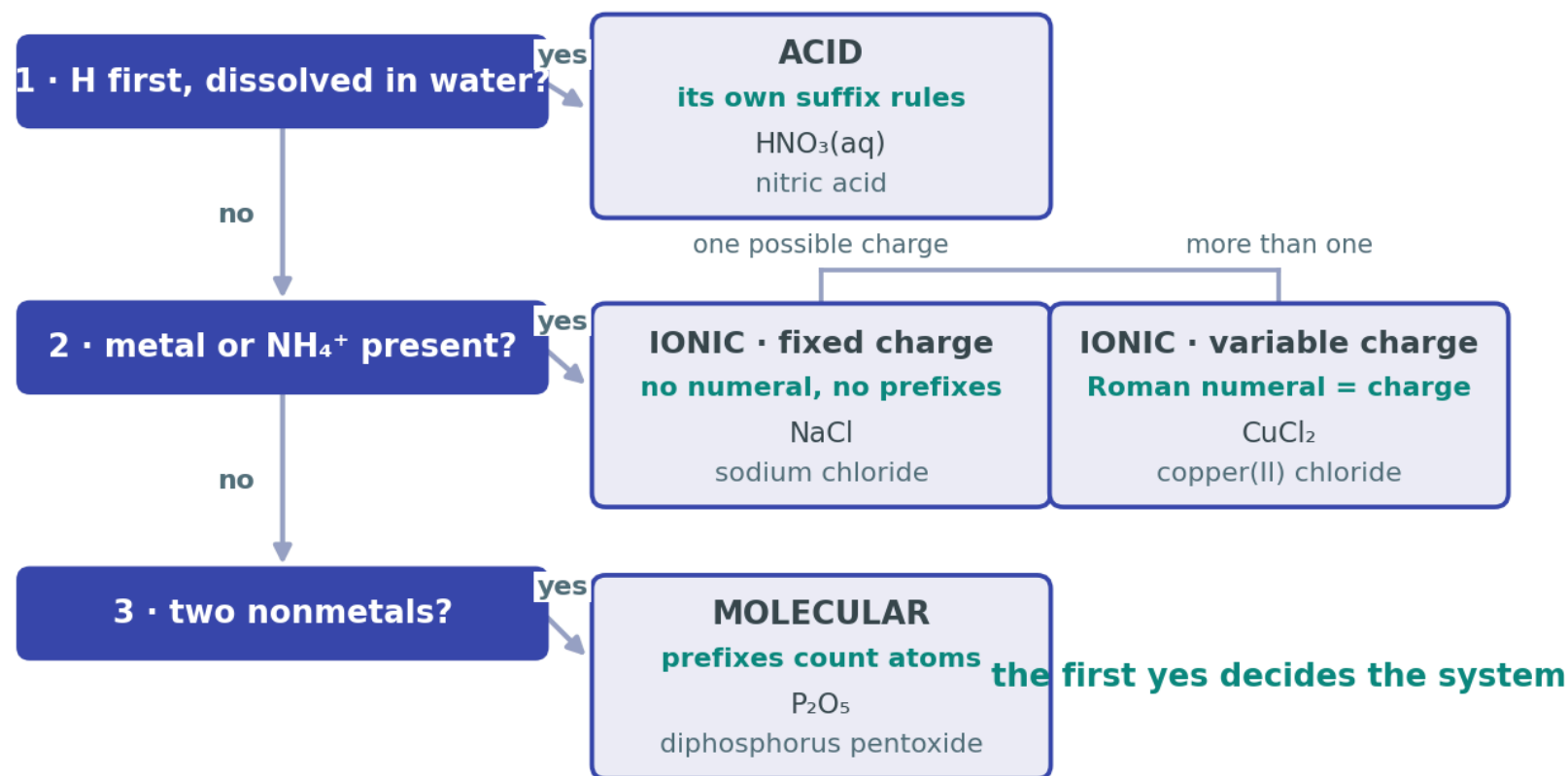


~~**carbon(IV) oxide**~~

ionic rules: a numeral states an ion charge, and CO₂ has no ions

Only one of these labels names the gas: carbon dioxide. The other applies ionic rules to a compound with no ions. Every naming problem starts by classifying the compound.

One compound, one system



Three naming systems exist, and a compound's type picks exactly one. Classify before any rule; a name built with the wrong system misleads or names nothing.

Three questions, asked in order

1 · H first, dissolved in water? → acid

$\text{HNO}_3(\text{aq})$: nitric acid

2 · metal or NH_4^+ present? → ionic

NaCl : sodium chloride · CuCl_2 : copper(II) chloride, numeral for a variable-charge metal

3 · two nonmetals? → molecular

P_2O_5 : diphosphorus pentoxide, prefixes count the atoms

The first yes wins. An acid outranks the metal test, and a metal or ammonium outranks counting prefixes.

Each system leaves a signature

Roman numeral → ionic, variable-charge metal · counting prefix → molecular · acid
ending → acid
copper(II) ... · dioxide, trichloride ... · hydro-...-ic, -ic, -ous

A name's own pieces reveal its system. Match the signature when reading a name; never borrow another system's pieces when writing one.



The method

1. **Classify the compound.** H first, (aq) → acid. Metal or NH_4^+ → ionic. Two nonmetals → molecular.
2. **Apply that system's rules.** Numeral for variable-charge metals; prefixes for molecular; suffix map for acids.
3. **Read the name back.**



Worked example 1: CuCl_2



given: the formula · wanted: the name

CuCl_2 colors flames blue-green in pyrotechnics. Name the compound.

A common first attempt reaches for prefixes: copper dichloride. Test it.

✓ Worked example 1: testing the first attempt



given: the formula · wanted: the name

A common first attempt

copper dichloride

a counting prefix on a compound that holds a metal ✕

Prefixes belong to the molecular system. The subscript here comes from charge balance and is never spoken.

 **Sense check:** The name's system must match the compound's type before any rule applies.

✓ Worked example 1: solution



given: the formula · wanted: the name

Step 1 · Classify the compound

Step 2 · Apply that system's rules

two $\text{Cl}^- \rightarrow 2(-1) = -2 \rightarrow \text{Cu is } 2+$

$1(+2) + 2(-1) = 0 \checkmark$ · the numeral reports the charge

Step 3 · Read the name back

$\text{CuCl}_2 \rightarrow$ copper(II) chloride

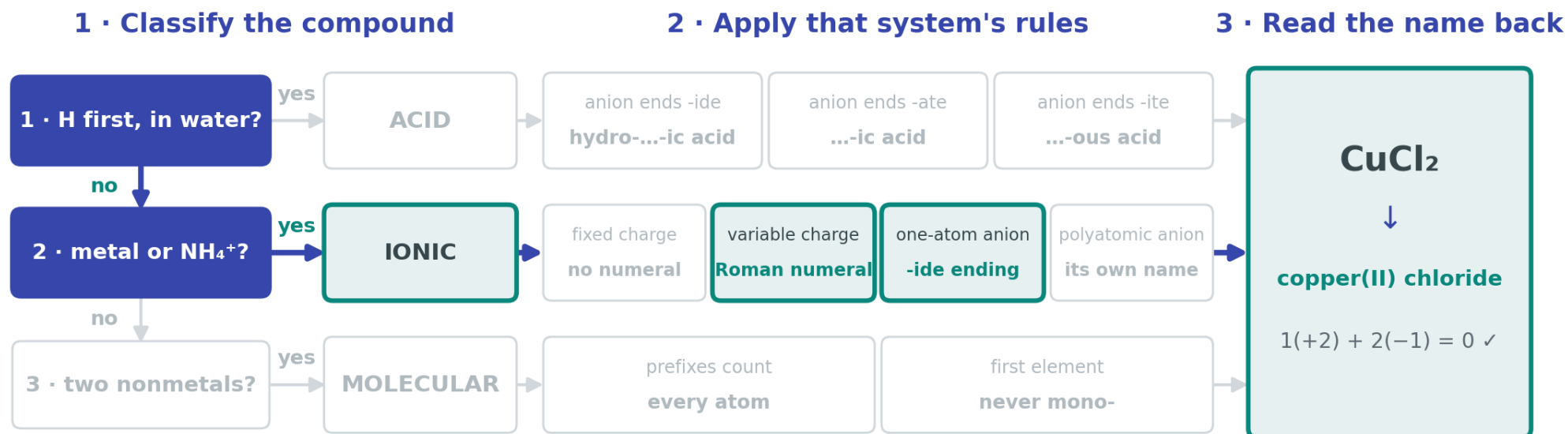
Cu^{2+} with 1– anions rebuilds exactly $\text{CuCl}_2 \checkmark$

 **Sense check:** Classification came first, and every later move (the numeral, the missing prefix) followed from it.

✓ Worked example 1: the route on the map



found: ionic · variable-charge metal · one-atom anion



Sense check: Any ionic chloride follows this path until the metal. Copper has more than one possible charge, so the numeral chip lights: (II) reports Cu^{2+} . ✓



Worked example 2: $\text{HNO}_2(\text{aq})$



given: the formula · wanted: the name

HNO_2 forms in cured meats from the preservative sodium nitrite. Name the dissolved compound.

✓ Worked example 2: solution



given: the formula · wanted: the name

Step 1 · Classify the compound

Step 2 · Apply that system's rules

anion: NO_2^- , nitrite → -ite becomes -ous

oxygen present, so no hydro- · nitrous acid

Step 3 · Read the name back



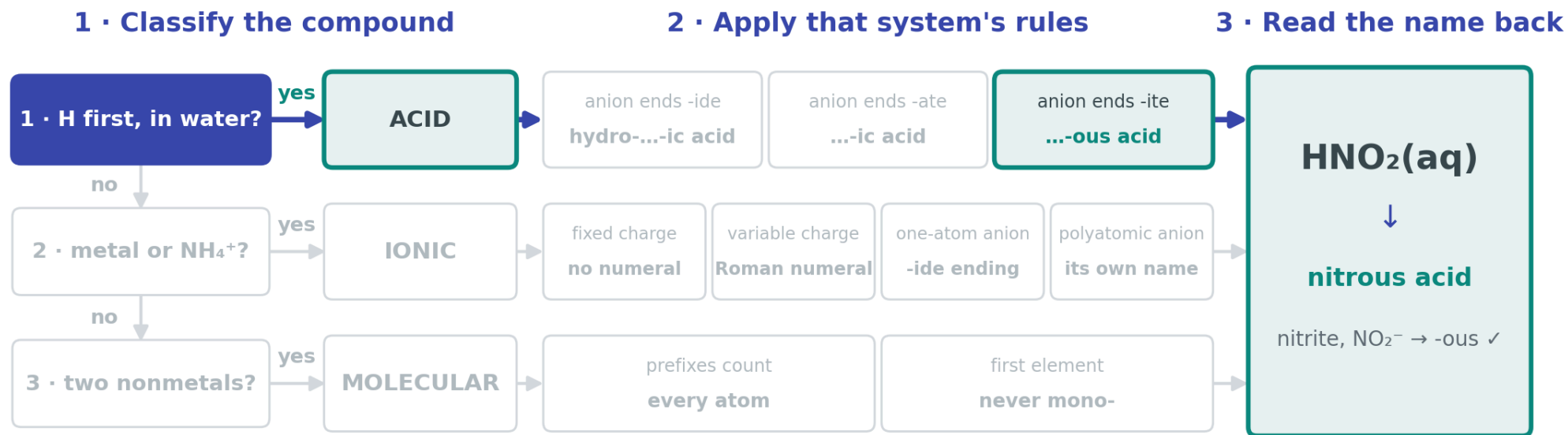
nitrous → nitrite, $\text{NO}_2^- \cdot 1(+1) + 1(-1) = 0 \rightarrow \text{one H} \checkmark$

 **Sense check:** The (aq) decided everything. Dry HNO_2 would be named as hydrogen nitrite, an ionic-style read-back.

✓ Worked example 2: the route on the map



found: acid at question 1 · nitrite, one O fewer than nitrate $\rightarrow$ -ous



 **Sense check:** The first question said yes, so the ionic and molecular rows never ran. An -ite anion lights the -ous chip. ✓

Your turn: SeF_6



selenium and fluorine · given: the formula · wanted: the name

step	question	answer
1 · classify the compound	H first? metal or NH_4^+ ?	_____
2 · apply that system's rules	1 Se · 6 F: which prefixes?	selenium _____fluoride
3 · read the name back	does the name rebuild SeF_6 ?	_____

Run the three questions in order, then name it.

$\text{SeF}_6 \rightarrow$ selenium hexafluoride

no H, no metal $\rightarrow$ molecular · mono- dropped on the first element · hexa- $\rightarrow$ 6 F · reads back to SeF_6 ✓

⚠ Where this goes wrong

A Roman numeral on a molecular compound. NO_2 is not nitrogen(IV) oxide. A numeral reports an ion's charge, and two nonmetals share electrons instead of forming ions: nitrogen dioxide.

Counting prefixes on an ionic compound. K_2SO_4 is potassium sulfate, never dipotassium sulfate. A metal is present, so charge balance fixes the counts unspoken.

The gas name for an acid. HBr(aq) is hydrobromic acid. Hydrogen bromide names the pure gas HBr(g) ; the (aq) switches the compound to the acid system.

An acid name with no hydrogen. SO_2 is not sulfurous acid: sulfurous acid is $\text{H}_2\text{SO}_3\text{(aq)}$. With no leading H and no (aq), SO_2 is the molecular compound sulfur dioxide.



Practice 1



iodine and chlorine · wanted: the name

Iodine and chlorine combine directly into ICl_3 , an orange solid. Name the compound.

- A. iodine(III) chloride
- B. iodine trichloride
- C. iodine chloride
- D. triiodine monochloride

✓ Practice 1 · answer: B

$\text{ICl}_3 \rightarrow$ iodine trichloride (answer B)

no H, no metal $\rightarrow$ molecular · tri- $\rightarrow$ 3 Cl

A borrows the ionic system's numeral, but a numeral reports an ion's charge and ICl_3 holds no ions. C is the fixed-charge ionic style, and without a prefix the name cannot separate ICl_3 from ICl . D swaps the prefix onto iodine: triiodine monochloride rebuilds I_3Cl .

 **Sense check:** Two nonmetals: the third question said molecular, so prefixes carry the whole formula.



Practice 2



strontium, a Group 2 metal · PO_4^{3-} on the memorized list · wanted: the name

$\text{Sr}_3(\text{PO}_4)_2$ is a ceramic used as a bone substitute. Name the compound.

- A. strontium(II) phosphate
- B. tristrontium diphosphate
- C. strontium phosphide
- D. strontium phosphate

✓ Practice 2 · answer: D

$\text{Sr}_3(\text{PO}_4)_2 \rightarrow$ strontium phosphate (answer D)

$3(+2) + 2(-3) = 0$ ✓ · atoms: 3 Sr · 2 P · $2 \times 4 = 8$ O

A writes a numeral for a metal with one possible charge; Group 2 is always 2+, so no numeral appears. B counts atoms with molecular prefixes, but the metal makes this ionic. C names the monatomic anion P^{3-} ; this compound holds the polyatomic group phosphate, PO_4^{3-} .

 **Sense check:** A metal plus a memorized polyatomic: plain ionic name, and balance rebuilds every subscript.



Practice 3



H first · dissolved in water · wanted: the name

Dissolved carbon dioxide forms H_2CO_3 in every carbonated drink. Name the compound.

- A. carbonic acid
- B. hydrogen carbonate
- C. hydrocarbonic acid
- D. dihydrogen carbonate

✓ Practice 3 · answer: A

$\text{H}_2\text{CO}_3(\text{aq}) \rightarrow$ carbonic acid (answer A)

anion: carbonate $\text{CO}_3^{2-} \rightarrow$ -ate becomes -ic · $2(+1) + 1(-2) = 0$ ✓

B is the ionic-style read-back, and hydrogen carbonate already names a different species, the ion HCO_3^- . C adds hydro-, which claims a no-oxygen anion; carbonate holds three. D counts atoms with a prefix, and prefixes never appear in acid names.

🧠 **Sense check:** H first plus (aq): the first question already picked the acid system.



Practice 4

Pb^{4+} · sulfate

one salt of these two ions · wanted: its formula and name

Pb^{4+} ions pair with sulfate ions in one salt. Which formula and name are both correct?

- A. $\text{Pb}_2(\text{SO}_4)_4$, lead(IV) sulfate
- B. $\text{Pb}(\text{SO}_4)_2$, lead(II) sulfate
- C. $\text{Pb}(\text{SO}_4)_2$, lead(IV) sulfate
- D. $\text{Pb}(\text{SO}_4)_2$, lead disulfate
- E. $\text{Pb}(\text{SO}_3)_2$, lead(IV) sulfite

✓ Practice 4 · answer: C

Pb^{4+} with SO_4^{2-} : criss-cross $\text{Pb}_2(\text{SO}_4)_4 \rightarrow$ reduce $\rightarrow \text{Pb}(\text{SO}_4)_2$, lead(IV) sulfate (answer C)

metal present $\rightarrow$ ionic · $1(+4) + 2(-2) = 0$ ✓ · lead is variable-charge: numeral IV

A stopped at the raw criss-cross: $2(+4) + 4(-2) = 0$ balances, but $2 : 4$ reduces to $1 : 2$. B read the subscript 2 as lead's charge: $1(+2) + 2(-2) = -2$. D borrows molecular prefixes for a compound with a metal. E swaps in sulfite, SO_3^{2-} , one oxygen fewer than sulfate.

 **Sense check:** Classify first: a metal with a polyatomic anion is ionic, so the numeral stays and the prefixes go.



Check yourself

1. Classify each compound, then name it: CaBr_2 and $\text{H}_2\text{S}(\text{aq})$.
2. N_2O_4 is offered two names: dinitrogen tetroxide and nitrogen(IV) oxide. Which system applies, and what rules out the other?

Every formula these names rebuild feeds the next skill: chemical equations balance atom counts, and the counts come straight from correct formulas.

Can you...?

- ☐ locate protons, neutrons, and electrons in the atom and state what each count determines?
- ☐ read and write isotope symbols, converting between mass number, atomic number, and particle counts?
- ☐ calculate the average atomic mass of an element from isotope masses and abundances?
- ☐ give an element's period, group, family, and metal/nonmetal/metalloid class?
- ☐ predict the charge an atom takes when it forms an ion, and count the particles in that ion?
- ☐ name ionic and molecular compounds and acids, and write formulas from names?
- ☐ recognize the common polyatomic ions and build formulas that contain them?
- ☐ name a straight-chain alkane from its carbon count, build its C_nH_{2n+2} formula, and recognize the common functional-group families?
- ☐ choose the right naming system for any formula (fixed or variable ionic, molecular, acid), rejecting the other systems' names?

If any box stays empty, the practice site has a drill for it. 