

Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

# Writing Ionic Formulas

## Learning goal

I can write formulas for binary ionic compounds by balancing charges.

## Part 1 · Notes

Fill in each blank using the word bank for that section.

### Section A · Charges from the Periodic Table

#### Word bank

2+ · negative · positive · 2- · 3- · 5- · 3+

- A **binary compound** is made of exactly two elements. In a binary ionic compound, a metal ion bonds with a nonmetal ion.
- To write the formula, you first need each ion's charge. You learned in C7.03 that the charge comes from the group:

| Group      | 1                                              | 2                                                     | 13               | 15              | 16              | 17                                             |
|------------|------------------------------------------------|-------------------------------------------------------|------------------|-----------------|-----------------|------------------------------------------------|
| Ion charge | 1+                                             | 2+                                                    | 3+               | 3-              | 2-              | 1-                                             |
| Examples   | Li <sup>+</sup> Na <sup>+</sup> K <sup>+</sup> | Mg <sup>2+</sup> Ca <sup>2+</sup><br>Ba <sup>2+</sup> | Al <sup>3+</sup> | N <sup>3-</sup> | O <sup>2-</sup> | F <sup>-</sup> Cl <sup>-</sup> Br <sup>-</sup> |

- Metals form \_\_\_\_\_ ions. Barium is in Group 2, so it forms a \_\_\_\_\_ ion. Nitrogen is in Group 15, so it forms a \_\_\_\_\_ ion.
- The charge is written as a small number and sign after the symbol: Ca<sup>2+</sup>, N<sup>3-</sup>. A charge of 1 is written with just the sign: Na<sup>+</sup>, Cl<sup>-</sup>.

### Section B · Balancing the Charges

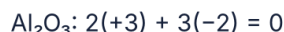
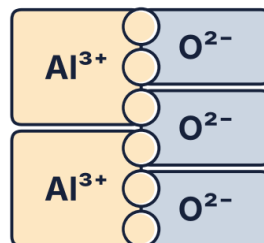
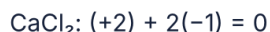
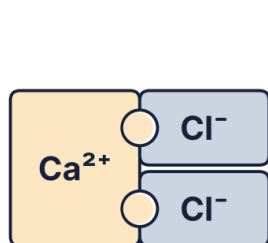
#### Word bank

ions · atoms · written as 1 · not written · electrons

- An ionic compound has no overall charge. The total positive charge must equal the total negative charge. This is **charge balance**.

**Remember****Writing an ionic formula**

1. Write each ion with its charge.
2. Find how many of each ion make the charges cancel. Use the smallest number both charges go into.
3. Write the metal first. A **subscript** after a symbol shows how many of that ion are in the formula unit. A subscript of 1 isn't written.

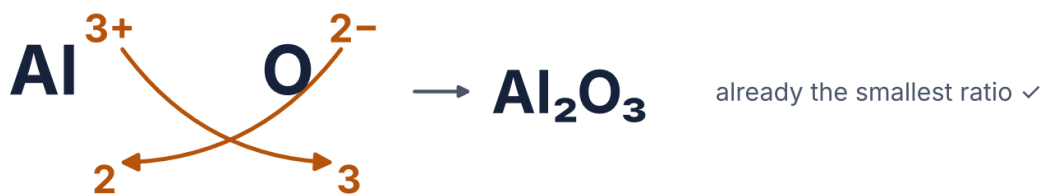


- **Worked example: calcium and chlorine.**  $\text{Ca}^{2+}$  and  $\text{Cl}^-$ . One  $\text{Ca}^{2+}$  is +2, so it takes two  $\text{Cl}^-$  (-1 each) to cancel it:  $(+2) + 2(-1) = 0$ . The formula is  **$\text{CaCl}_2$** .
- **Worked example: aluminum and oxygen.**  $\text{Al}^{3+}$  and  $\text{O}^{2-}$ . The smallest number both 3 and 2 go into is 6. Two  $\text{Al}^{3+}$  give +6 and three  $\text{O}^{2-}$  give -6. The formula is  **$\text{Al}_2\text{O}_3$** .
- In  $\text{CaCl}_2$ , the subscript 2 tells how many \_\_\_\_\_ of chloride there are. In  $\text{NaCl}$ , the subscript 1 is \_\_\_\_\_.

**Section C · The Criss-Cross Shortcut****Word bank**

MgO · don't balance ·  $\text{Mg}_2\text{O}_2$  ·  $\text{MgO}_2$  · balance

- There's a shortcut. Take the **size** of each ion's charge (drop the sign) and make it the **other** ion's subscript:  $\text{Al}^{3+} \text{O}^{2-} \rightarrow \text{Al}_2\text{O}_3$  (the 3 goes under O, the 2 goes under Al).



- Criss-crossing always gives charges that \_\_\_\_\_:  $2 \times (+3) = +6$  and  $3 \times (-2) = -6$ .
- But the shortcut can mislead. For magnesium oxide,  $\text{Mg}^{2+} \text{O}^{2-}$  criss-crosses to  $\text{Mg}_2\text{O}_2$ . The charges balance, but a **formula unit** uses the **smallest** whole-number ratio. 2 : 2 reduces to 1 : 1, so  $\text{Mg}_2\text{O}_2$  reduces to \_\_\_\_\_.

### Remember

Criss-cross is a shortcut, not a rule. After you criss-cross, check whether the subscripts can be divided by the same number. If they can, reduce them.

## Part 2 · Charge Puzzle

Cut out the pieces on the last page of Part 2 (or draw them). A **positive** piece has one tab for each unit of charge. A **negative** piece has one notch for each unit of charge. Pieces fit together only when every tab fills a notch.

### Card 1 · Pick the piece (do this after Section A)

For each element, find its group, decide how many electrons it loses or gains, and write its ion. Then decide what its piece looks like: one **tab** for each + charge, one **notch** for each – charge. The first row is done for you.

| Element      | Group    | Loses or gains how many? | Ion (symbol + charge) | Piece: tabs or notches? |
|--------------|----------|--------------------------|-----------------------|-------------------------|
| <i>Ex: K</i> | <i>1</i> | <i>loses 1</i>           | $K^+$                 | <i>1 tab</i>            |
| Na           |          |                          |                       |                         |
| Ca           |          |                          |                       |                         |
| Al           |          |                          |                       |                         |
| Cl           |          |                          |                       |                         |
| O            |          |                          |                       |                         |
| N            |          |                          |                       |                         |

Glue one piece for each element here (Na, Ca, Al, Cl, O, N)

Calcium's piece has two tabs but sodium's has one. Where does that difference come from?

Sentence stem:

"Calcium's piece has \_\_\_ tabs because Ca is in Group \_\_\_ and loses \_\_\_ electrons, but sodium \_\_\_."

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## Card 2 · Build (do this after Section B)

Start with one piece of each ion. Add pieces until the + total equals the – total, then write the formula: metal first, and a subscript only when there's more than 1. In the example,  $O^{2-}$  has two notches but each  $Li^+$  has one tab, so two  $Li^+$  pieces are needed:  $(+1) + (+1) + (-2) = 0$ .

| Metal + nonmetal  | Ions          | Pieces (metal : nonmetal) | + total | – total | Formula |
|-------------------|---------------|---------------------------|---------|---------|---------|
| <b>Ex: Li + O</b> | $Li^+ O^{2-}$ | 2 : 1                     | +2      | –2      | $Li_2O$ |
| <b>K + Cl</b>     |               |                           |         |         |         |
| <b>Ca + Cl</b>    |               |                           |         |         |         |
| <b>Na + O</b>     |               |                           |         |         |         |
| <b>Al + F</b>     |               |                           |         |         |         |
| <b>Ca + N</b>     |               |                           |         |         |         |

$Ca_3N_2$  needed three calcium pieces and two nitride pieces. How did the charges decide those numbers?

Sentence stem: “Each  $Ca^{2+}$  has \_\_\_\_ and each  $N^{3-}$  has \_\_\_\_\_. The smallest number both go into is \_\_\_\_\_, so \_\_\_\_\_.”

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**Card 2 · Glue your builds here**

Glue each finished compound in its own space, with the pieces snapped together. Write the formula under it.

**K + Cl****Ca + Cl****Na + O****Al + F**

**Ca + N (the tallest build: three  $\text{Ca}^{2+}$  and two  $\text{N}^{3-}$ )**

### Card 3 · Criss-cross check (do this in Section C)

Move each charge number (drop the sign) to the OTHER ion's subscript. Then decide: can both subscripts be divided by the same number? If so, reduce. Follow the example:



| Ions                                      | Criss-cross result      | Reduce? (yes / no)              | Final formula |
|-------------------------------------------|-------------------------|---------------------------------|---------------|
| <b>Ex:</b> $\text{Ba}^{2+} \text{O}^{2-}$ | $\text{Ba}_2\text{O}_2$ | yes (2 : 2 $\rightarrow$ 1 : 1) | BaO           |
| $\text{Al}^{3+} \text{O}^{2-}$            |                         |                                 |               |
| $\text{Mg}^{2+} \text{O}^{2-}$            |                         |                                 |               |
| $\text{Ca}^{2+} \text{N}^{3-}$            |                         |                                 |               |
| $\text{Ca}^{2+} \text{O}^{2-}$            |                         |                                 |               |

Criss-cross gave  $\text{Al}_2\text{O}_3$  right away, but  $\text{Mg}_2\text{O}_2$  had to be reduced. What's different about the charges in those two compounds?

Sentence stem: "For  $\text{Al}_2\text{O}_3$  the charges were \_\_\_\_ and \_\_\_\_, but for  $\text{MgO}$  they were \_\_\_\_, so \_\_\_\_."

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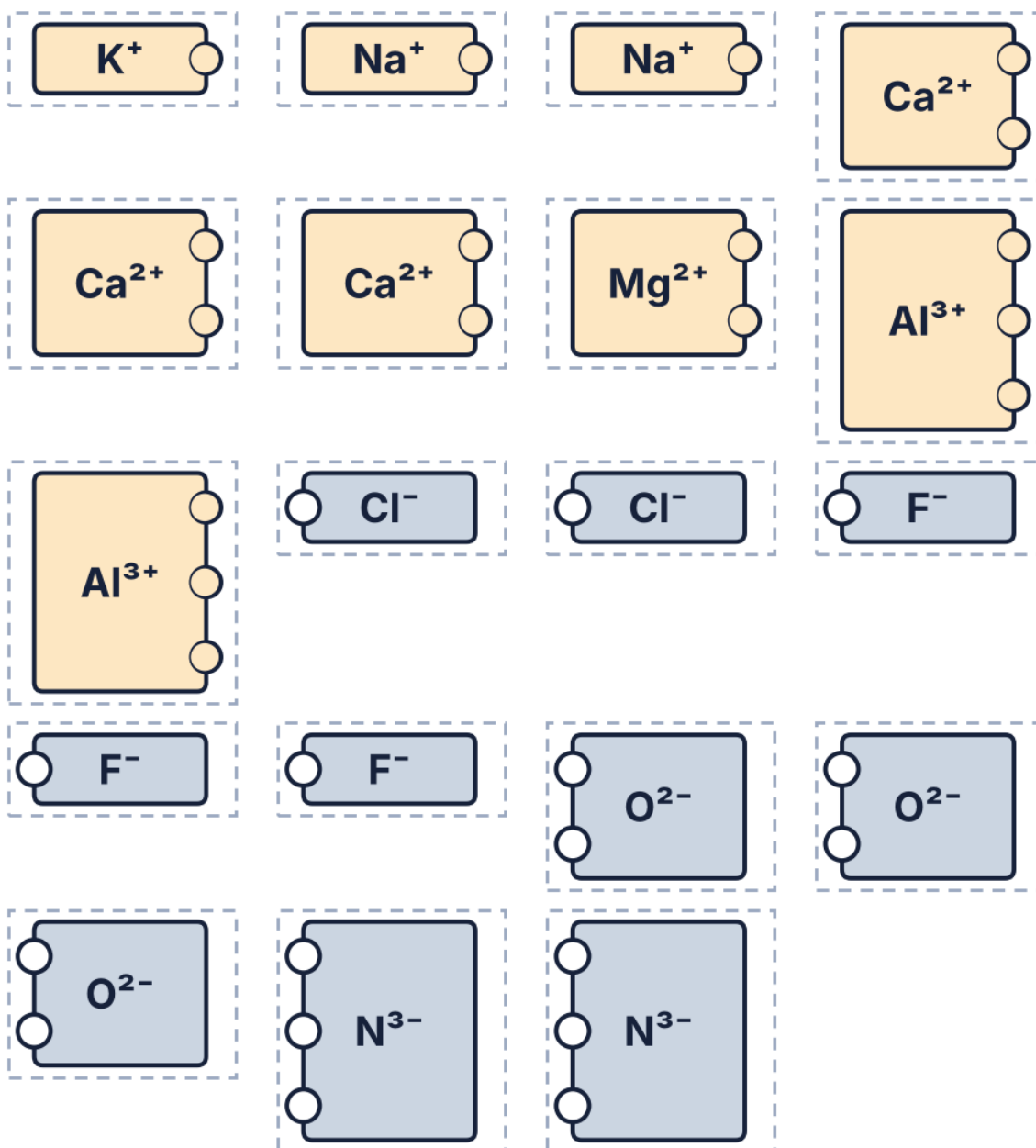
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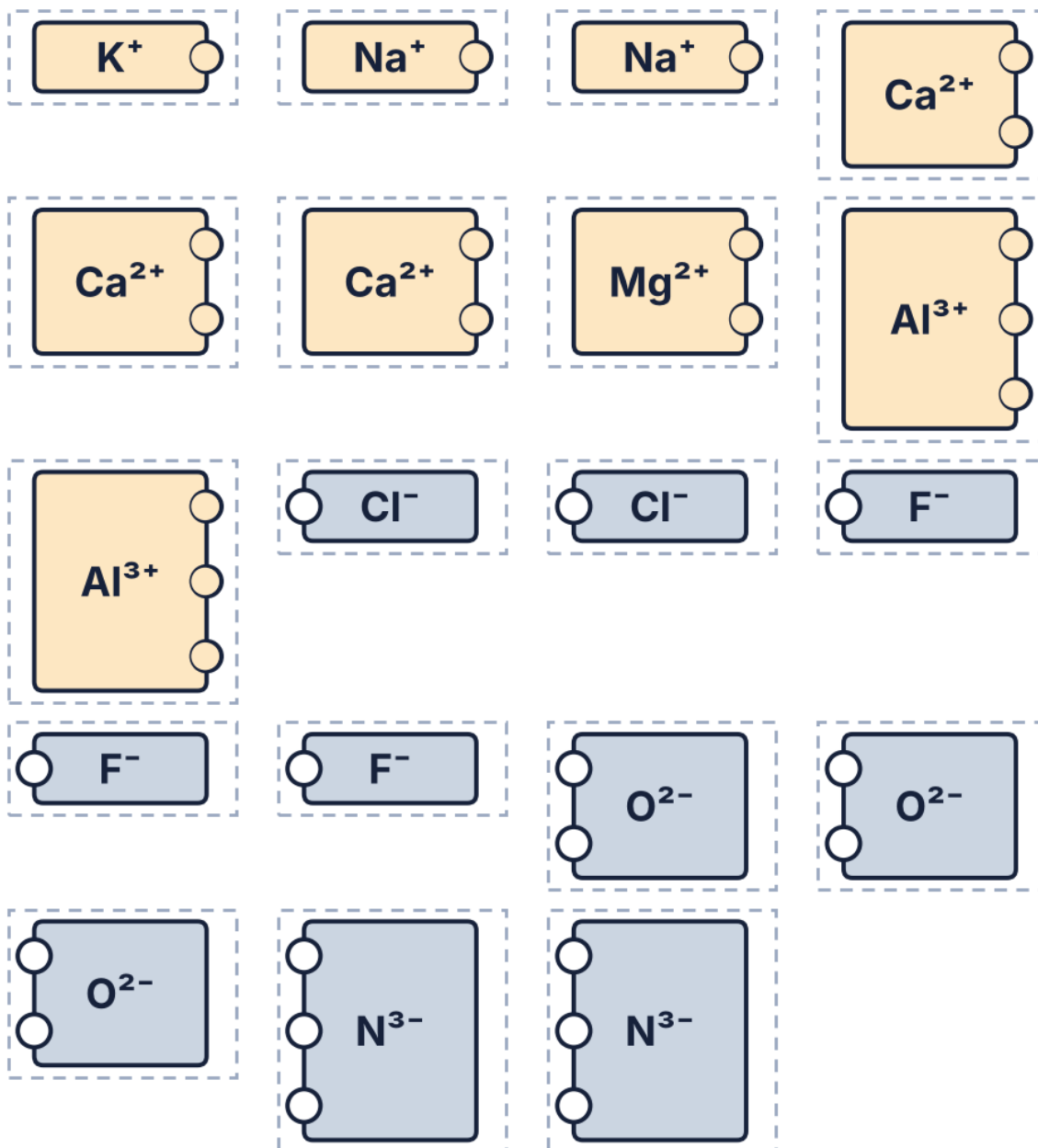
**Puzzle pieces · cut along the dashed lines**

Tabs (+) are bumps; notches (−) are holes. Enough pieces for one compound at a time.



**Puzzle pieces · cut along the dashed lines**

Tabs (+) are bumps; notches (−) are holes. Enough pieces for one compound at a time.



## Part 3 · Checkpoints

### How to use this section

1. Answer the ▲ main questions for each checkpoint.
2. Check your answers with your teacher.
3. Your teacher may give you a ● or ■ page for that checkpoint. Finish it before you move on.

### Checkpoint 1 · Charge from the group

#### ▲ Main questions

T1.1. Barium (Ba) is in the same group as calcium. What is the charge on a barium ion?

- A. 2+
- B. 3+
- C. 2-
- D. 1+

T1.2. Which element forms an ion with a 3- charge?

- A. F
- B. N
- C. O
- D. Al

T1.3. Potassium and oxygen form ions. What are their charges?

- A.  $K^-$  and  $O^{2+}$
- B.  $K^+$  and  $O^{6-}$
- C.  $K^+$  and  $O^{2-}$
- D.  $K^{2+}$  and  $O^-$

T1.4. Which pair of ions has charges equal in size but opposite in sign?

- A.  $Ca^{2+}$  and  $Cl^-$
- B.  $Na^+$  and  $O^{2-}$
- C.  $Al^{3+}$  and  $F^-$
- D.  $Mg^{2+}$  and  $O^{2-}$

## Checkpoint 2 · Writing formulas

### ▲ Main questions

T2.1. Lithium forms  $\text{Li}^+$  and nitrogen forms  $\text{N}^{3-}$ . What is the formula?

- A.  $\text{Li}_3\text{N}$
- B.  $\text{LiN}_3$
- C.  $\text{LiN}$
- D.  $\text{Li}_3\text{N}_3$

T2.2. Barium forms  $\text{Ba}^{2+}$  and bromine forms  $\text{Br}^-$ . What is the formula?

- A.  $\text{BaBr}$
- B.  $\text{BaBr}_2$
- C.  $\text{Ba}_2\text{Br}$
- D.  $\text{Ba}_2\text{Br}_2$

T2.3. Aluminum forms  $\text{Al}^{3+}$  and fluorine forms  $\text{F}^-$ . What is the formula?

- A.  $\text{Al}_3\text{F}$
- B.  $\text{AlF}$
- C.  $\text{AlF}_3$
- D.  $\text{Al}_3\text{F}_3$

T2.4. Which formula has charges that balance?

- A.  $\text{Ca}_3\text{N}$
- B.  $\text{CaN}$
- C.  $\text{Ca}_2\text{N}_3$
- D.  $\text{Ca}_3\text{N}_2$

## Checkpoint 3 · Reducing subscripts

### ▲ Main questions

T3.1. Which formula is **not** written as a correct formula unit?

- A. CaO
- B. Ca<sub>2</sub>O<sub>2</sub>
- C. CaCl<sub>2</sub>
- D. Na<sub>2</sub>O

T3.2. Criss-crossing Ba<sup>2+</sup> and O<sup>2-</sup> gives Ba<sub>2</sub>O<sub>2</sub>. What is the correct formula?

- A. BaO<sub>2</sub>
- B. Ba<sub>2</sub>O<sub>2</sub>
- C. BaO
- D. Ba<sub>2</sub>O

T3.3. Criss-crossing Al<sup>3+</sup> and O<sup>2-</sup> gives Al<sub>2</sub>O<sub>3</sub>. What should you do next?

- A. Reduce it to AlO
- B. Add the charges to the formula
- C. Swap it to Al<sub>3</sub>O<sub>2</sub>
- D. Nothing: 2 and 3 share no factor, so it's already reduced

T3.4. For which pair of ions does the criss-cross shortcut give a formula that must be reduced?

- A. Ba<sup>2+</sup> and O<sup>2-</sup>
- B. Na<sup>+</sup> and Cl<sup>-</sup>
- C. Ca<sup>2+</sup> and F<sup>-</sup>
- D. Li<sup>+</sup> and O<sup>2-</sup>

## Part 4 · Claim, Evidence, Reasoning

Question: A student uses the criss-cross shortcut and writes the formula for magnesium oxide as  $\text{Mg}_2\text{O}_2$ . Explain how the criss-cross shortcut works, why it always balances the charges, and why  $\text{Mg}_2\text{O}_2$  is still not the correct formula.

|                   | Mg                   | O                    |
|-------------------|----------------------|----------------------|
| Group             | 2                    | 16                   |
| Ion               | $\text{Mg}^{2+}$     | $\text{O}^{2-}$      |
| After criss-cross | subscript 2          | subscript 2          |
| Charge check      | $2 \times (+2) = +4$ | $2 \times (-2) = -4$ |

### Sentence stems (use them if you need them)

I claim that the correct formula is \_\_\_\_, not  $\text{Mg}_2\text{O}_2$ .

My evidence is that criss-cross gives  $\text{Mg}_2\text{O}_2$  and the charges are \_\_\_\_ and \_\_\_\_, which \_\_\_\_.

This means the subscripts must be \_\_\_\_ because a formula unit uses the \_\_\_\_ ratio.

Evidence bank:  $\text{Mg}^{2+}$  ·  $\text{O}^{2-}$  · criss-cross →  $\text{Mg}_2\text{O}_2$  ·  $2 \times (+2) = +4$  ·  $2 \times (-2) = -4$  ·  $2 : 2 \rightarrow 1 : 1$  · smallest whole-number ratio

Claim:

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Evidence:

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Reasoning:

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### ■ Take it further

Someone says you should never use criss-cross because it gives wrong answers. Respond.

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## Glossary · Glosario · Bảng thuật ngữ

| English                                                                                                                | Español                                                                                                                            | Tiếng Việt                                                                                                    |
|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| <b>binary compound:</b> a compound made of exactly two elements                                                        | <b>compuesto binario:</b> un compuesto formado por exactamente dos elementos                                                       | <b>hợp chất hai nguyên tố:</b> hợp chất được tạo thành từ đúng hai nguyên tố                                  |
| <b>charge balance:</b> in an ionic compound, the total positive charge equals the total negative charge                | <b>balance de cargas:</b> en un compuesto iónico, la carga positiva total es igual a la carga negativa total                       | <b>cân bằng điện tích:</b> trong hợp chất ion, tổng điện tích dương bằng tổng điện tích âm                    |
| <b>subscript:</b> a small number written after a symbol in a formula that shows how many of that atom or ion there are | <b>subíndice:</b> un número pequeño escrito después de un símbolo en una fórmula que indica cuántos átomos o iones de ese tipo hay | <b>chỉ số dưới:</b> số nhỏ viết sau ký hiệu trong công thức, cho biết có bao nhiêu nguyên tử hoặc ion loại đó |

## Key directions · Instrucciones · Hướng dẫn

| English                                        | Español                                            | Tiếng Việt                                          |
|------------------------------------------------|----------------------------------------------------|-----------------------------------------------------|
| Pick the piece that matches the ion's charge.  | Elige la pieza que corresponde a la carga del ion. | Chọn mảnh ghép khớp với điện tích của ion.          |
| Add pieces until the charges balance.          | Agrega piezas hasta que las cargas se equilibren.  | Thêm mảnh ghép cho đến khi điện tích cân bằng.      |
| Move each charge to the other ion's subscript. | Mueve cada carga al subíndice del otro ion.        | Chuyển mỗi điện tích thành chỉ số dưới của ion kia. |
| Reduce the subscripts if you can.              | Simplifica los subíndices si puedes.               | Rút gọn các chỉ số dưới nếu có thể.                 |
| Write a claim, evidence, and reasoning.        | Escribe una afirmación, evidencia y razonamiento.  | Viết nhận định, bằng chứng và lập luận.             |

Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

**Checkpoint 1 · Charge from the group**

- Your teacher gave you this page. Finish it before you move on to the next section.

**• Need a boost?**

S1.1. Calcium is in Group 2. What is the charge on a calcium ion?

- A. 0
- B. 2+
- C. 2-

S1.2. Bromine is in Group 17. What is the charge on a bromide ion?

- A. 7-
- B. 1+
- C. 1-

S1.3. Which element forms a positive ion?

Circle one: **Li** or **F**

Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

## Checkpoint 2 · Writing formulas

- Your teacher gave you this page. Finish it before you move on to the next section.

### • Need a boost?

Use the puzzle pieces: add pieces until every tab fills a notch.

S2.1.  $\text{Na}^+$  and  $\text{Cl}^-$ : +1 and -1 already cancel. What is the formula?

- A.  $\text{NaCl}$
- B.  $\text{NaCl}_2$
- C.  $\text{Na}_2\text{Cl}$

S2.2.  $\text{Ca}^{2+}$  and  $\text{Cl}^-$ : it takes two  $\text{Cl}^-$  to cancel one  $\text{Ca}^{2+}$ . What is the formula?

- A.  $\text{CaCl}$
- B.  $\text{CaCl}_2$
- C.  $\text{Ca}_2\text{Cl}$

S2.3.  $\text{K}^+$  and  $\text{O}^{2-}$ : how many  $\text{K}^+$  ions cancel one  $\text{O}^{2-}$ ?

- A. 1
- B. 3
- C. 2

Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

**Checkpoint 3 · Reducing subscripts**

- Your teacher gave you this page. Finish it before you move on to the next section.

**• Need a boost?**

S3.1. Criss-crossing  $\text{Mg}^{2+}$  and  $\text{O}^{2-}$  gives  $\text{Mg}_2\text{O}_2$ . What is the formula with the smallest ratio?

- A.  $\text{MgO}$
- B.  $\text{Mg}_2\text{O}_2$
- C.  $\text{Mg}_4\text{O}_4$

S3.2. Is  $\text{Ca}_3\text{N}_2$  already the smallest whole-number ratio?

Circle one: **Yes** or **No**

S3.3. Reduce  $\text{Ca}_2\text{Cl}_4$  to the smallest ratio.

- A.  $\text{Ca}_2\text{Cl}_4$
- B.  $\text{CaCl}_2$
- C.  $\text{CaCl}$

Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

**Checkpoint 1 · Charge from the group**

■ Your teacher gave you this page. Try these after your main questions.

**■ Take it further**H1.1. An element forms ions with a 2<sup>-</sup> charge. Which group is it most likely in?

- A. Group 18
- B. Group 14
- C. Group 16
- D. Group 2

H1.2. Why don't Group 14 elements like carbon usually form ions?

- A. They already have a full outer shell
- B. Their ions would have no charge
- C. They have no valence electrons
- D. Gaining or losing 4 electrons would take too much energy, so they share instead

H1.3. Explain why a Group 1 ion has a 1<sup>+</sup> charge but a Group 17 ion has a 1<sup>-</sup> charge.

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Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

## Checkpoint 2 · Writing formulas

■ Your teacher gave you this page. Try these after your main questions.

### ■ Take it further

In these names, **nitride**, **oxide** and **fluoride** mean the nitrogen, oxygen and fluorine ions. (Naming rules come in C7.05.)

H2.1. Write the formula for barium nitride.

- A.  $\text{Ba}_3\text{N}$
- B.  $\text{BaN}$
- C.  $\text{Ba}_2\text{N}_3$
- D.  $\text{Ba}_3\text{N}_2$

H2.2. Write the formula for aluminum oxide.

- A.  $\text{Al}_2\text{O}_3$
- B.  $\text{AlO}$
- C.  $\text{Al}_3\text{O}_2$
- D.  $\text{Al}_2\text{O}$

H2.3. Write the formula for magnesium fluoride and show that the charges balance.

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Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

**Checkpoint 3 · Reducing subscripts**

■ Your teacher gave you this page. Try these after your main questions.

**■ Take it further**

H3.1. A student writes calcium oxide as  $\text{Ca}_2\text{O}_2$  and says, "The charges balance, so it's right."  
What's the best response?

- A. The charges don't balance
- B.  $\text{Ca}_2\text{O}_2$  is correct because criss-cross always works
- C. It should be  $\text{CaO}_2$  because oxygen is  $2^-$
- D. The charges do balance, but a formula unit uses the smallest ratio, so it's  $\text{CaO}$

H3.2. Which statement about the criss-cross shortcut is always true?

- A. It gives balanced charges, but the subscripts may need reducing
- B. It always gives the smallest ratio
- C. It works only when the charges are equal
- D. It changes the charges on the ions

H3.3. Barium and nitrogen form a compound. Write its formula and show that the charges balance.

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