

Ions & Naming Compounds

Preparation for General Chemistry · Dr. Karmach

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

- Name ionic and molecular compounds and acids, and write formulas from names
- Recognize the common polyatomic ions and build formulas that contain them

Today's route

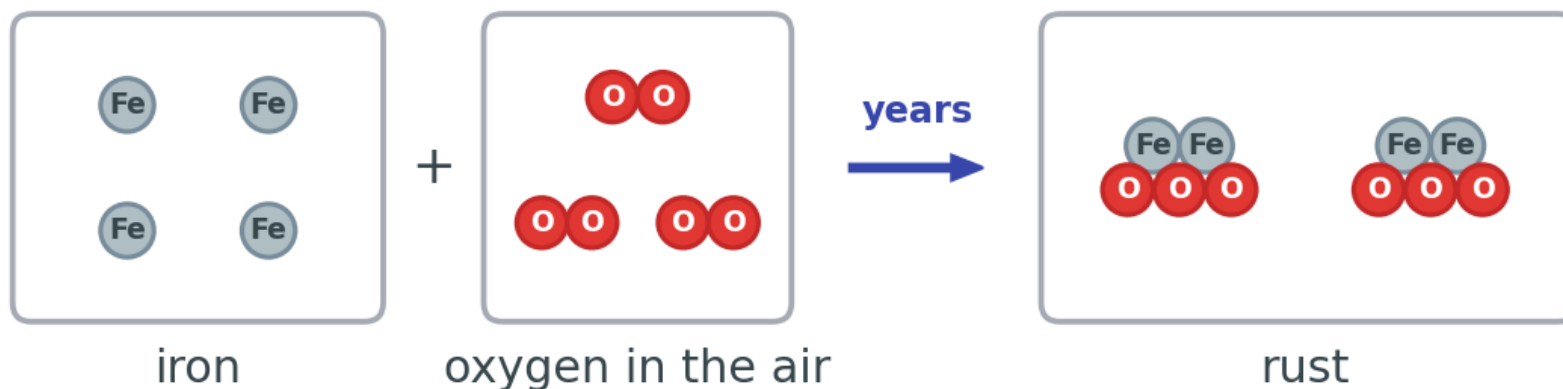
1. **Naming Ionic Compounds**
2. **Polyatomic Ions**
3. **Naming Molecular Compounds and Acids**
4. **Choosing the Naming System**

1 • 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.

Ionic compounds: a metal cation and a nonmetal anion

NaCl: Na^+ and Cl^- → ionic · H_2O : shared electrons, no ions → molecular

Na, a metal, gives up an electron: cation · Cl, a nonmetal, takes it: anion · H and O: two nonmetals

A metal cation held to a nonmetal anion makes an ionic compound. Its formula and name follow one rule: total positive charge equals total negative charge.

Sort CaF_2 , SO_2 , and K_2O .

CaF_2 and K_2O : a metal with a nonmetal → ionic · SO_2 : two nonmetals → molecular

Ca, K: metals · F, O, S: nonmetals

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

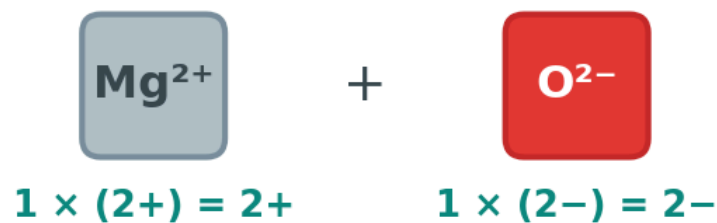
a 2+ cation needs two 1- anions



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



2+ meets 2-: one of each



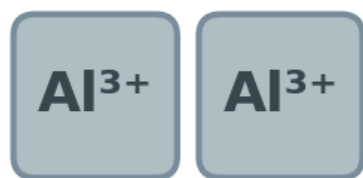
$$1(+2) + 1(-2) = 0$$



Ca²⁺ carries twice the charge of Cl⁻, so two chlorides are needed: CaCl₂. Mg²⁺ meets O²⁻, 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⁺

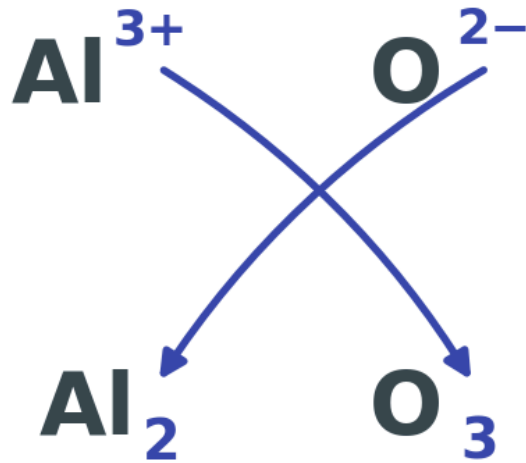
iron(II) = Fe²⁺ $\cdot$ iron(III) = Fe³⁺ $\cdot$ the Roman numeral states the cation's charge

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

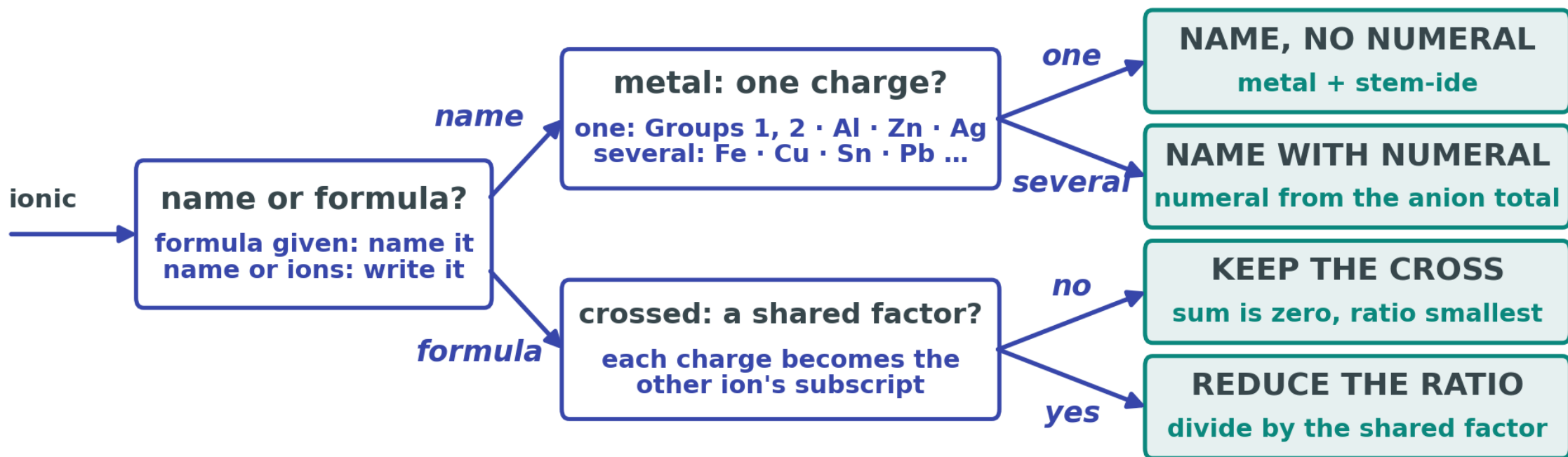
Each charge number becomes the other ion's subscript, because those counts make the totals cancel. The shortcut is bookkeeping for charge balance, so finish with its two checks: the sum is zero, the ratio is smallest.



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.

One map for names and formulas



The first question asks what is wanted. A name turns on the metal: one possible charge or several. A formula turns on the crossed subscripts: do they share a factor?



Guided example: lithium in air

Step 1 • Classify the compound

lithium + nitrogen

lithium, a metal • nitrogen, a nonmetal → ionic • wanted: the formula and the name

Lithium is the one alkali metal that reacts with the nitrogen in air, forming a reddish solid. Write the formula and the name of that solid.

On the map, take the formula branch first, then the name branch.

✓ Guided example: solution

lithium + nitrogen

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

Step 2 · Identify the ions

Li^+ and N^{3-}

Li: Group 1 → 1+, fixed · N: Group 5A → $8 - 5 = 3$ → 3–

Step 3 · Balance the charges to zero

one of each: $1(+1) + 1(-3) = -2 \times$ · three Li^+ : $3(+1) + 1(-3) = 0$ ✓

criss-cross: nitrogen's 3 becomes lithium's subscript · 3 and 1 share no factor → Li_3N

 **Sense check:** Three 1+ charges cancel one 3– charge. The formula is Li_3N .

✓ Guided example: the name

lithium + nitrogen $\rightarrow$ Li_3N

Li^+ and N^{3-} · $3(+1) + 1(-3) = 0$ ✓ · wanted now: the name

Step 4 · Assemble the answer

$\text{Li}_3\text{N} \rightarrow$ lithium nitride

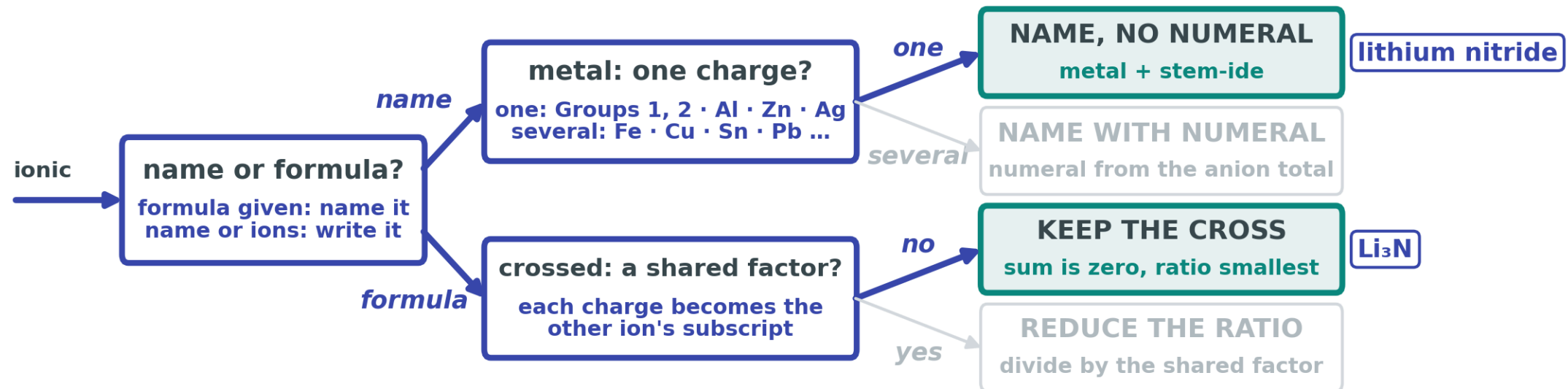
nitr- + -ide · lithium has one possible charge: no numeral · the 3 is not spoken

🧠 **Sense check:** The name needs no number: the charges alone fix the 3 : 1 ratio.

✓ Guided example: the route on the map

lithium + nitrogen: Li_3N , lithium nitride

formula: crossed 3 and 1, no shared factor $\rightarrow$ keep · name: lithium has one possible charge $\rightarrow$ no numeral



🧠 **Sense check:** One compound, both branches: write the formula, then name it. ✓



Practice 1



barium, a metal · fluoride, a nonmetal anion → ionic

Barium fluoride crystals make windows for infrared instruments. Which formula is correct for barium fluoride?

- A. Ba_2F
- B. BaF_2
- C. BaF
- D. F_2Ba

✓ Practice 1 · answer: B

Ba²⁺ and F⁻: BaF₂ (answer B)

1(+2) + 2(-1) = 0 ✓ · two F⁻ cancel one Ba²⁺ · 2 and 1 share no factor

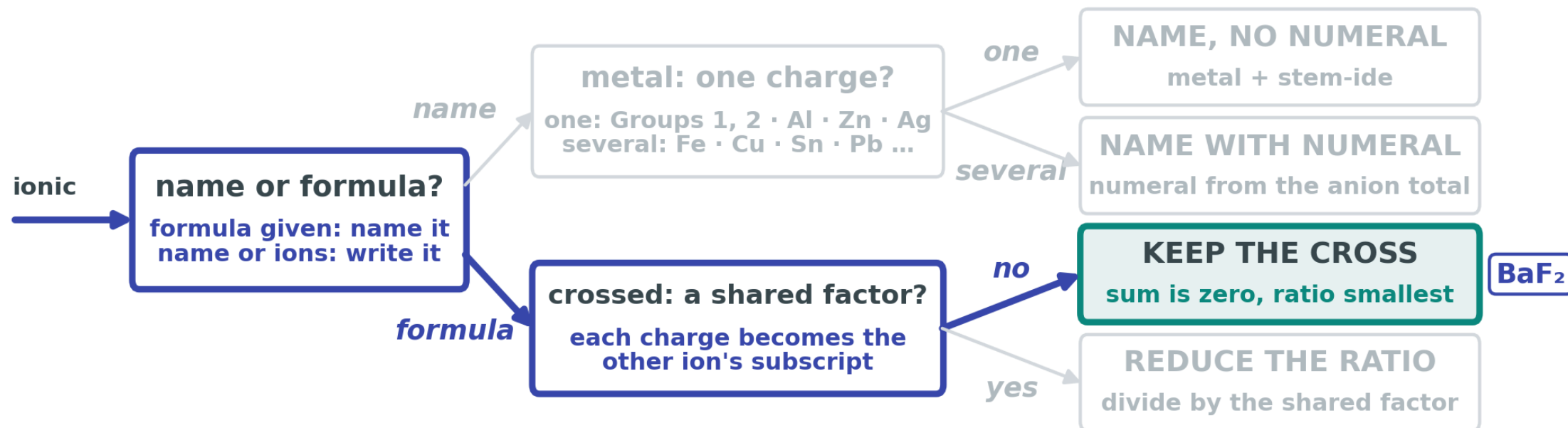
A wrote each ion's own charge as its own subscript: 2(+2) + 1(-1) = +3, not neutral. C pairs one of each: 1(+2) + 1(-1) = +1. D has the right counts in the wrong order; the cation is written first.

 **Sense check:** Barium's 2+ takes two 1- charges to cancel. ✓

✓ Practice 1: the route on the map



formula wanted · crossed 1 and 2, no shared factor → keep



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



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



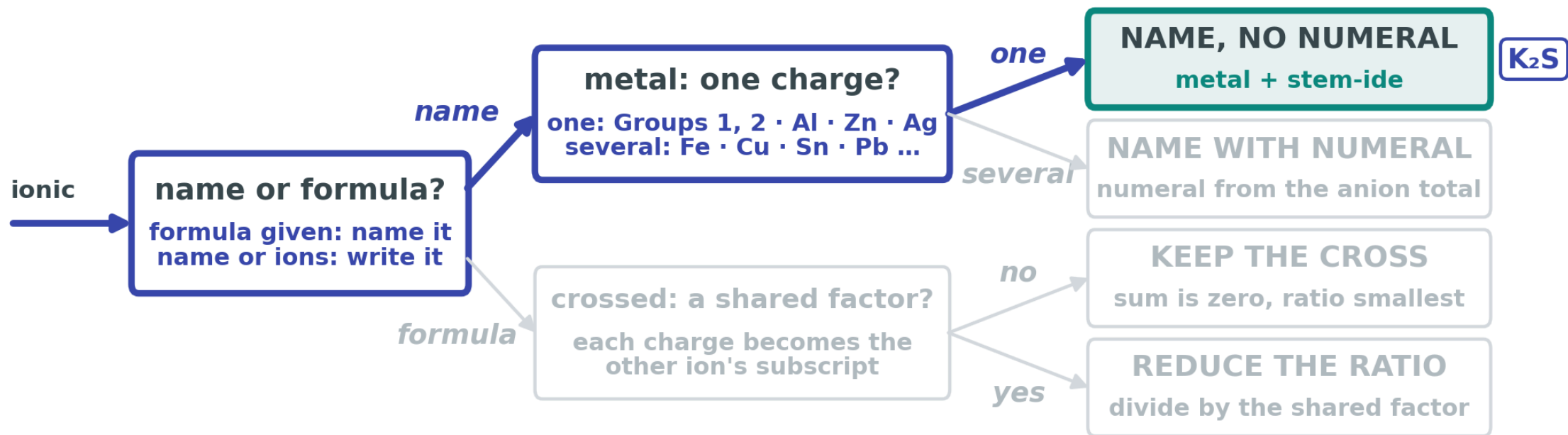
$2(+1) + 1(-2) = 0$ ✓ · sulf- + -ide · the 2 is not spoken

 **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

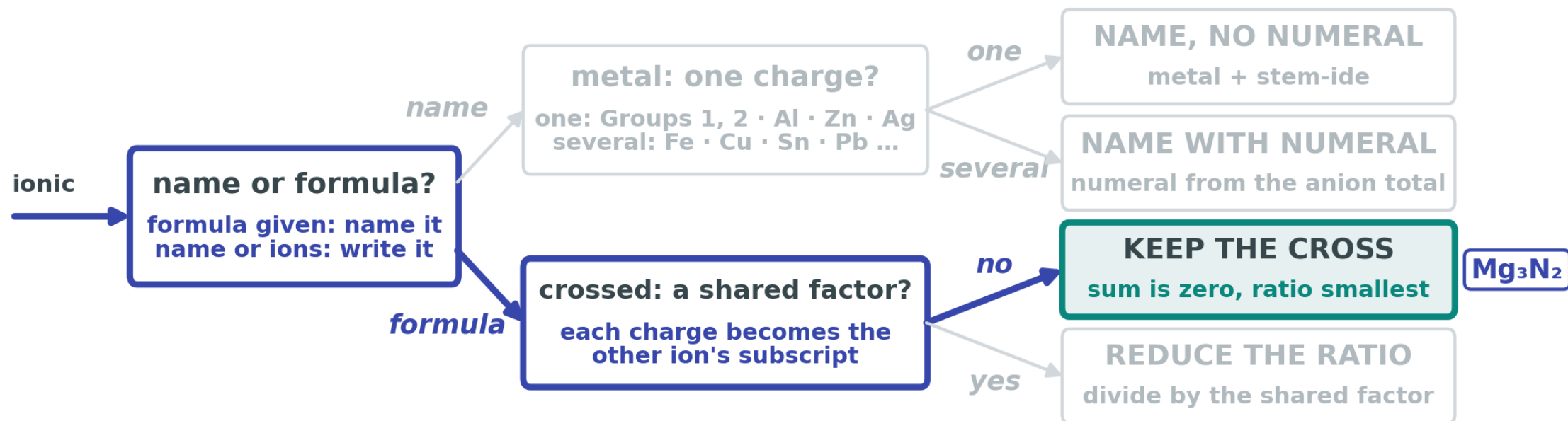
$3(+2) + 2(-3) = +6 - 6 = 0 \checkmark$ · 3 and 2 share no common factor

 **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 2



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 2 · answer: C

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

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

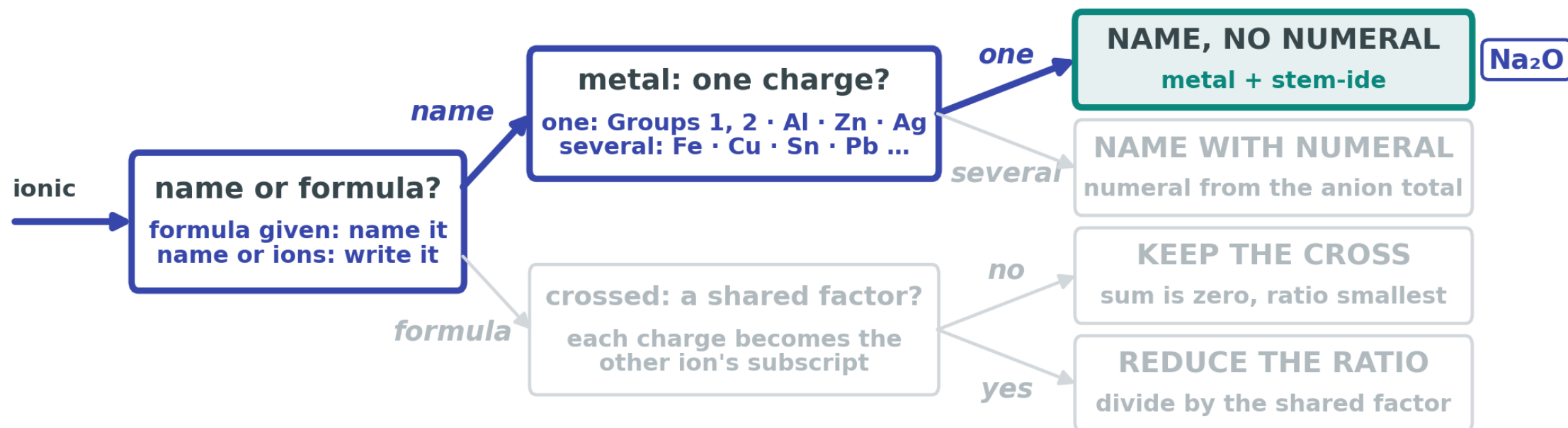
A read the subscript as a charge: sodium 2+ would give $2(+2) + 1(-2) = +2$, not neutral; the 2 counts Na^+ ions. B counts atoms with Greek prefixes, the naming system for molecular compounds. D writes a numeral for a metal with only one possible charge; numerals mark variable-charge metals only.

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

✓ Practice 2: the route on the map

Na_2O : sodium oxide

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



🧠 **Sense check:** Same exit as K_2S : a fixed-charge metal never carries a numeral. ✓



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



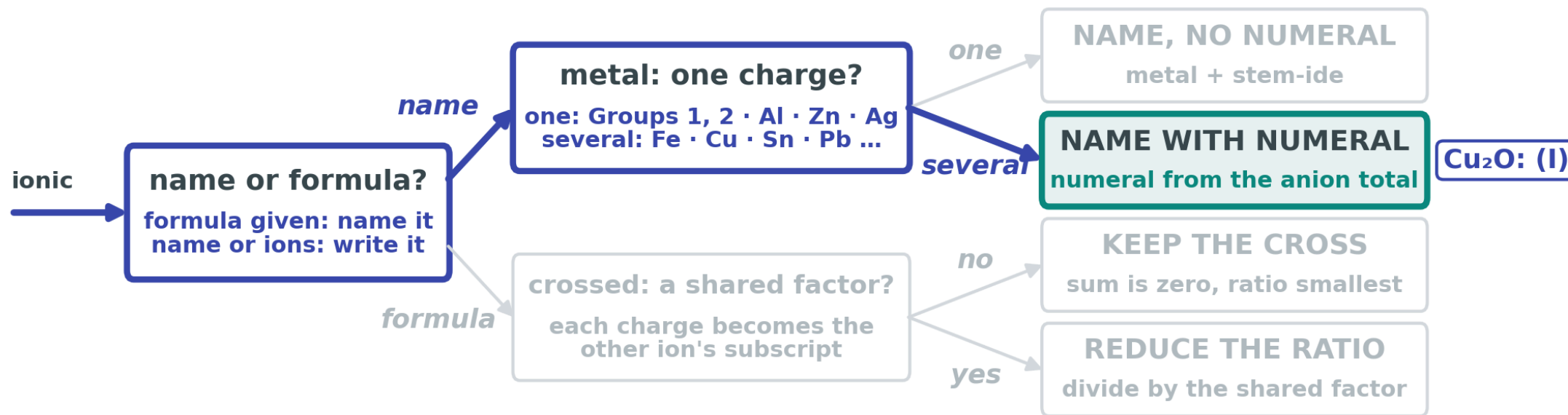
the numeral reports the charge on each Cu, 1+ · the subscript already counts the ions

 **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. ✓

Take-home: the Roman numeral is a charge, not a count

$\text{Cu}_2\text{O} \rightarrow \text{copper(I) oxide}$

two Cu ions, each $1+$ · $2(+1) + 1(-2) = 0$ ✓

$\text{CuO} \rightarrow \text{copper(II) oxide}$

one Cu ion at $2+$ · $1(+2) + 1(-2) = 0$ ✓

The numeral states the charge on the cation, found by balancing the anion's total. Subscripts count ions; the numeral never does.



Practice 3



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 3 · answer: A

FeO → iron(II) oxide (answer A)

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

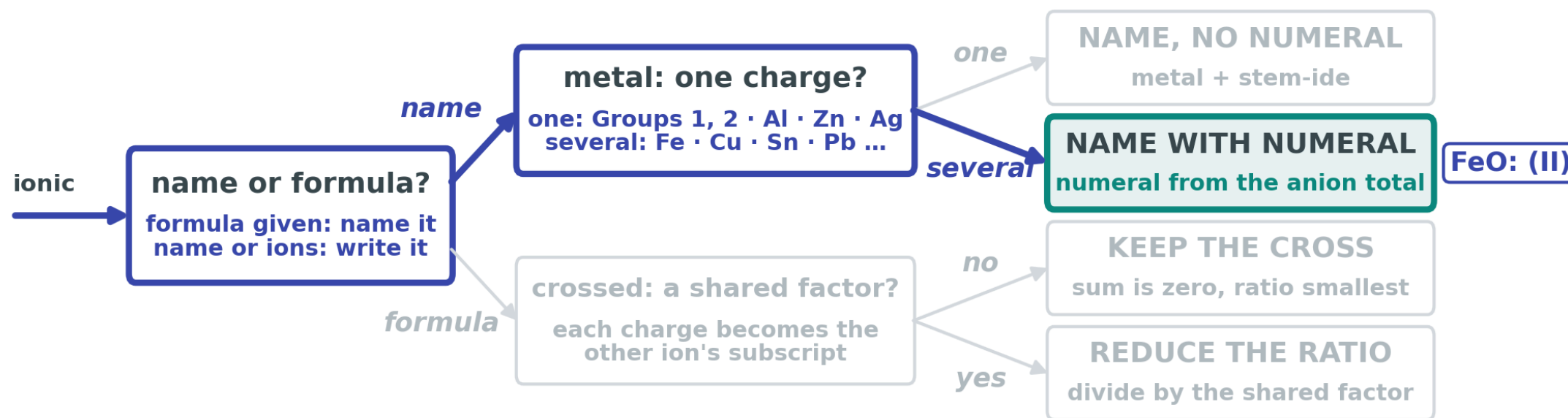
B recycles the 3+ from rust: here $1(+3) + 1(-2) = +1$, not neutral; the numeral must balance this formula. C omits the numeral: iron has more than one possible charge, so "iron oxide" cannot separate FeO from Fe_2O_3 . D counts atoms with a Greek prefix, the system for molecular compounds.

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

✓ Practice 3: the route on the map

FeO: iron(II) oxide

name wanted · iron: several possible charges → numeral · O²⁻ total 2- ÷ 1 Fe = 2+



🧠 **Sense check:** One cation carries the whole anion total, so iron is 2+. ✓



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

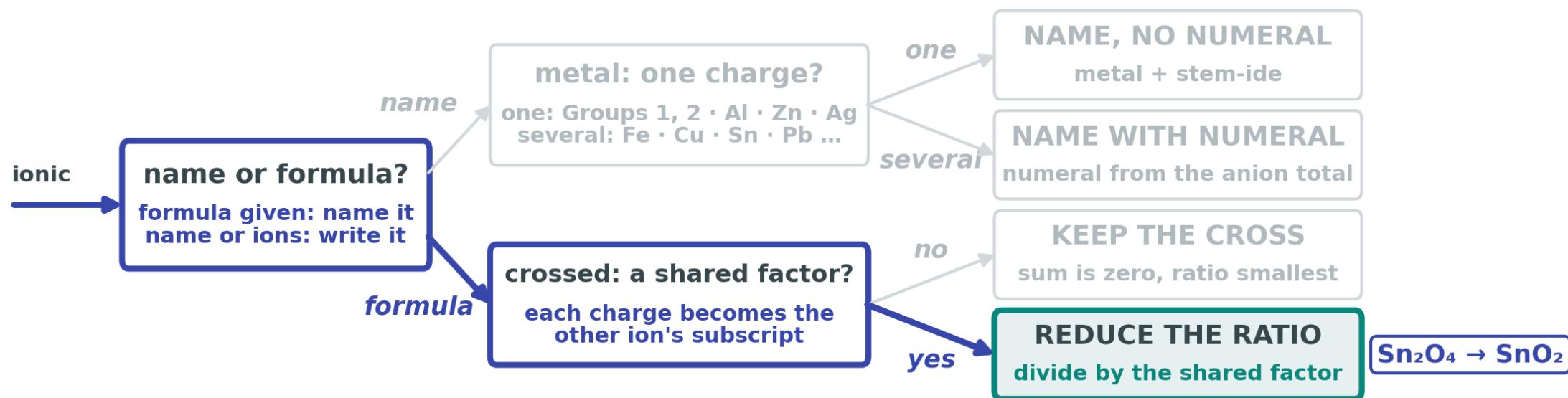
$1(+4) + 2(-2) = 0 \checkmark$ · smallest whole-number ratio

 **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 4

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 4 · 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

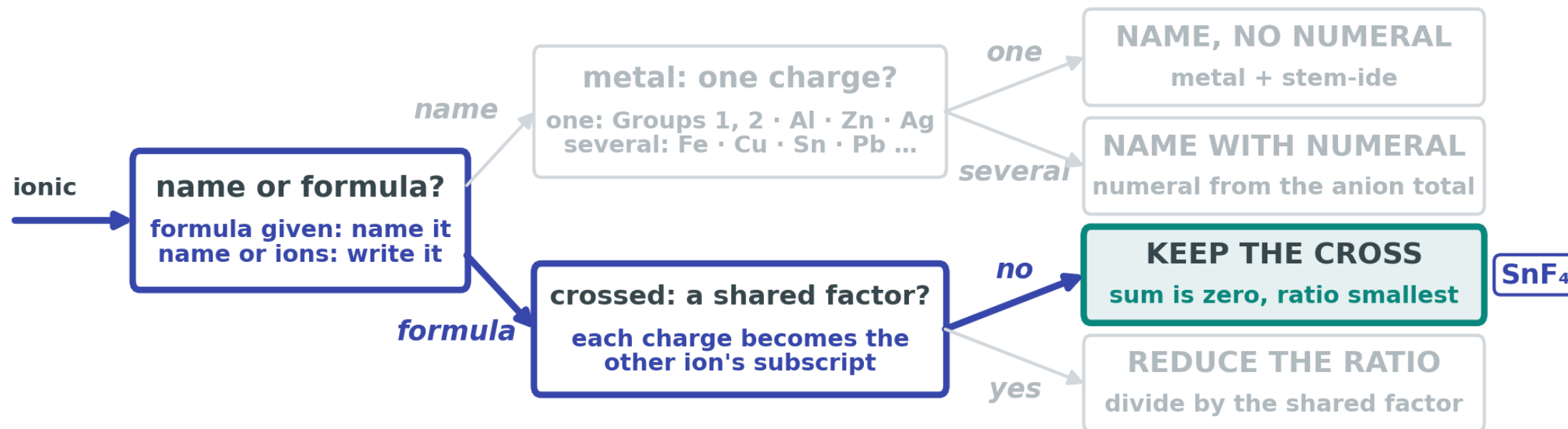
B balances a different cation: $1(+2) + 2(-1) = 0$ holds for Sn^{2+} , so SnF_2 is tin(II) fluoride, the stannous fluoride on toothpaste labels. C pairs one of each ion: $1(+4) + 1(-1) = +3$, not neutral. A writes the numeral as a count of tin atoms: $4(+4) + 1(-1) = +15$.

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

✓ Practice 4: the route on the map

tin(IV) fluoride: SnF_4

formula wanted · Sn^{4+} and F^- cross to 1 and 4 · no shared factor → keep



Sense check: Same metal as tin(IV) oxide, different exit: 4 and 1 share no factor. ✓



Practice 5



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 5 · 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: $1(+1) + 2(-1) = -1$ ✕

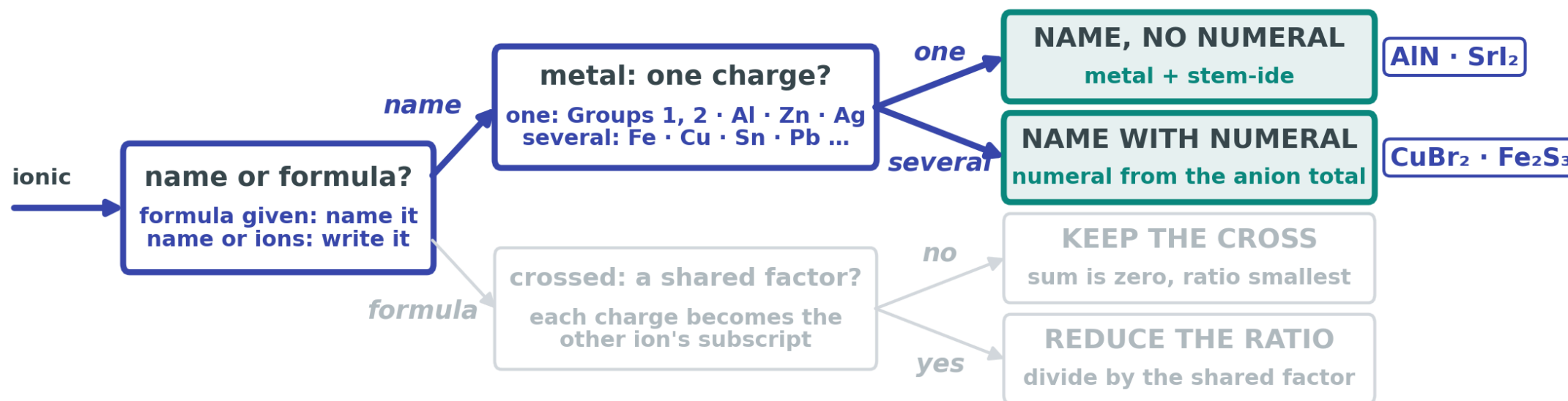
B is correct: three S^{2−} carry $3(-2) = -6$, split over two Fe, $6 \div 2 = 3+$ each; reading the subscript 2 as the charge gives the wrong numeral. C is correct: aluminum is fixed at 3+, $1(+3) + 1(-3) = 0$, so no numeral. D is correct: $1(+2) + 2(-1) = 0$, and strontium diiodide would borrow molecular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

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

✓ Practice 5: the route on the map



Al, Sr: one possible charge → no numeral · Cu, Fe: several → numeral from the anion total: Cu 2+, Fe 3+



🧠 **Sense check:** All four pairs run the name branch. Only CuBr₂ left with the wrong numeral. ✓

 Extra practice: Mn_2O_3

Mn_2O_3 , named "manganese(III) trioxide"

manganese, a metal · oxygen, a nonmetal → ionic

A student names Mn_2O_3 "manganese(III) trioxide": the numeral gives the charge, and tri-counts the oxides. What is wrong with this reasoning, if anything?

- A. Nothing: the numeral and the prefix report different facts
- B. The numeral should be (VI): three oxides carry 6–
- C. The numeral should be (II): the formula holds two Mn
- D. Drop both markers: manganese oxide, since the formula shows the counts
- E. The (III) is right, but tri- borrows the molecular system: manganese(III) oxide

✓ Extra practice · answer: E

$\text{Mn}_2\text{O}_3 \rightarrow$ manganese(III) oxide (answer E)

three O^{2-} : $3(-2) = -6$ · split over two Mn: $6 \div 2 = 3+$ each · $2(+3) + 3(-2) = 0$ ✓

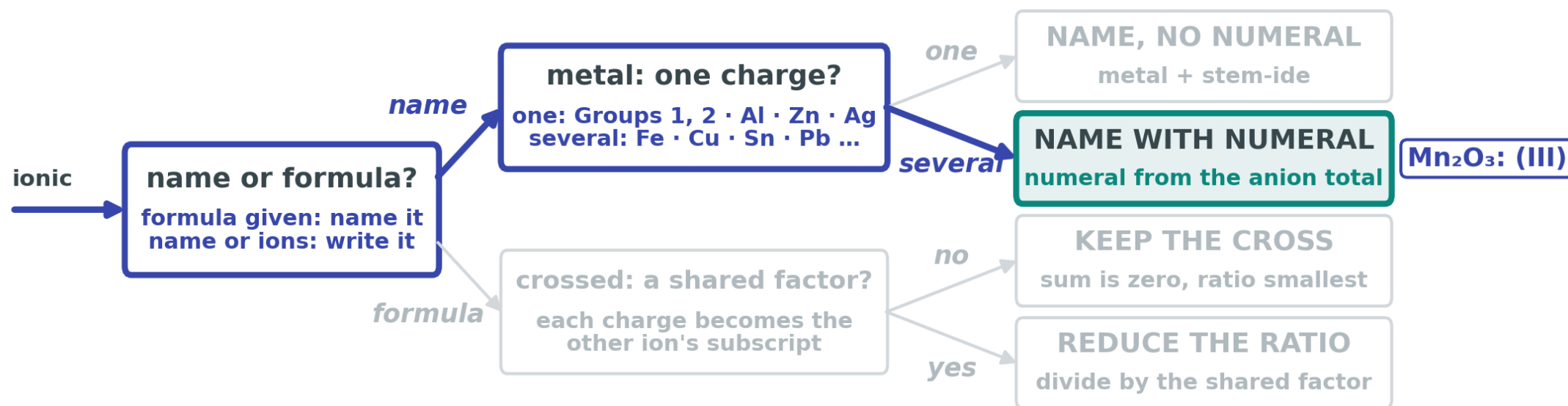
A keeps a counting prefix on an ionic name; the numeral already fixes the formula. B never split the anion total over two Mn: $2(+6) + 3(-2) = +6$, not neutral. C read the subscript 2 as the charge: $2(+2) + 3(-2) = -2$. D drops the numeral a variable-charge metal needs; "manganese oxide" also fits MnO and MnO_2 .

 **Sense check:** The numeral checks out; the prefix is the error. An ionic name carries a numeral when needed, never a counting prefix. ✓

✓ Extra practice: the route on the map

Mn_2O_3 : manganese(III) oxide

name wanted · manganese: several possible charges → numeral · no exit on the map adds a prefix



🧠 **Sense check:** The name branch ends at a numeral or at no numeral. No exit adds a counting prefix. ✓

Check yourself

1. Name CrCl_3 . Chromium is a variable-charge metal: where does its Roman numeral come from?
2. Write the formula for barium nitride. Does your formula sum to zero charge?

A compound of two nonmetals contains no ions. Those **molecular compounds** are named with Greek prefixes: CO_2 is carbon dioxide. And some ions are charged groups of atoms; they carry their own names and follow the same charge-balance rule.

2 · Polyatomic Ions

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

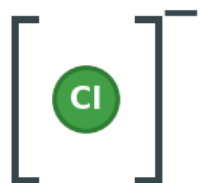
The names on the shelf



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.

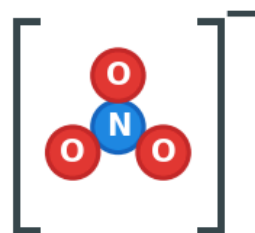
One group, one charge

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.

Finding the group in a formula



baking soda · bleach · a fertilizer · household ammonia

Sodium forms Na^+ and calcium forms Ca^{2+} . What remains after the metal is the group. Split each formula into its ions; the group's charge cancels the metal's.



one Na^+ takes one 1– group · one Ca^{2+} takes two 1– groups · NH_4OH : two groups, no metal

The common polyatomic ions

The six -ate bases below are given on every exam. Hydroxide and ammonium are memorized. Every -ite, per- and hypo- member is derived from its -ate.

NO_3^- nitrate · ClO_3^- chlorate · SO_4^{2-} sulfate · CO_3^{2-} carbonate · CrO_4^{2-} chromate · PO_4^{3-} phosphate

GIVEN on every exam: the six -ate bases, with their charges

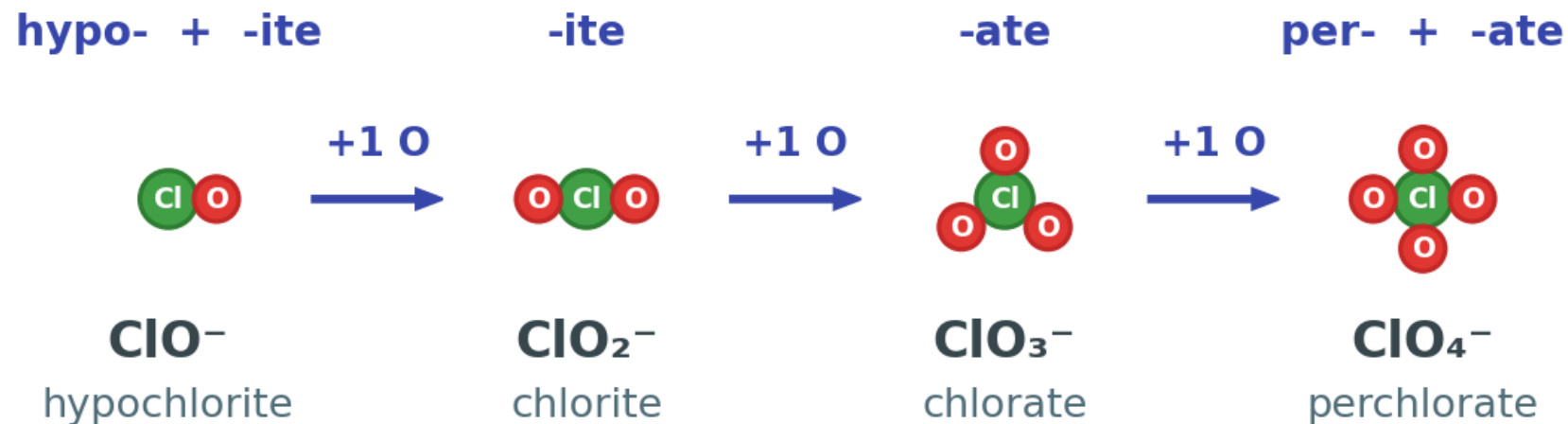
NO_2^- nitrite · SO_3^{2-} sulfite · ClO_2^- chlorite · ClO_4^- perchlorate · ClO^- hypochlorite · HCO_3^- hydrogen carbonate

DERIVED from the -ate: one O fewer, one more, two fewer, or one H^+ added · the charge follows the rules

OH^- hydroxide · NH_4^+ ammonium

MEMORIZED: they belong to no family · ammonium is 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–.

Adding H⁺ to an -ate

CO₃²⁻ carbonate → HCO₃⁻ hydrogen carbonate

one H⁺ added: $-2 + 1 = -1$ · the oxygen count stays 3

PO₄³⁻ phosphate → HPO₄²⁻ hydrogen phosphate → H₂PO₄⁻ dihydrogen phosphate

each H⁺ raises the charge by one: $-3 + 1 = -2$ · $-3 + 2 = -1$

Each added H⁺ shows in the formula and in the name. Sulfate, SO₄²⁻, is given: write hydrogen sulfate.

SO₄²⁻ + H⁺ → HSO₄⁻ hydrogen sulfate

$-2 + 1 = -1$ · four O, as in sulfate

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–

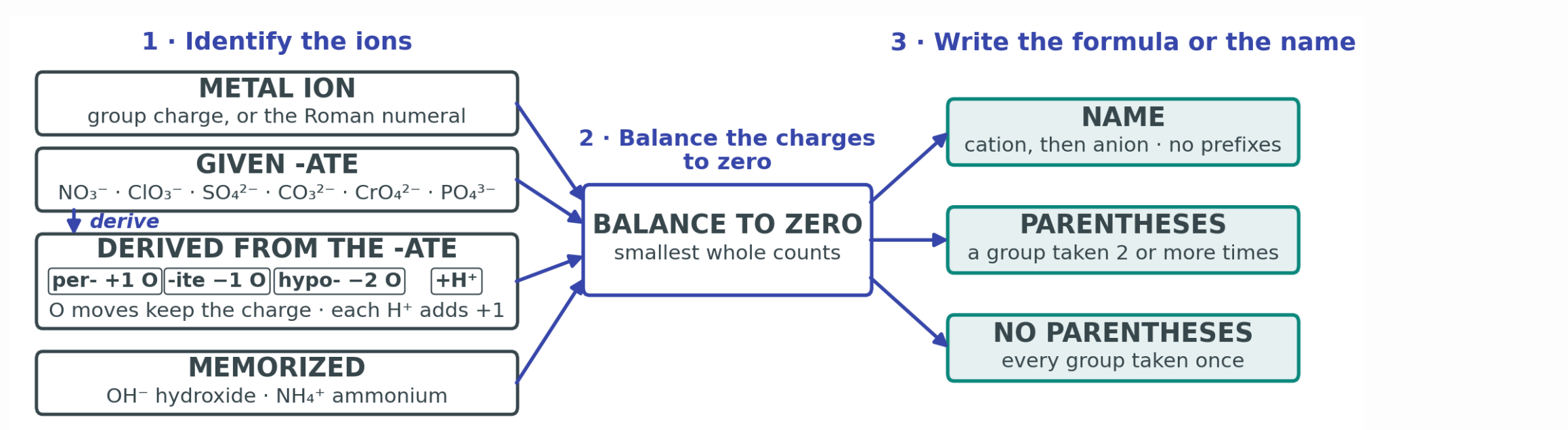
Table position sets the oxygen count; the -ate charge usually matches the monatomic anion. Nitrogen is the exception. Labels write bicarbonate for hydrogen carbonate.



The method

1. **Identify the ions.** Read the given -ate, or derive the member from it.
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.

One map for every formula and name



Step 1 finds each ion: a metal, a given -ate, a member derived from it, or a memorized ion. Steps 2 and 3 run the same way for every compound.

Guided example: sodium nitrite

sodium nitrite: the curing salt in bacon and ham
given: the name · nitrate NO_3^- given · wanted: the formula

Write the formula, one method step at a time.

✓ Guided example: solution

sodium nitrite

given: the name · nitrate NO_3^- given · wanted: the formula

Step 1 · Identify the ions

Step 2 · Balance the charges to zero

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

one Na^+ for one NO_2^-

Step 3 · Write the formula or the name



atoms: 1 Na · 1 N · 2 O · one nitrite, so no parentheses

 **Sense check:** Nitrate's three O became two; the 1– stayed. One Na^+ cancels it. ✓

✓ Guided example: the route on the map

sodium nitrite $\rightarrow \text{Na}^+ + \text{NO}_2^- \rightarrow \text{NaNO}_2$
 given: the name and nitrate · found: the formula

1 · Identify the ions

METAL ION

Na^+ · Group 1

GIVEN -ATE

NO_3^- nitrate

↓ *derive*

DERIVED FROM THE -ATE

per- +1 O **-ite -1 O** hypo- -2 O +H⁺

$\text{NO}_3^- \rightarrow \text{NO}_2^-$ nitrite

MEMORIZED

OH^- hydroxide · NH_4^+ ammonium

2 · Balance the charges to zero

BALANCE TO ZERO

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

3 · Write the formula or the name

NAME

cation, then anion · no prefixes

PARENTHESES

a group taken 2 or more times

NO PARENTHESES

NaNO_2

🧠 **Sense check:** One derive move: nitrate minus one O is nitrite, still 1-. Each ion appears once, so no parentheses.





Practice 1

phosphate: PO_4^{3-}

given: the -ate · wanted: the -ite member

Which formula and charge belong to phosphite?



✓ Practice 1 · answer: A

$\text{PO}_4^{3-} \rightarrow \text{one O fewer} \rightarrow \text{PO}_3^{3-}$ phosphite (answer A)

-ite: $4 - 1 = 3$ O · the charge stays 3–

B kept the -ate: PO_4^{3-} is phosphate itself. C dropped the charge along with the oxygen: PO_3^{2-} ; -ite never changes the charge. D removed two O, $4 - 2 = 2$: the hypo- ... -ite step. E added one, $4 + 1 = 5$: the per- direction.

🧠 **Sense check:** Only the oxygen count moves, by one and downward. Every phosphorus member keeps the 3–. ✓

✓ Practice 1: the route on the map

PO_4^{3-} phosphate $\rightarrow$ PO_3^{3-} phosphite
given: the -ate · found: the -ite member

1 · Identify the ions

METAL ION

group charge, or the Roman numeral

GIVEN -ATE

PO_4^{3-} phosphate

↓ derive

DERIVED FROM THE -ATE

per- +1 O **-ite -1 O** hypo- -2 O +H⁺

$\text{PO}_4^{3-} \rightarrow \text{PO}_3^{3-}$ phosphite

MEMORIZED

OH⁻ hydroxide · NH₄⁺ ammonium

2 · Balance the charges to zero

BALANCE TO ZERO

smallest whole counts

3 · Write the formula or the name

NAME

cation, then anion · no prefixes

PARENTHESES

a group taken 2 or more times

NO PARENTHESES

every group taken once

🧠 **Sense check:** One box and one derive move. Steps 2 and 3 wait until the ion sits in a compound. ✓

 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 ion 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

GIVEN -ATE

CO_3^{2-} carbonate

↓ derive

DERIVED FROM THE -ATE

per- +1 O -ite -1 O hypo- -2 O +H⁺
O moves keep the charge · each H⁺ adds +1

MEMORIZED

OH^- hydroxide · NH_4^+ ammonium

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:** No derive move: carbonate is a given -ate. 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

METAL ION

Mg^{2+} · Group 2

GIVEN -ATE

NO_3^- nitrate

derive

DERIVED FROM THE -ATE

per- +1 O -ite -1 O hypo- -2 O +H⁺
O moves keep the charge · each H⁺ adds +1

MEMORIZED

OH^- hydroxide · NH_4^+ ammonium

2 · Balance the charges to zero

BALANCE TO ZERO

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

3 · Write the formula or the name

NAME

cation, then anion · no prefixes

PARENTHESES

$\text{Mg}(\text{NO}_3)_2$

NO PARENTHESES

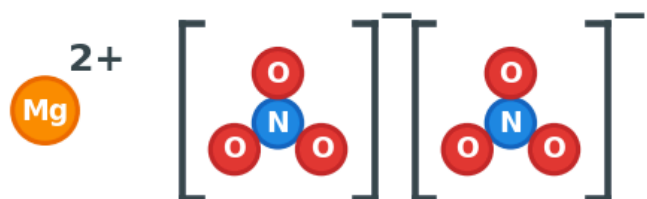
every group taken once



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 given identity, and every derived member keeps it.

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 2

KClO_4 : K^+ with one ion from the chlorine series
given: the formula · chlorate ClO_3^- given · 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
- E. potassium(I) perchlorate

✓ Practice 2 · 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. E puts a numeral on potassium, a fixed-charge metal: K^+ never takes one.

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

✓ Practice 2: the route on the map



given: the formula and chlorate · found: the name

1 · Identify the ions

METAL ION

K^+ · Group 1

GIVEN -ATE

ClO_3^- chlorate

↓ derive

DERIVED FROM THE -ATE

per- +1 O -ite -1 O hypo- -2 O +H⁺

$\text{ClO}_3^- \rightarrow \text{ClO}_4^-$ perchlorate

MEMORIZED

OH^- hydroxide · NH_4^+ ammonium

2 · Balance the charges to zero

BALANCE TO ZERO

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

3 · Write the formula or the name

NAME

potassium perchlorate

PARENTHESES

a group taken 2 or more times

NO PARENTHESES

every group taken once

🧠 **Sense check:** Perchlorate is derived: the given chlorate plus one O, still 1-. ✓



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. Phosphate is a given -ate; ammonium is one of the two memorized ions.

✓ Worked example 3: solution

ammonium phosphate

given: the name · wanted: the formula

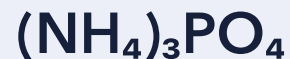
Step 1 · Identify the ions

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

GIVEN -ATE

PO_4^{3-} phosphate

derive

DERIVED FROM THE -ATE

per- +1 O -ite -1 O hypo- -2 O +H⁺
O moves keep the charge · each H⁺ adds +1

MEMORIZED

NH_4^+ ammonium

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: the cation is memorized ammonium. Three of it put NH_4 in parentheses. ✓



Practice 3

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 3 · 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.

✓ Practice 3: the route on the map



given: the name and both ions · found: the formula

1 · Identify the ions

METAL ION

group charge, or the Roman numeral

GIVEN -ATE

SO_4^{2-} sulfate

derive

DERIVED FROM THE -ATE

per- +1 O -ite -1 O hypo- -2 O +H⁺
O moves keep the charge · each H⁺ adds +1

MEMORIZED

NH_4^+ ammonium

2 · Balance the charges to zero

BALANCE TO ZERO

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

3 · Write the formula or the name

NAME

cation, then anion · no prefixes

PARENTHESES

$(\text{NH}_4)_2\text{SO}_4$

NO PARENTHESES

every group taken once

🧠 **Sense check:** Ammonium is memorized and sulfate is given. Two ammoniums take the parentheses. ✓



Practice 4

sodium hydrogen sulfite: a food preservative

Na^+ · sulfate SO_4^{2-} given · wanted: the formula

Which formula is sodium hydrogen sulfite?

- A. NaHSO_4
- B. Na_2HSO_3
- C. NaHSO_3
- D. NaH_2SO_3

✓ Practice 4 · answer: C



-ite: $4 - 1 = 3$ O, still $2-$ · one H^+ : $-2 + 1 = -1 \cdot 1(+1) + 1(-1) = 0$ ✓

A added the H^+ but kept the -ate: NaHSO_4 is sodium hydrogen sulfate. B kept sulfite's $2-$ after adding H^+ : $2(+1) + 1(-2) = 0$ balances a charge HSO_3 does not carry. D added two H^+ : $-2 + 2 = 0$, and $1(+1) + 1(0) = +1$ is not neutral.

 **Sense check:** Two derive moves, in order: drop one O for -ite, then add one H^+ . A $1-$ anion needs one Na^+ , and one group needs no parentheses. ✓

✓ Practice 4: the route on the map



given: the name and sulfate · found: the formula

1 · Identify the ions

METAL ION

Na^+ · Group 1

GIVEN -ATE

SO_4^{2-} sulfate

↓ *derive*

DERIVED FROM THE -ATE

per- +1 O **-ite -1 O** hypo- -2 O **+H⁺**

$\text{SO}_4^{2-} \rightarrow \text{SO}_3^{2-} \rightarrow \text{HSO}_3^-$

MEMORIZED

OH^- hydroxide · NH_4^+ ammonium

2 · Balance the charges to zero

BALANCE TO ZERO

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

3 · Write the formula or the name

NAME

cation, then anion · no prefixes

PARENTHESES

a group taken 2 or more times

NO PARENTHESES

NaHSO_3

🧠 **Sense check:** Both derive moves fire: -ite keeps the 2-, then H^+ raises it to 1-. One of each ion, no 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

GIVEN -ATE

SO_4^{2-} sulfate

derive

DERIVED FROM THE -ATE

per- +1 O -ite -1 O hypo- -2 O +H⁺
O moves keep the charge · each H⁺ adds +1

MEMORIZED

OH^- hydroxide · NH_4^+ ammonium

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 5

calcium hydrogen carbonate

$\text{Ca}^{2+} \cdot \text{HCO}_3^-$, charge 1 – · wanted: the formula

Calcium hydrogen carbonate is the dissolved mineral in hard water. Write the formula.

- A. CaHCO_3
- B. $\text{Ca}(\text{HCO}_3)_2$
- C. Ca_2HCO_3
- D. CaCO_3

✓ Practice 5 · answer: B

calcium hydrogen carbonate → $\text{Ca}(\text{HCO}_3)_2$ (answer B)

$1(+2) + 2(-1) = 0$ ✓ · the whole HCO_3^- group repeats, so it takes parentheses

A stops at one anion: $1(+2) + 1(-1) = +1$, not neutral. C doubles the cation instead: $2(+2) + 1(-1) = +3$. D balances, $1(+2) + 1(-2) = 0$, but its anion is carbonate: CaCO_3 is calcium carbonate, a different compound.

🧠 **Sense check:** Hydrogen carbonate carries 1– as one unit; two whole groups cancel one Ca^{2+} .

✓ Practice 5: the route on the map

calcium hydrogen carbonate $\rightarrow \text{Ca}^{2+} + 2 \text{HCO}_3^- \rightarrow \text{Ca}(\text{HCO}_3)_2$
 given: the name · found: the formula

1 · Identify the ions

METAL ION

Ca^{2+} · Group 2

GIVEN -ATE

CO_3^{2-} carbonate

↓ derive

DERIVED FROM THE -ATE

per- +1 O -ite -1 O hypo- -2 O **+H⁺**

$\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{HCO}_3^-$

MEMORIZED

OH^- hydroxide · NH_4^+ ammonium

2 · Balance the charges to zero

BALANCE TO ZERO

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

3 · Write the formula or the name

NAME

cation, then anion · no prefixes

PARENTHESES

$\text{Ca}(\text{HCO}_3)_2$

NO PARENTHESES

every group taken once

🧠 **Sense check:** One H^+ on carbonate makes a 1- group. Two of them need parentheses. ✓



Practice 6

iron(III) sulfite

iron, a variable-charge metal · sulfate SO_4^{2-} given · 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 6 · 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.

✓ Practice 6: the route on the map



given: the name and sulfate · found: the formula

1 · Identify the ions

METAL ION

Fe^{3+} · the (III)

GIVEN -ATE

SO_4^{2-} sulfate

↓ derive

DERIVED FROM THE -ATE

per- +1 O **-ite -1 O** hypo- -2 O +H⁺

$\text{SO}_4^{2-} \rightarrow \text{SO}_3^{2-}$ sulfite

MEMORIZED

OH^- hydroxide · NH_4^+ ammonium

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

$\text{Fe}_2(\text{SO}_3)_3$

NO PARENTHESES

every group taken once

 **Sense check:** Every box but the memorized one is used: the numeral, the derive move, the criss-cross, the parentheses. ✓



Check yourself

1. Sodium carbonate contains Na^+ and CO_3^{2-} . Write the formula, and show the charge sum that makes it neutral.
2. KClO_4 and KClO_3 : name both. Which piece of each name reports the oxygen count?

In a chemical equation, a polyatomic ion that passes through a reaction unchanged is balanced as **one unit**: count nitrate as nitrate, not as separate N and O atoms.

3 · 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



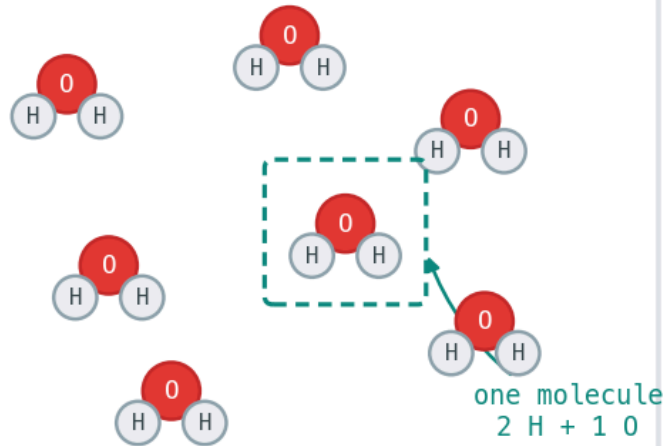
harmless: the fizz in every soda

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.

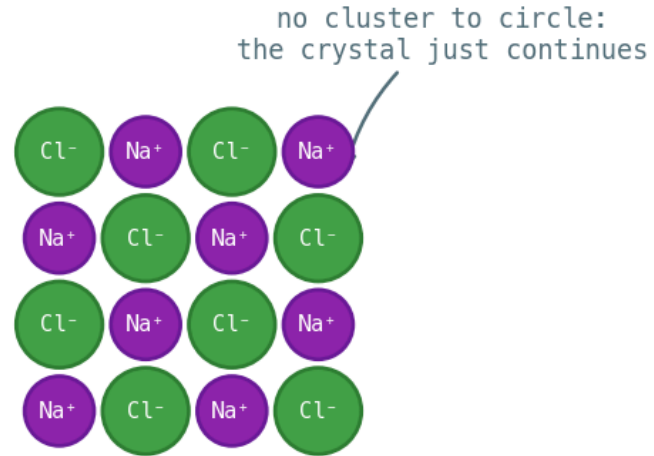
What a molecule is

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.

Ionic or molecular: read the elements

metal + nonmetal: ions → ionic · nonmetals only: shared electrons → molecular
the elements in the formula decide the type before any naming starts

Sort each compound as ionic or molecular.

Li_2O · NBr_3 · CaCl_2 · P_2O_5
four compounds · wanted: ionic or molecular

Li_2O ionic · NBr_3 molecular · CaCl_2 ionic · P_2O_5 molecular
Li, Ca: metals · N, Br, P, O: nonmetals

Only the molecular compounds take counting prefixes.

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 $\rightarrow \text{O}_2$

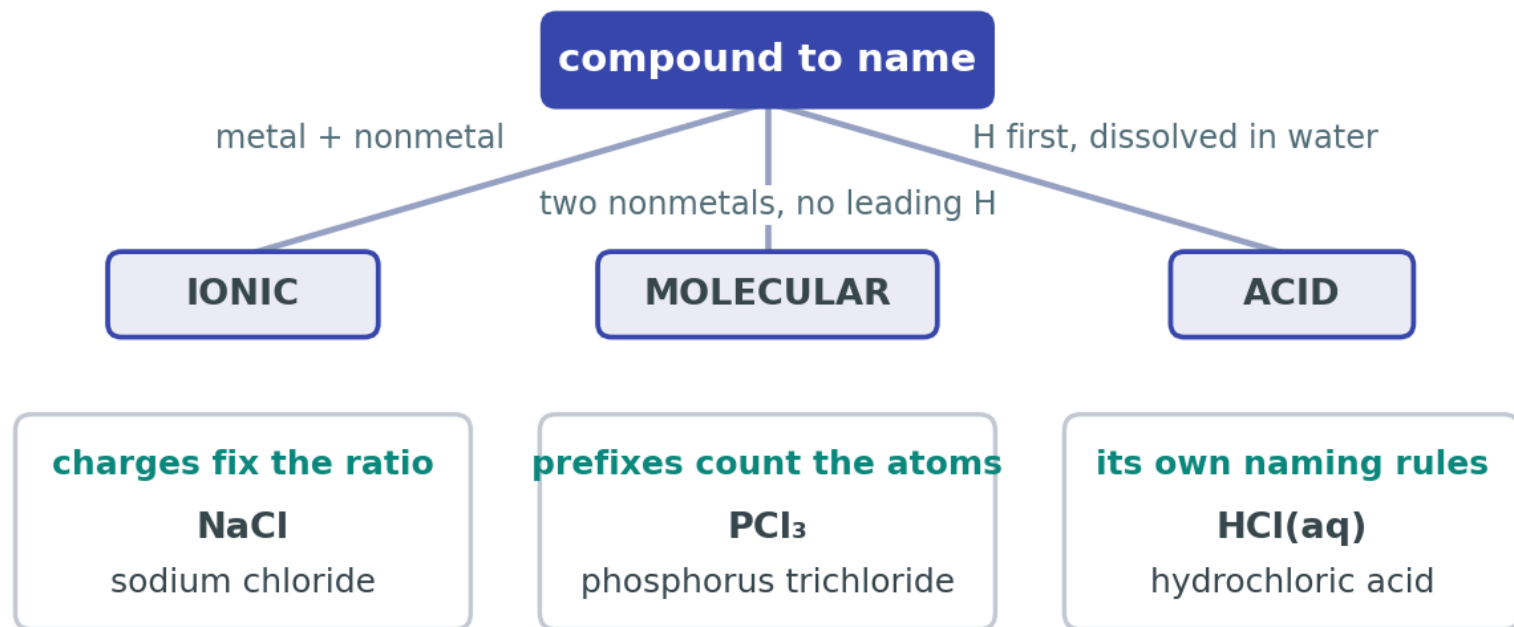
a sample of the pure element: every molecule is a pair

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: NH_4Cl 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⁺

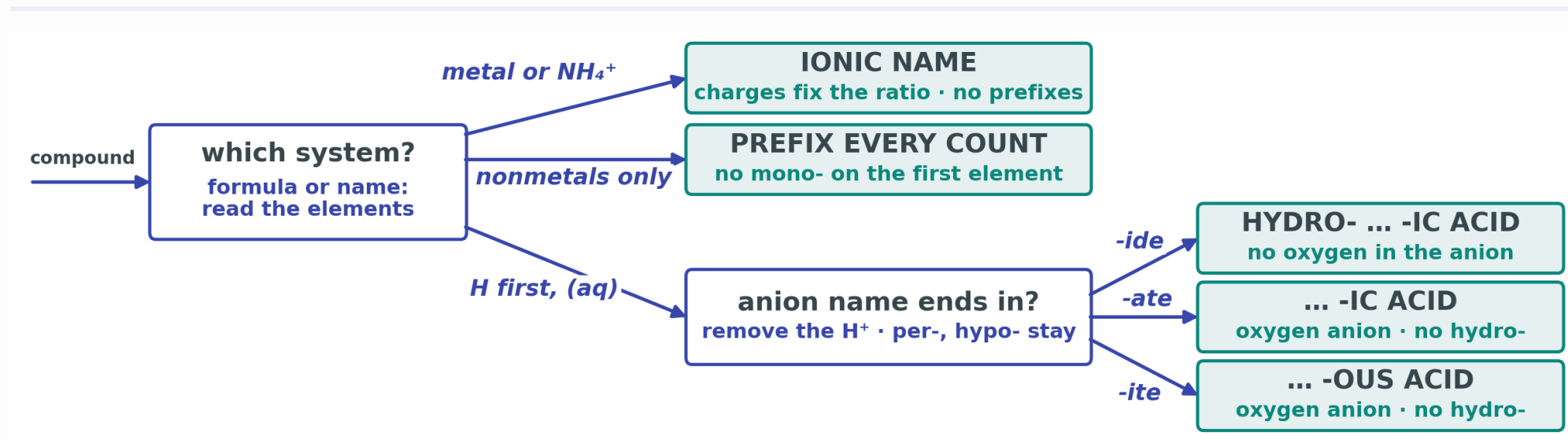
An acid is a compound that releases H⁺ when dissolved in water. Its formula starts with H and carries (aq). Acids get their own names, under their own rules.



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.

One map for every name



Step 1 picks the branch from the elements. Step 2 follows it to one rule. An acid needs one more question: how its anion's name ends.

 Guided example: CCl_4 

given: the formula · wanted: the name

Carbon and chlorine form CCl_4 , once the fluid in fire extinguishers. Name the compound.

✓ Guided example: solution



given: the formula · wanted: the name

Step 1 · Classify the compound

C and Cl: nonmetals only · no leading H
molecular: a prefix counts each element's atoms

Step 2 · Apply that system's rules

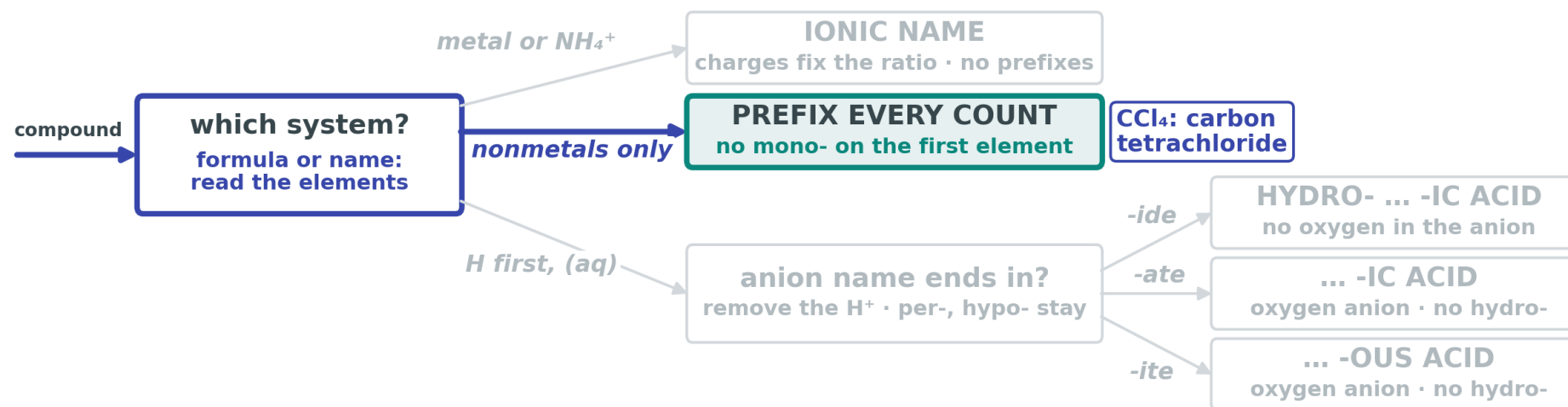
1 C: carbon · 4 Cl: tetra- + chlor- + -ide = tetrachloride
first element: its full name, mono- dropped · second: prefix + root + -ide

Step 3 · Read the name back

🧠 **Sense check:** One prefix per count. The name rebuilds the formula atom for atom. ✓

✓ Guided example: the route on the map

$\text{CCl}_4 \rightarrow$ carbon tetrachloride
given: the formula · found: the name



🧠 **Sense check:** Nonmetals only: the molecular branch and one rule. The acid question never comes up. ✓



Practice 1



nitrogen and fluorine

Chip makers use NF_3 gas to clean their equipment. What is the name of NF_3 ?

- A. nitrogen(III) fluoride
- B. nitrogen fluoride
- C. trinitrogen fluoride
- D. nitrogen trifluoride

✓ Practice 1 · answer: D

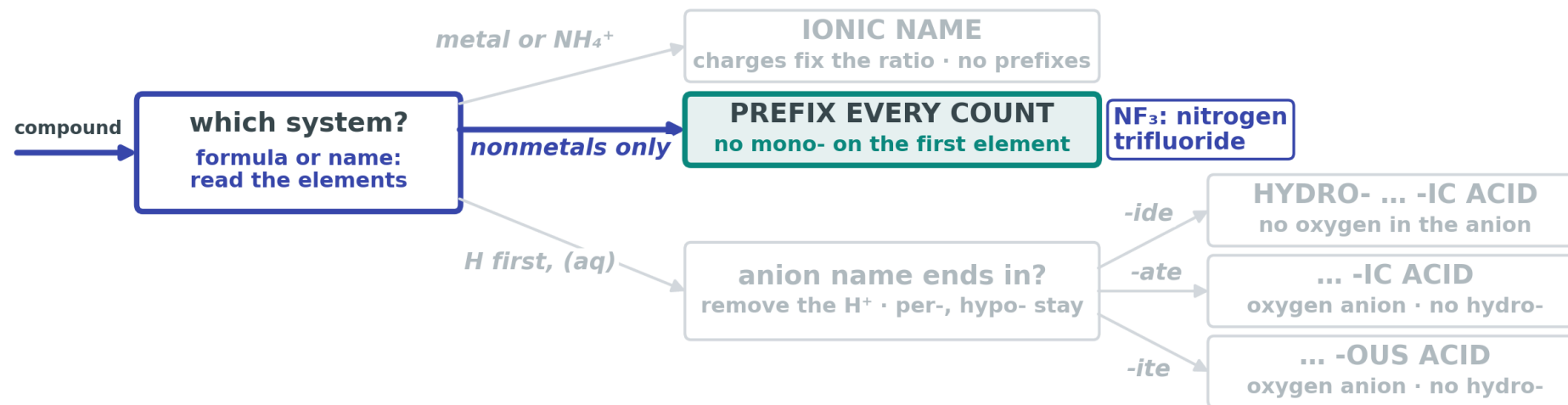
$\text{NF}_3 \rightarrow$ nitrogen trifluoride (answer D)
nonmetals only $\rightarrow$ molecular · 1 N: no prefix · tri- $\rightarrow$ 3 F

A borrows the ionic numeral: two nonmetals share electrons, and a numeral names a metal's charge. B drops the prefixes, and that name fits NF_3 and N_2F_4 alike. C puts tri- on the wrong element and rebuilds N_3F .

🧠 **Sense check:** Read the name back: no prefix $\rightarrow$ 1 N, tri- $\rightarrow$ 3 F $\rightarrow \text{NF}_3$ ✓

✓ Practice 1: the route on the map

$\text{NF}_3 \rightarrow$ nitrogen trifluoride
given: the formula · found: the name



🧠 **Sense check:** The molecular branch again: one prefix per element, and no numeral anywhere on it. ✓



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

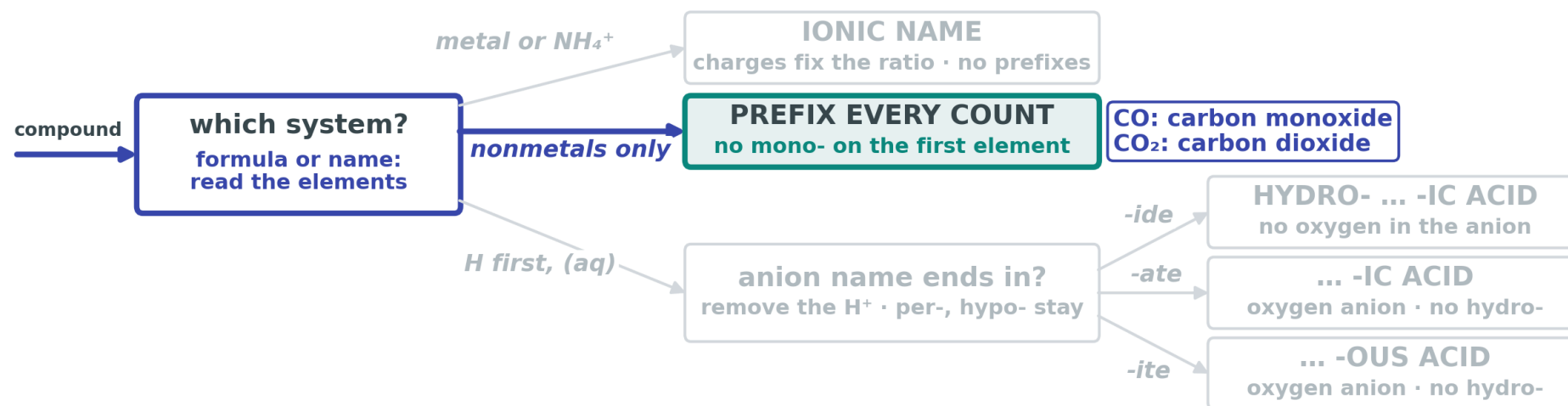
1 C: mono- dropped on the first element · mono- + oxide → monoxide · 2 O → dioxide

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

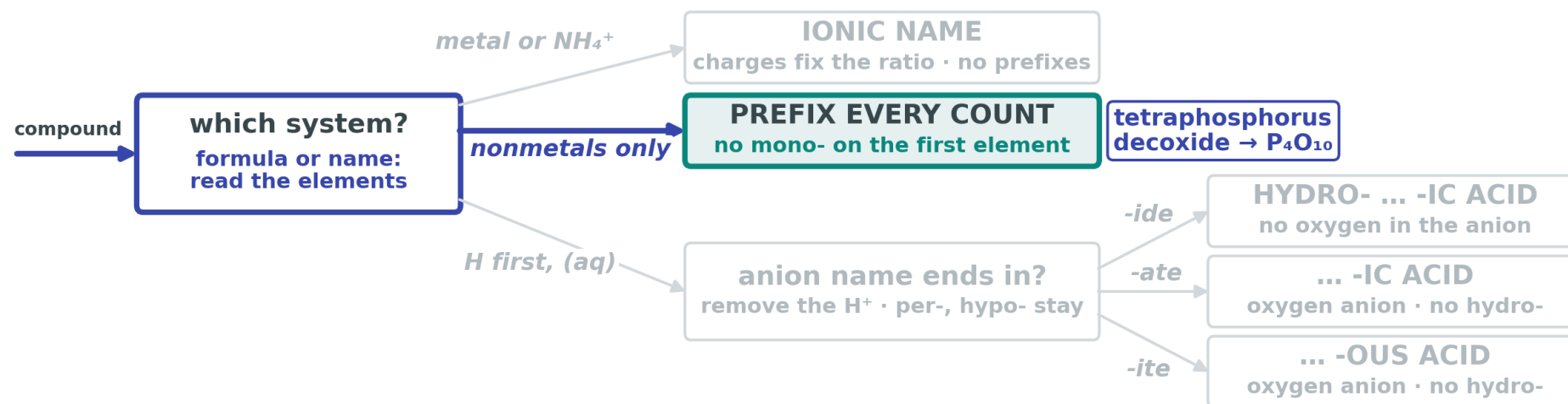
Step 3 · Read the name back

🧠 **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 2



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 2 · answer: B

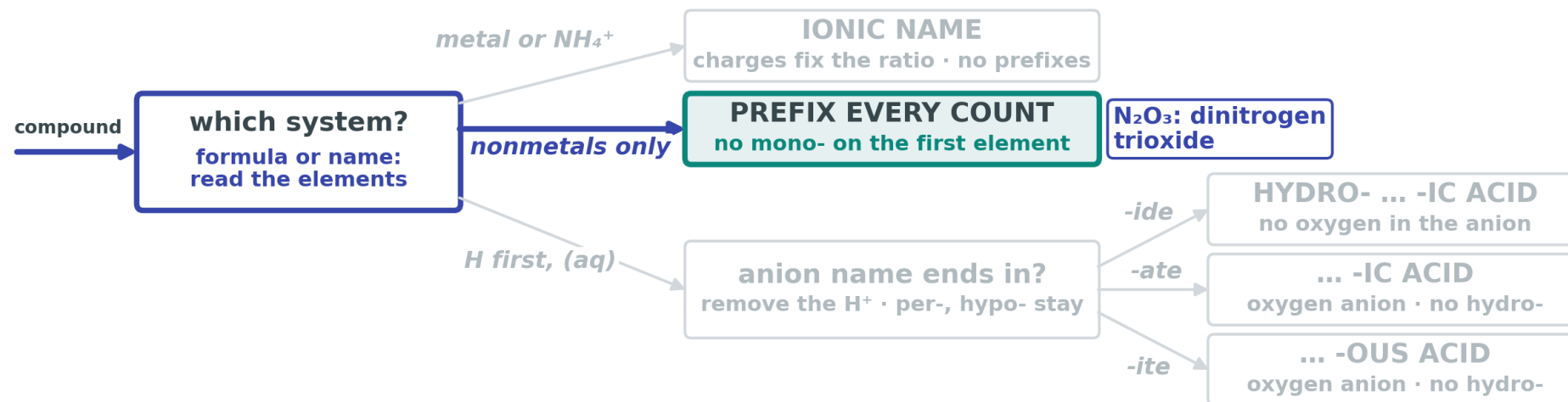
$\text{N}_2\text{O}_3 \rightarrow$ dinitrogen trioxide (answer B)
two nonmetals $\rightarrow$ molecular · di- $\rightarrow$ 2 N · tri- $\rightarrow$ 3 O

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.

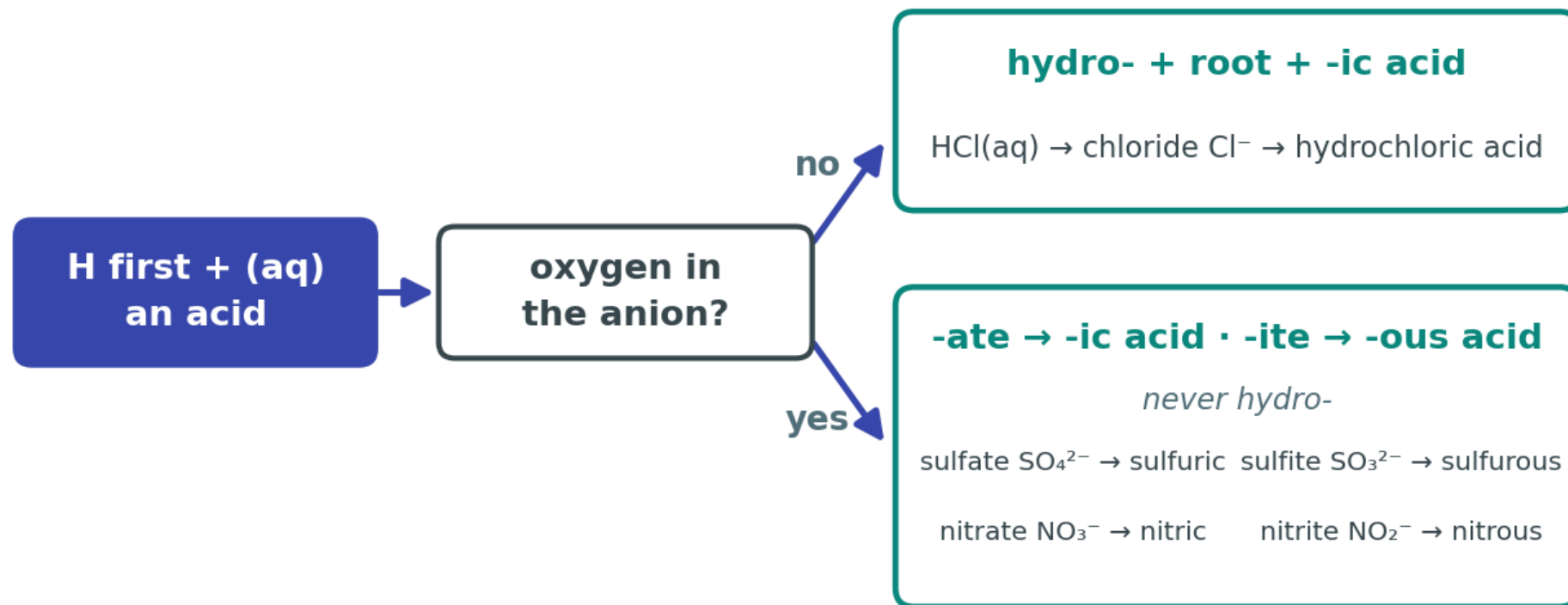
✓ Practice 2: the route on the map

$\text{N}_2\text{O}_3 \rightarrow$ dinitrogen trioxide
given: the formula · found: the name



Sense check: No metal and no leading H: the molecular branch. Nitrous acid sits on the acid branch and needs an H. ✓

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



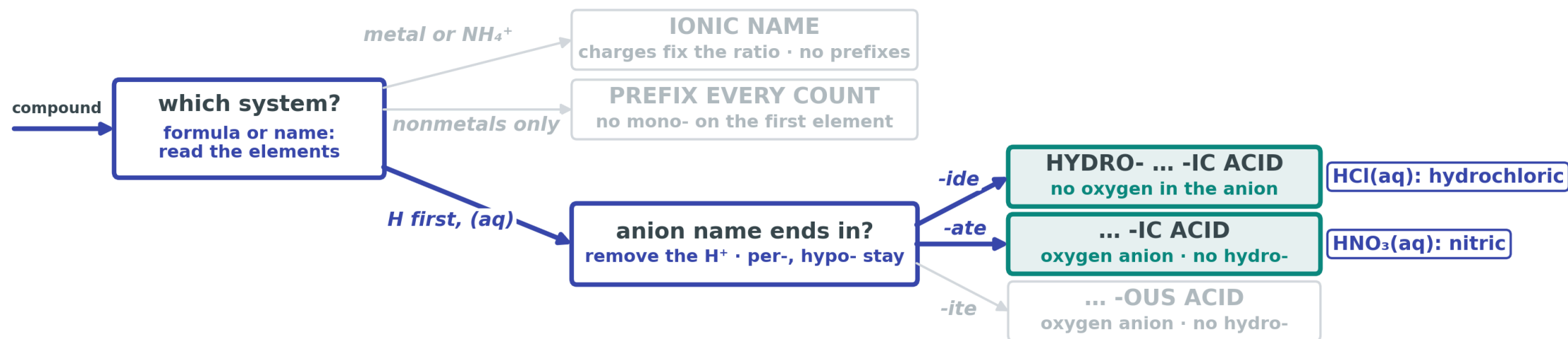
anion: nitrate → -ate becomes -ic · no hydro-

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

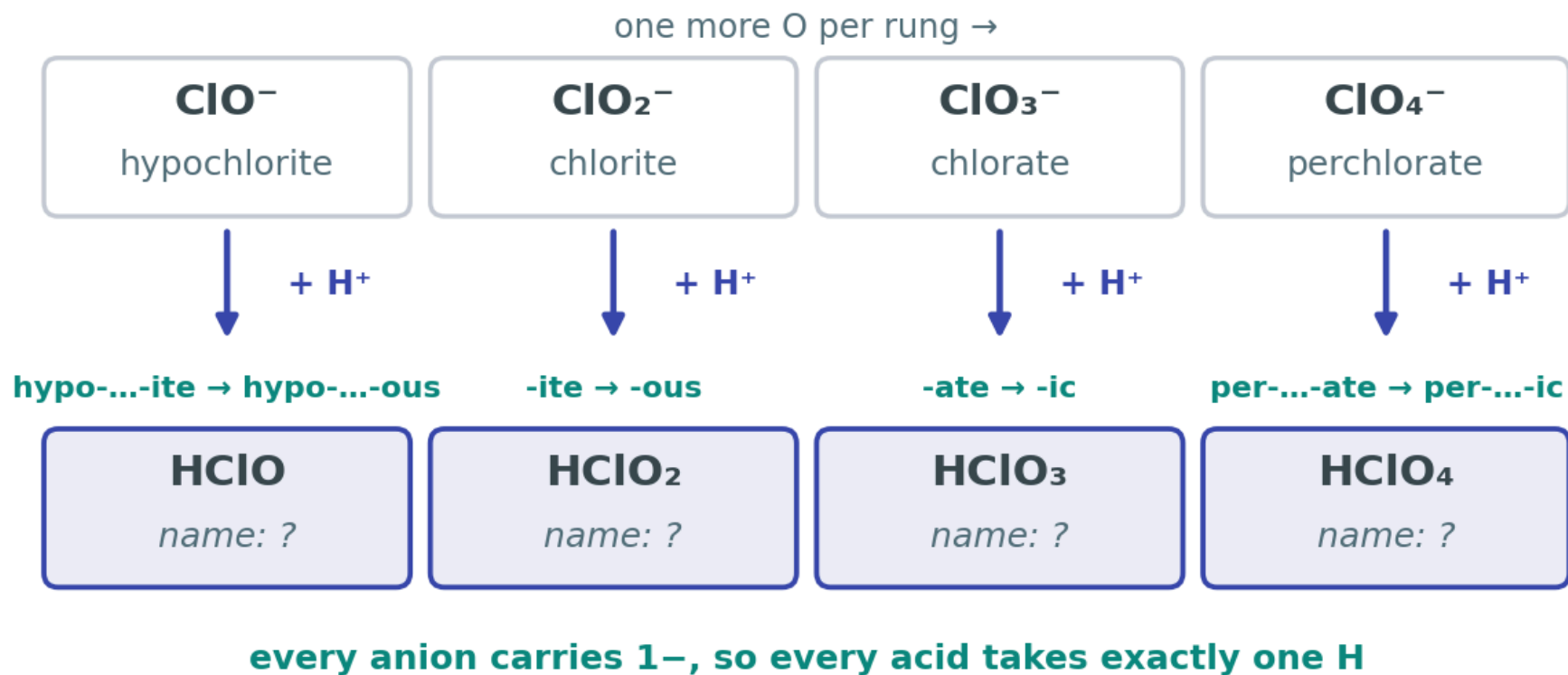
anion: sulfide, S^{2-} · no oxygen $\rightarrow$ hydro- + -ic

$\text{H}_2\text{SO}_4(\text{aq}) \rightarrow$ 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 3

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 3 · answer: C

HF(aq) → hydrofluoric acid (answer C)

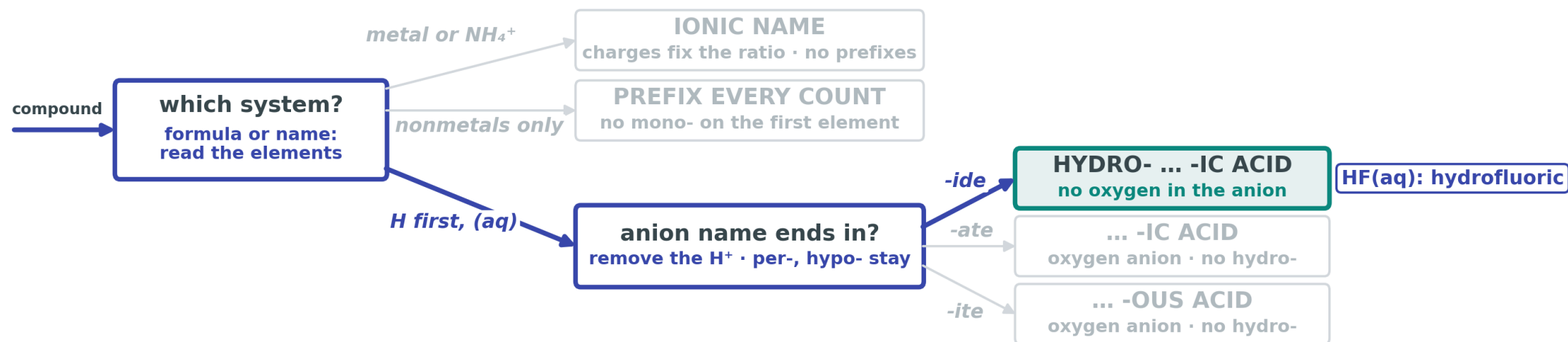
an acid · anion: fluoride, F^- · no oxygen → hydro- + fluor- + -ic acid

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).

✓ Practice 3: the route on the map

HF(aq) → hydrofluoric acid
given: the formula · found: the name



🧠 **Sense check:** H first with (aq): the acid branch. Fluoride ends in -ide, so hydro- goes on the front. ✓



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



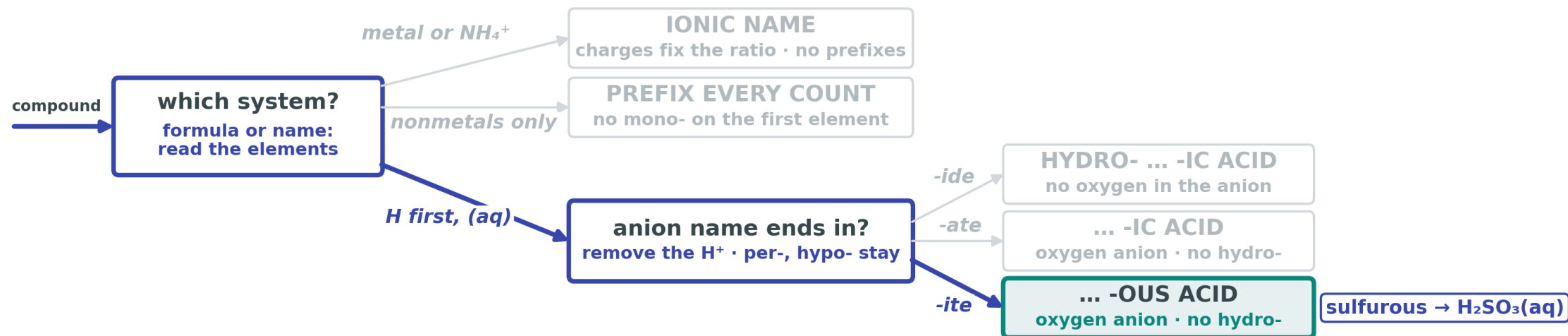
a 2– anion takes exactly two H^+ · the name never states the 2; balance rebuilds it

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 the given sulfate; its 2- sets two H. ✓



Practice 4

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 4 · answer: D

phosphoric acid $\rightarrow$ $\text{H}_3\text{PO}_4(\text{aq})$ (answer D)

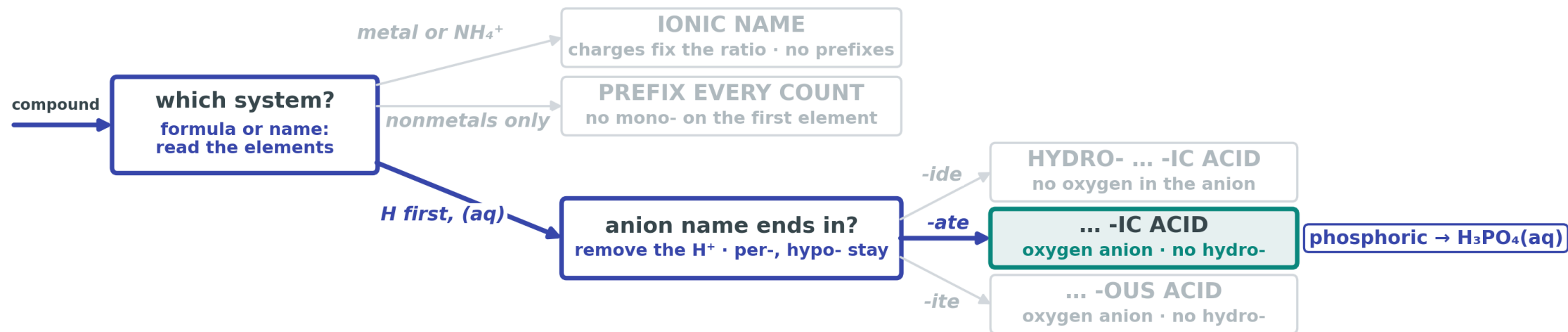
-ic came from -ate: phosphate, $\text{PO}_4^{3-} \cdot 3(+1) + 1(-3) = 0$ ✓

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.

✓ Practice 4: the route on the map

phosphoric acid → $\text{H}_3\text{PO}_4(\text{aq})$
given: the name · found: the formula



🧠 **Sense check:** -ic traces back to -ate: phosphate, PO_4^{3-} , on the given list. Its 3- charge sets three H. ✓

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

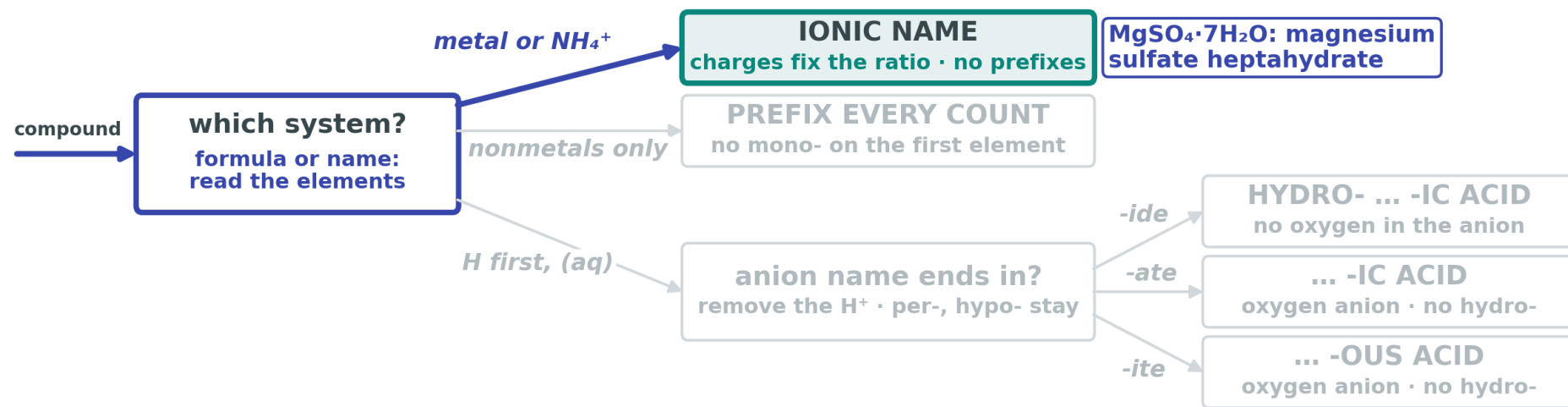
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O} \rightarrow$ magnesium sulfate heptahydrate

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· chlorate ClO_3^- given

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

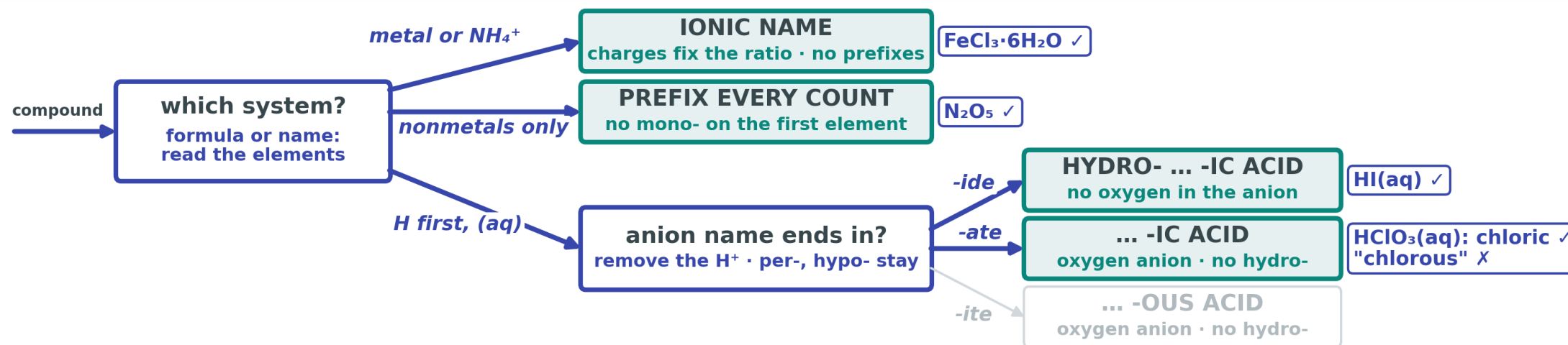
$\text{HClO}_3(\text{aq})$: anion ClO_3^- , chlorate $\rightarrow$ -ate becomes -ic $\rightarrow$ chloric acid (answer C)
chlorous acid is $\text{HClO}_2(\text{aq})$, built on chlorite $\cdot 1(+1) + 1(-1) = 0 \rightarrow$ one H ✓

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.

✓ Practice 5: the route on the map

N_2O_5 ✓ · $\text{HI}(\text{aq})$ ✓ · $\text{HClO}_3(\text{aq})$: chloric acid ✓, not chlorous ✗ · $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ ✓
four compounds, four branches · the error sits on the acid branch



🧠 **Sense check:** Chlorous belongs on the -ite exit. ClO_3^- is the given chlorate, so $\text{HClO}_3(\text{aq})$ exits at -ic. ✓



Extra practice 1



H first · dissolved in water · the anion is on the chlorine ladder

HClO(aq) is the working disinfectant in chlorinated pools. Name the compound.

- A. hypochlorous acid
- B. chlorous acid
- C. hydrochloric acid
- D. perchloric acid

✓ Extra practice 1 · answer: A

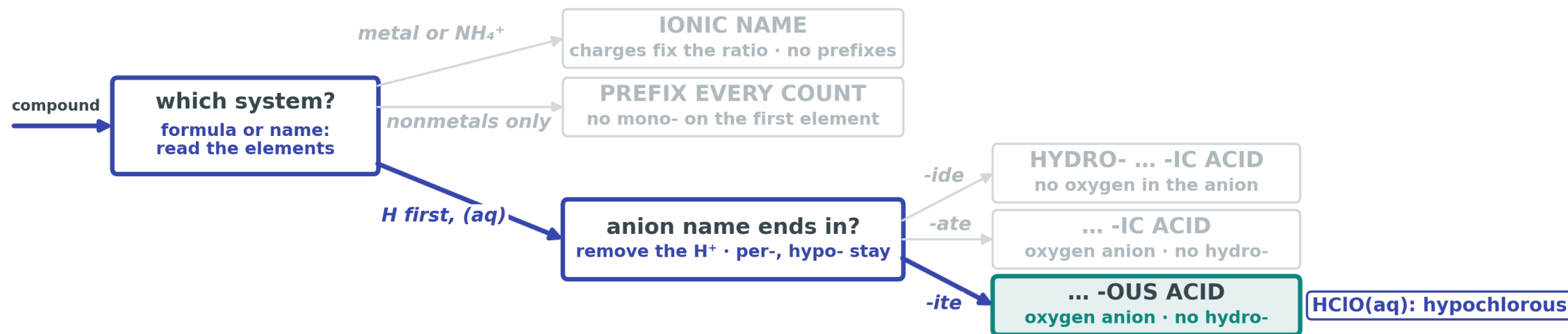
$\text{HClO}(\text{aq}) \rightarrow$ hypochlorous acid (answer A)
anion: ClO^- , hypochlorite, 1 O · hypo-...-ite $\rightarrow$ hypo-...-ous

B starts from chlorite, ClO_2^- , one rung up: chlorous acid is $\text{HClO}_2(\text{aq})$. C is the no-oxygen binary acid, $\text{HCl}(\text{aq})$; this anion holds one oxygen, so hydro- never appears. D starts from perchlorate, ClO_4^- , the top rung: perchloric acid is $\text{HClO}_4(\text{aq})$.

🧠 **Sense check:** Four rungs, four acids. The oxygen count picks the rung; the rung picks the name.

✓ Extra practice 1: the route on the map

$\text{HClO}(\text{aq}) \rightarrow$ hypochlorous acid
given: the formula · found: the name



🧠 **Sense check:** ClO^- holds two O fewer than the given chlorate: hypochlorite. Hypo- stays; -ite becomes -ous. ✓



Extra practice 2

$\text{H}_2\text{CrO}_4(\text{aq})$ named "chromous acid"
chromate CrO_4^{2-} given

A student names $\text{H}_2\text{CrO}_4(\text{aq})$ "chromous acid" and explains: "Removing the H's leaves an anion with oxygen, so no hydro-, and an oxygen acid ends in -ous." Evaluate the name.

- A. Nothing is wrong: chromous acid is correct
- B. The flaw is the system: chromium is a metal, so it is hydrogen chromate
- C. The flaw is the missing hydro-: it is hydrochromic acid
- D. The flaw is the formula: chromate needs one H, so $\text{HCrO}_4(\text{aq})$
- E. The flaw is the suffix: chromate is an -ate ion, so chromic acid

✓ Extra practice 2 · answer: E

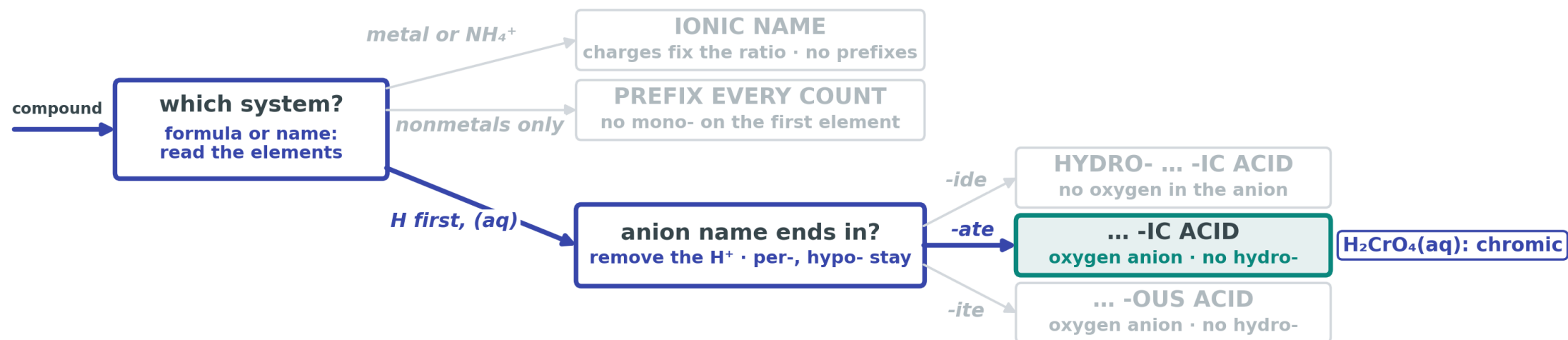
$\text{H}_2\text{CrO}_4(\text{aq})$: anion CrO_4^{2-} , chromate $\rightarrow$ -ate becomes -ic $\rightarrow$ chromic acid (answer E)
 $2(+1) + 1(-2) = 0 \rightarrow$ two H ✓ · the formula is right; only the suffix is wrong

A applies -ous, which belongs to -ite anions; CrO_4^{2-} is the given -ate itself. B names the pure compound the way $\text{HCl}(\text{g})$ is hydrogen chloride; the (aq) calls for the acid name, and the chromium sits inside the anion, so the metal test never applies. C adds hydro-, which marks an anion with no oxygen; chromate holds four. D miscounts the H: $1(+1) + 1(-2) = -1$, not neutral.

 **Sense check:** The student's first two moves were right. The last one used the -ite rule on an -ate ion.

✓ Extra practice 2: the route on the map

$\text{H}_2\text{CrO}_4(\text{aq}) \rightarrow$ chromic acid
given: the formula · found: the name



🧠 **Sense check:** H first with (aq) settles the branch before the metal test: acid. Chromate ends in -ate, so the exit is -ic.





Check yourself

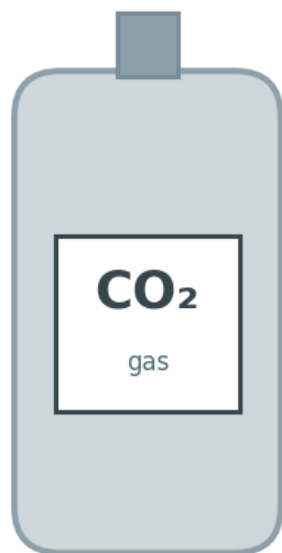
1. Sulfur and fluorine form SF_6 , a gas used to insulate electrical equipment. Classify the compound and name it.
2. NO_2^- is nitrite and NO_3^- is nitrate. Name $\text{HNO}_2(\text{aq})$ and $\text{HNO}_3(\text{aq})$.

Sulfate, sulfite, nitrate, and nitrite are the **polyatomic ions** of the last section put to work: each oxyacid name is built from its oxyanion.

4 · 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.

Ionic or molecular: look for a metal

CaF₂: calcium, a metal + fluorine, a nonmetal
electrons move from Ca to F → Ca²⁺ and F⁻ ions → ionic

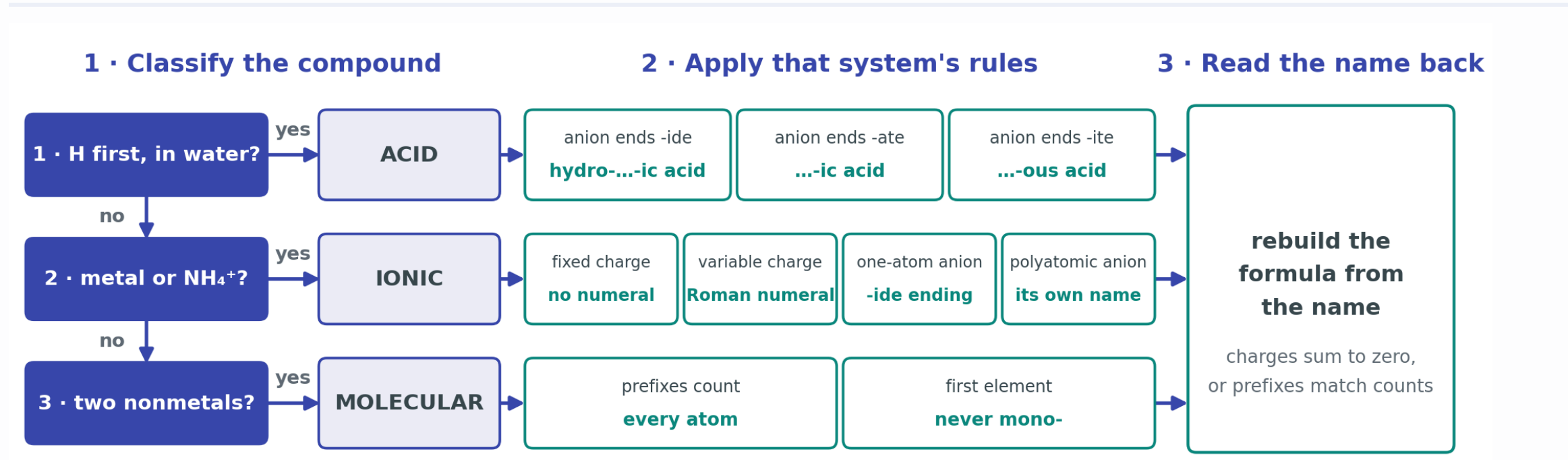
SF₆: sulfur + fluorine, two nonmetals
electrons are shared, no ions form → molecular

A metal gives electrons to a nonmetal, and the ions attract: an ionic compound. Nonmetals share electrons instead: a molecular compound. Acids form a third group: H first, dissolved in water.

Al₂O₃ · PF₃
sort each one: ionic or molecular

Al₂O₃: ionic · PF₃: molecular
aluminum is a metal · phosphorus and fluorine are both nonmetals

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.**

 Guided example: CaCl_2 

given: the formula · wanted: the name

Road crews spread CaCl_2 to melt ice on winter roads. Name the compound, one step at a time.

✓ Guided example: solution



given: the formula · wanted: the name

Step 1 · Classify the compound

H first? no · metal or NH_4^+ ? yes, Ca
the first yes ends the questions → ionic

Step 2 · Apply that system's rules

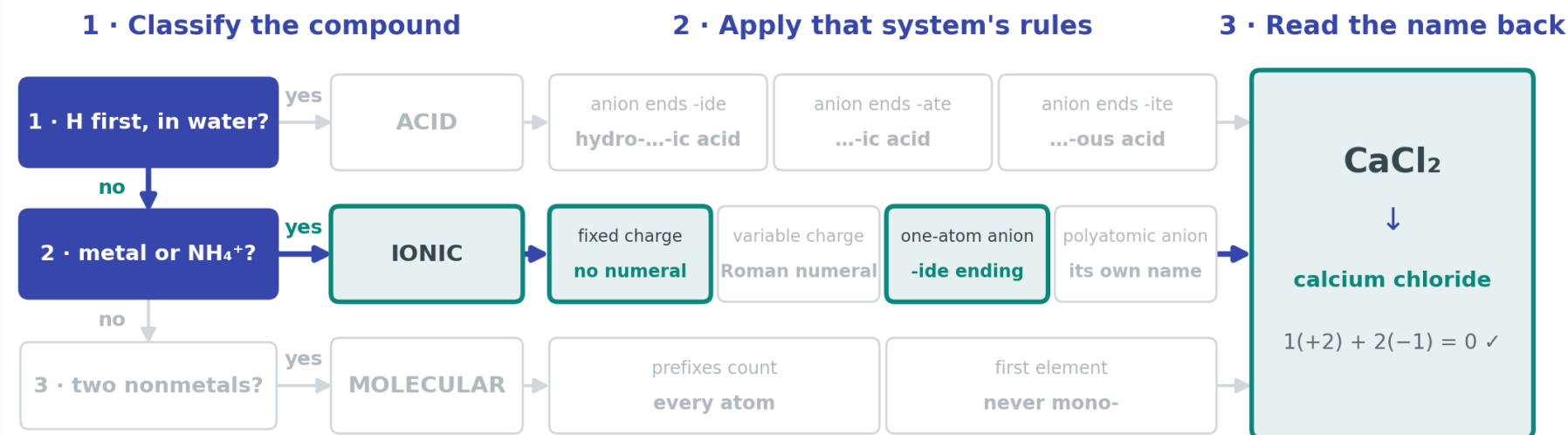
Ca: Group 2, always $2+$ → calcium, no numeral
Cl → chloride · the 2 comes from charge balance, so no prefix

 **Sense check:** Calcium's charge is fixed, so the name carries no numeral. The subscript is never spoken, so it carries no prefix. ✓

✓ Guided example: the route on the map

Step 3 • Read the name back

calcium chloride $\rightarrow \text{Ca}^{2+}$ with $\text{Cl}^- \rightarrow \text{CaCl}_2$
 $1(+2) + 2(-1) = 0 \checkmark$ • found: ionic, fixed charge, one-atom anion



🧠 **Sense check:** Two questions asked, two ionic rules used. The acid and molecular rows never ran. ✓



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

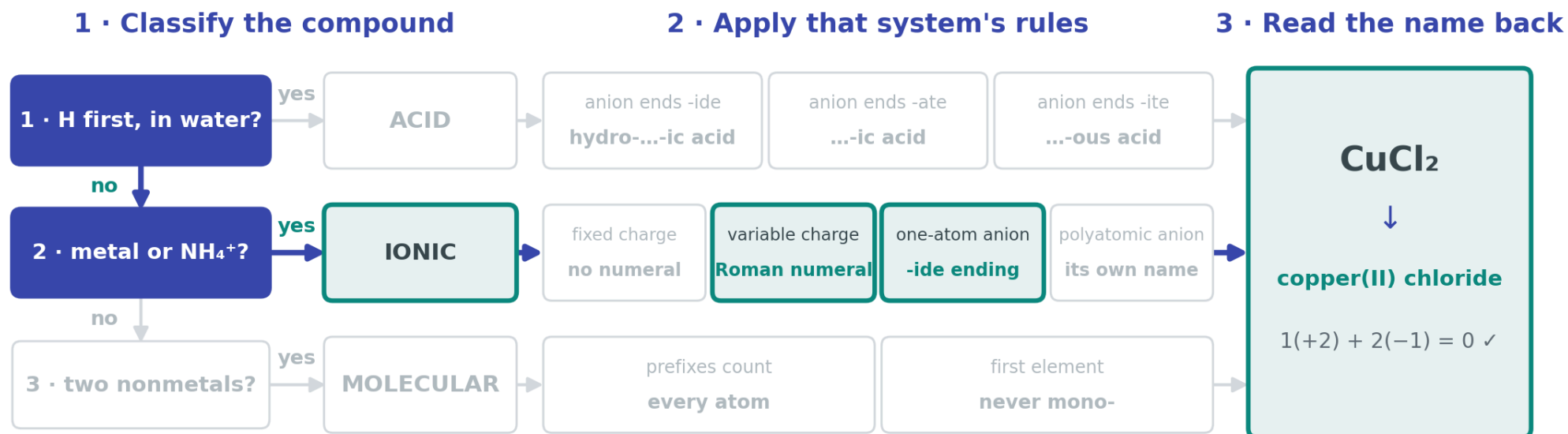
Cu^{2+} with 1– anions rebuilds exactly $\text{CuCl}_2 \checkmark$

 **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



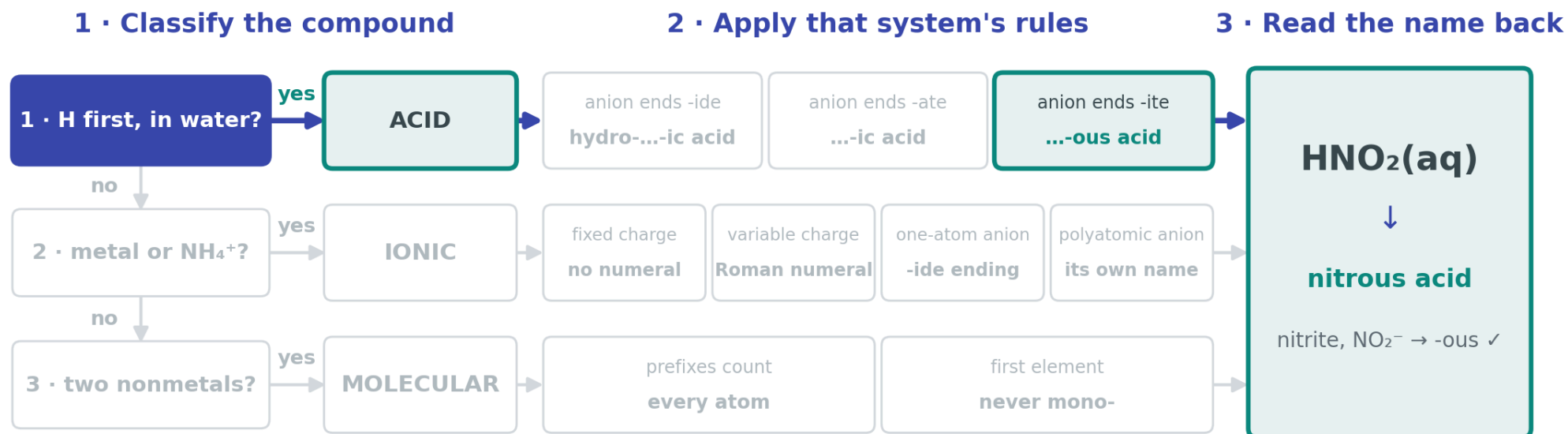
nitrous → nitrite, $\text{NO}_2^- \cdot 1(+1) + 1(-1) = 0 \rightarrow \text{one H} \checkmark$

 **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 the given 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 ?	_____

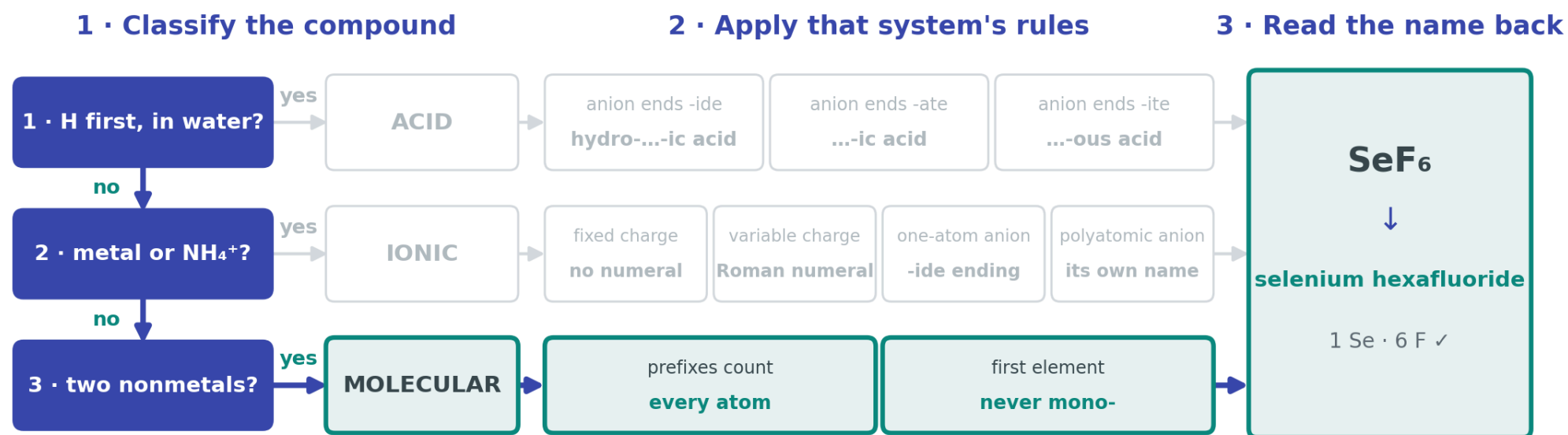
Run the three questions in order, then name it.

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

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

✓ Your turn: the route on the map

$\text{SeF}_6 \rightarrow$ selenium hexafluoride
found: molecular, after two no answers



🧠 **Sense check:** Prefixes applied only after questions 1 and 2 said no: hexa- for 6 F, and no mono- on selenium. ✓

⚠ 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



four compounds · wanted: the one named with counting prefixes

Which compound is named with counting prefixes?

- A. N_2O
- B. Na_2O
- C. NH_4NO_3
- D. $\text{HI}(\text{aq})$

✓ Practice 1 · answer: A

$\text{N}_2\text{O} \rightarrow$ dinitrogen monoxide (answer A)

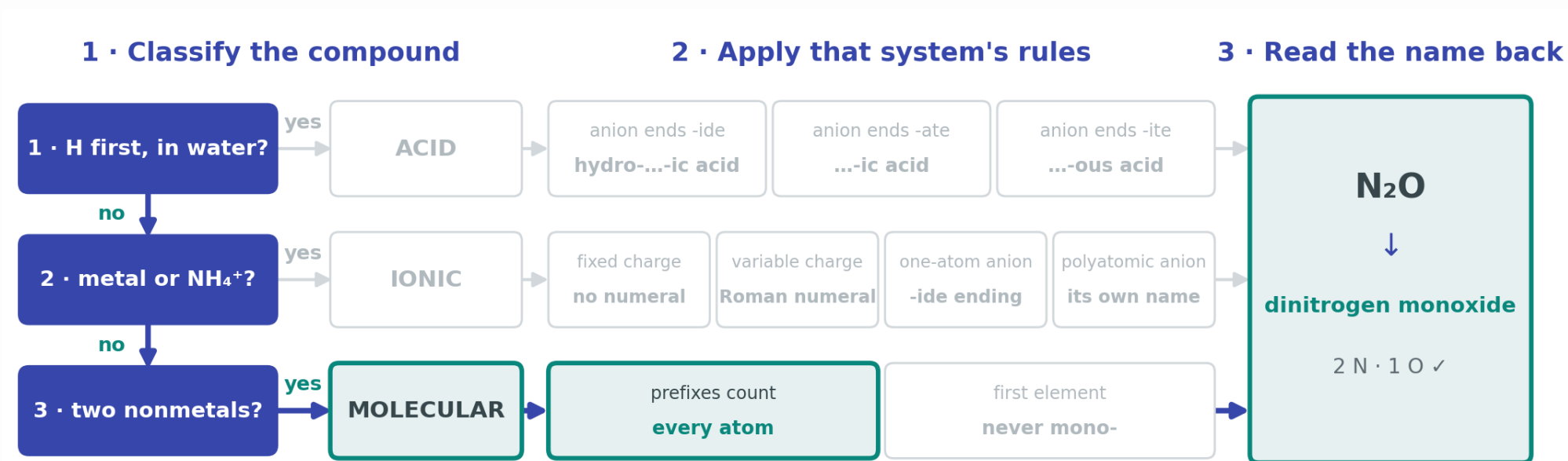
no H first · no metal, no NH_4^+ · two nonmetals $\rightarrow$ molecular

B holds sodium, a metal: Na_2O is sodium oxide, and its 2 comes from charge balance. C is all nonmetals but holds NH_4^+ , which question 2 catches: ammonium nitrate is ionic. D has two nonmetals, but H first in water answers question 1: hydroiodic acid.

🧠 **Sense check:** Prefixes appear only when the first two questions say no and the third says yes. ✓

✓ Practice 1: the route on the map

$\text{N}_2\text{O} \rightarrow$ dinitrogen monoxide
found: molecular · di- for 2 N · mono- for 1 O



🧠 **Sense check:** All three questions ran. Only the third said yes, so the prefix chip is the one rule used. ✓



Practice 2



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 2 · answer: B

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

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

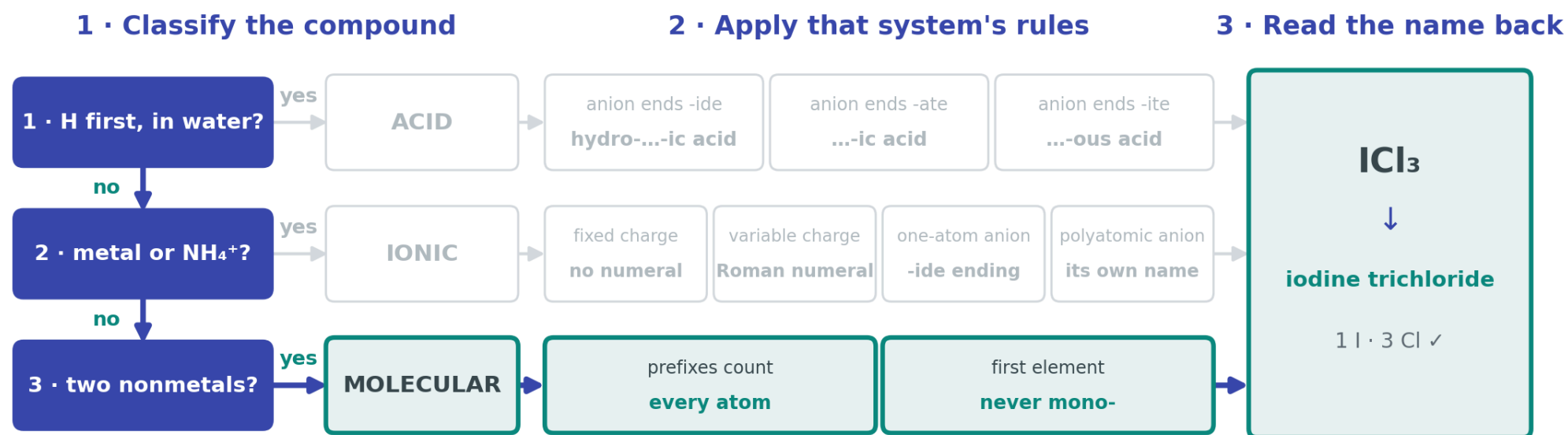
A borrows the ionic system's numeral, but a numeral reports an ion's charge and ICl_3 holds no ions. C is the fixed-charge ionic style, and without a prefix the name cannot separate ICl_3 from ICl . D swaps the prefix onto iodine: triiodine monochloride rebuilds I_3Cl .

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

✓ Practice 2: the route on the map



found: molecular · tri- for 3 Cl · no mono- on iodine



🧠 **Sense check:** Iodine and chlorine are both nonmetals, so the numeral chip stays dark. Prefixes carry the formula. ✓



Practice 3



strontium, a Group 2 metal · PO_4^{3-} a given -ate · 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 3 · 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

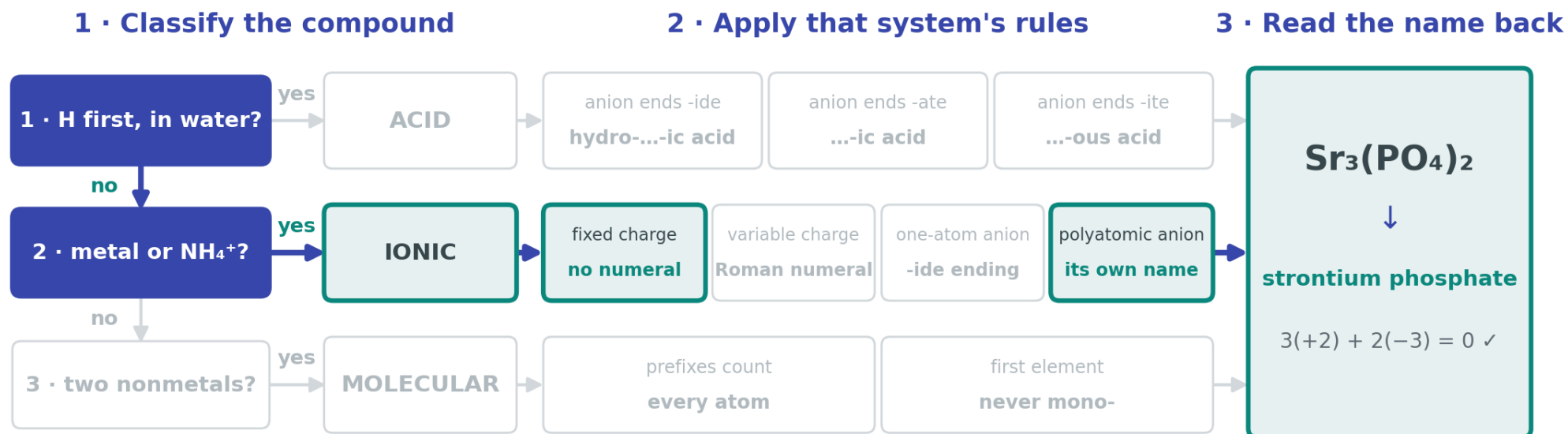
A writes a numeral for a metal with one possible charge; Group 2 is always 2+, so no numeral appears. B counts atoms with molecular prefixes, but the metal makes this ionic. C names the monatomic anion P^{3-} ; this compound holds the polyatomic group phosphate, PO_4^{3-} .

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

✓ Practice 3: the route on the map



found: ionic · fixed-charge metal · polyatomic anion



Sense check: Strontium has one possible charge, so no numeral. Phosphate is a given -ate and keeps its own name. ✓



Practice 4



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 4 · 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 · $2(+1) + 1(-2) = 0$ ✓

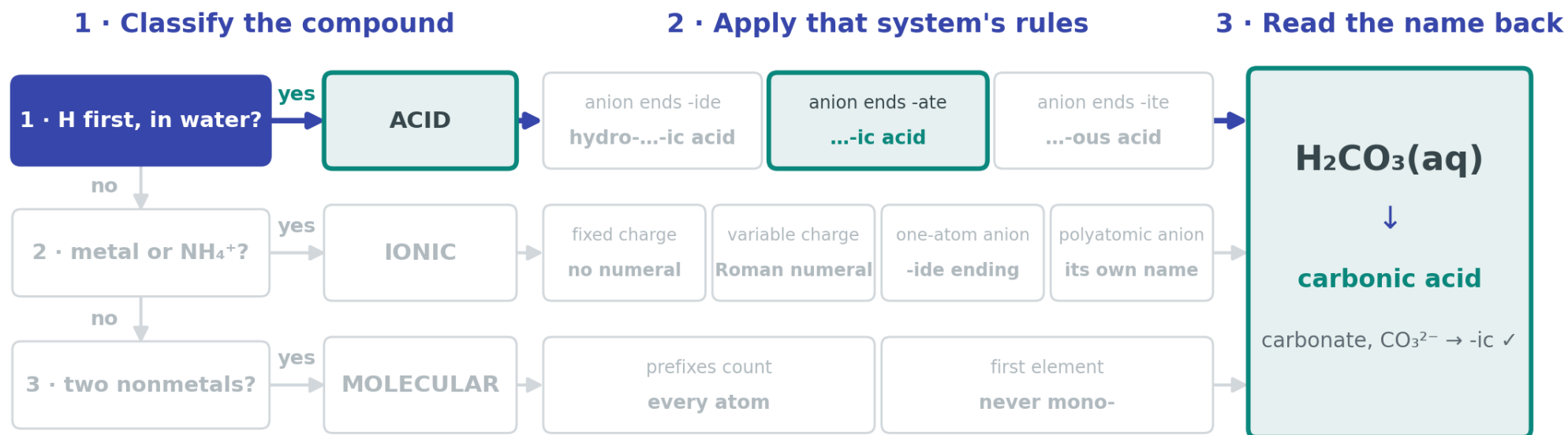
B is the ionic-style read-back, and hydrogen carbonate already names a different species, the ion HCO_3^- . C adds hydro-, which claims a no-oxygen anion; carbonate holds three. D counts atoms with a prefix, and prefixes never appear in acid names.

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

✓ Practice 4: the route on the map



found: acid at question 1 · carbonate, a given -ate → -ic



🧠 **Sense check:** Question 1 said yes, so the metal and nonmetal questions never ran. An -ate anion lights the -ic chip.



 Practice 5

chlorate, ClO_3^- , a given -ate · wanted: the name

$\text{Cu}(\text{ClO}_4)_2$ dissolves in water to give a blue solution. Name the compound.

- A. copper(II) chlorate
- B. copper(II) perchlorate
- C. copper perchlorate
- D. copper diperchlorate
- E. copper(II) chloride

✓ Practice 5 · answer: B

$\text{Cu}(\text{ClO}_4)_2 \rightarrow$ copper(II) perchlorate (answer B)

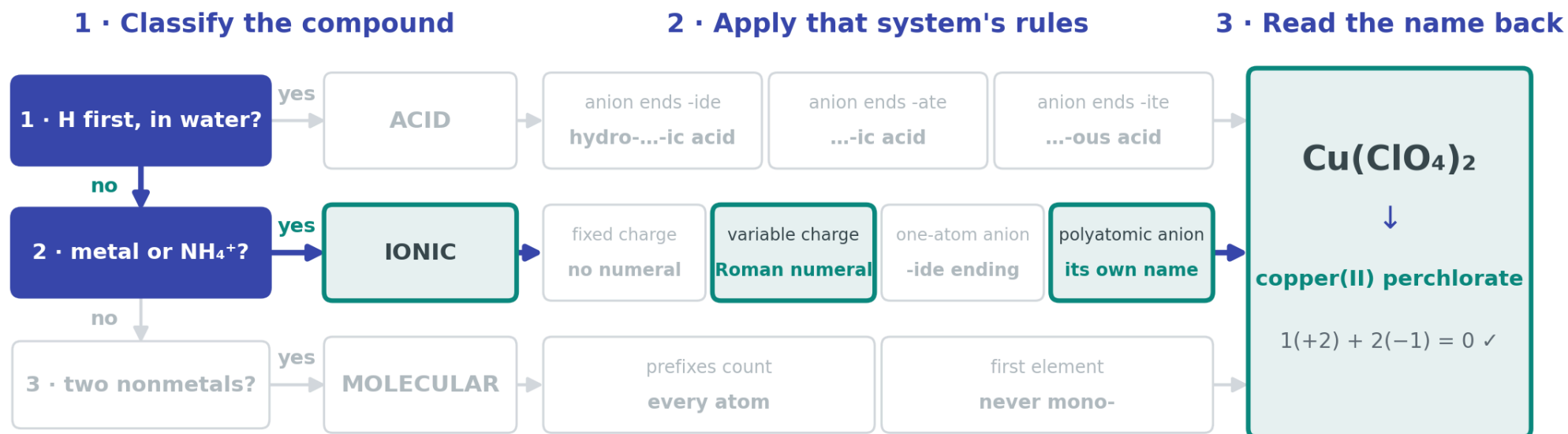
ClO_4^- : one O more than chlorate $\rightarrow$ perchlorate · two 1– anions $\rightarrow \text{Cu}^{2+} \cdot 1(+2) + 2(-1) = 0$ ✓

A names ClO_3^- , one oxygen short: copper(II) chlorate rebuilds $\text{Cu}(\text{ClO}_3)_2$. C drops the numeral, but copper has more than one possible charge. D counts the anions with a prefix, a molecular rule on a compound with a metal. E names the one-atom ion Cl^- : copper(II) chloride rebuilds CuCl_2 , with no oxygen.

🧠 **Sense check:** Metal present: ionic. Then the anion's name, then the numeral from charge balance. ✓

✓ Practice 5: the route on the map

$\text{Cu}(\text{ClO}_4)_2 \rightarrow \text{copper(II) perchlorate}$
found: ionic · variable-charge metal · polyatomic anion



Sense check: Two ionic chips lit: the numeral for copper, and the anion's own name, perchlorate, built from the given chlorate. ✓

Extra practice: Pb^{4+} and sulfate

Pb^{4+} · sulfate, SO_4^{2-} , a given -ate
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

✓ Extra practice · 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

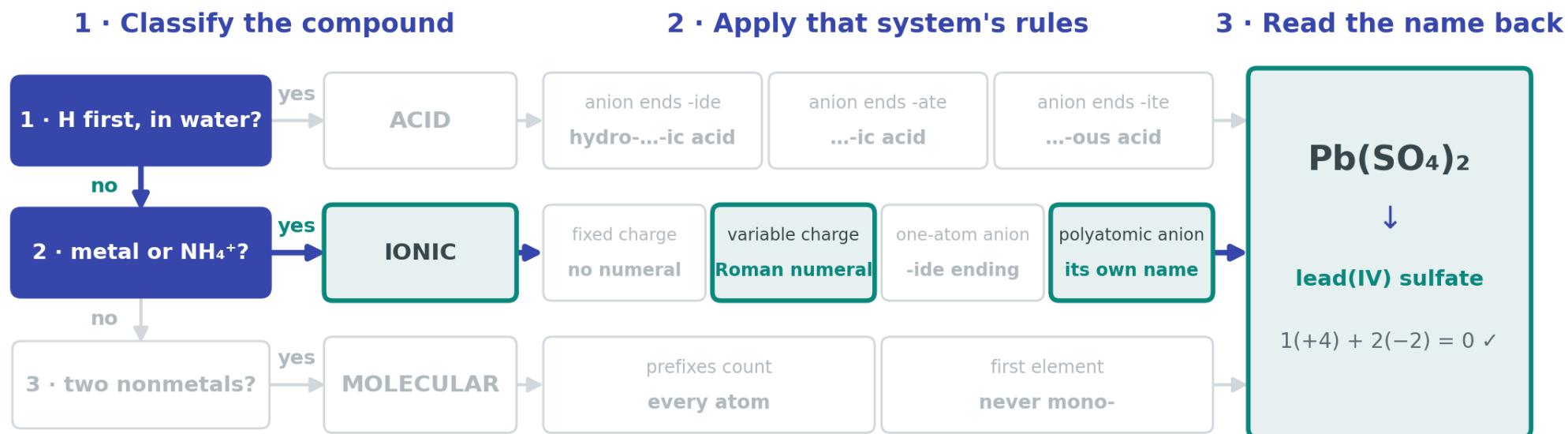
A stopped at the raw criss-cross: $2(+4) + 4(-2) = 0$ balances, but $2 : 4$ reduces to $1 : 2$. B read the subscript 2 as lead's charge: $1(+2) + 2(-2) = -2$. D borrows molecular prefixes for a compound with a metal. E swaps in sulfite, SO_3^{2-} , one oxygen fewer than sulfate.

 **Sense check:** Classify first: a metal with a polyatomic anion is ionic, so the numeral stays and the prefixes go.

✓ Extra practice: the route on the map



found: ionic · variable-charge metal · polyatomic anion



Sense check: Lead has more than one possible charge, so the numeral chip lights: (IV) reports Pb^{4+} . Sulfate keeps its own name. ✓



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...?

- ☐ name ionic and molecular compounds and acids, and write formulas from names?
- ☐ recognize the common polyatomic ions and build formulas that contain them?

If any box stays empty, the practice site has a drill for it. 