

Names and Formulas for Atoms with More Than One Ionic Charge

Some metals are able to form more than one kind of ion. For example, the element copper forms two completely different compounds when it reacts with chlorine. One of the compounds is white; the other is yellow. Chemists have found that the ionic charge on the copper in the white compound is $1+$. Its chemical formula is CuCl , since the ionic charge of chlorine is always 1^- . The ionic charge on the copper in the yellow compound is $2+$. Its formula is therefore CuCl_2 . Table 2 shows the names and ionic charges of some metals that have more than one ionic charge.

These compounds are named in the same way as other ionic compounds, except that a Roman numeral (as shown in Table 2) is added in round brackets after the metal to indicate its ionic charge. For example, CuCl is called copper(I) chloride because the ionic charge on the copper is $1+$. CuCl_2 is called copper(II) chloride because the ionic charge on the copper is $2+$. Remember that you have to use the Roman numeral system only when naming the ions of metals that can have more than one ionic charge.

Table 2 Names and Multiple Ionic Charges of Some Metals

Name of element	Symbol	Ionic charges	Roman numeral
copper	Cu	$1+$, $2+$	I, II
iron	Fe	$2+$, $3+$	II, III
lead	Pb	$2+$, $4+$	II, IV
tin	Sn	$2+$, $4+$	II, IV



Challenge

- 1 Are there any ionic compounds in your product? What are their names?

Understanding Concepts

1. (a) How does the sum of the charges on the positive ions compare to the sum of the charges on the negative ions in ionic compounds?
(b) Calculate the sum of the ionic charges in the compound Al_2O_3 . Show your calculation.
2. Draw a Bohr diagram to show the electron transfer that occurs when magnesium and fluorine form the compound magnesium fluoride.
3. Write the formulas for the compounds formed by the following combinations of elements:
(a) lithium and fluorine
(b) calcium and bromine
(c) sodium and nitrogen
(d) aluminum and nitrogen
4. Name each of the compounds in question 3.
5. Write the formulas for the following compounds:
(a) sodium iodide
(b) beryllium fluoride
(c) magnesium oxide
(d) aluminum sulfide
6. Write the names for the following compounds:
(a) KCl
(b) Na_3P
(c) CaF_2
7. Write the formulas for the following compounds:
(a) copper(I) bromide
(b) copper(II) bromide
(c) iron(II) sulfide
8. Write the names for the following compounds:
(a) SnCl_2
(b) SnCl_4
(c) PbBr_2
9. Write the formula and name of the compound formed by each of the following combinations of ions. (Note that some of these ions will require the use of Roman numerals in the names.)
(a) Fe^{3+} and O^{2-}
(b) Ca^{2+} and F^-
(c) Cu^+ and S^{2-}
10. In mining, some minerals are referred to as ferrous. What metallic element is present in these compounds? (Hint: Look at the letters that begin the word.)

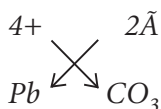
Consider the following example.

What is the formula of lead(IV) carbonate? Note that lead has two different valences, but the Roman numeral tells you which one to use.

Rule 1: Write the symbols of the metal and of the polyatomic group.



Crisscross Rule: Write the ionic charges above the symbols and crisscross them.



The formula is $\text{Pb}_2(\text{CO}_3)_4$, which must be reduced to $\text{Pb}(\text{CO}_3)_2$. Note that parentheses are included in the formula to show the number of CO_3 ions in the formula.

Oxyacids

There are many types of polyatomic ions, but one special group should be mentioned. Oxyacids are compounds formed when hydrogen combines with polyatomic ions that contain oxygen. The hydrogen has an ionic charge of 1+ in these compounds. Table 3 describes and names some common oxyacids.

Table 3 Common Oxyacids

Ion name	Ion formula	Ionic charge	Oxyacid formula	Oxyacid name
nitrate	$\text{NO}_3^{\bar{A}}$	1 \bar{A}	HNO_3	nitric acid
nitrite	$\text{NO}_2^{\bar{A}}$	1 \bar{A}	HNO_2	nitrous acid
chlorate	$\text{ClO}_3^{\bar{A}}$	1 \bar{A}	HClO_3	chloric acid
carbonate	$\text{CO}_3^{2\bar{A}}$	2 \bar{A}	H_2CO_3	carbonic acid
sulfate	$\text{SO}_4^{2\bar{A}}$	2 \bar{A}	H_2SO_4	sulfuric acid
sulfite	$\text{SO}_3^{2\bar{A}}$	2 \bar{A}	H_2SO_3	sulfurous acid
phosphate	$\text{PO}_4^{3\bar{A}}$	3 \bar{A}	H_3PO_4	phosphoric acid

Understanding Concepts

- In your own words, explain what is meant by the term *polyatomic ion*. Give two examples.
- What happens to the ions in the compound sodium nitrate when it dissolves in water?
- Write the formulas for the following compounds:
 - sodium phosphate
 - calcium sulfate
 - potassium chlorate
 - aluminum hydroxide
 - beryllium nitrate
 - magnesium hydrogen carbonate (magnesium bicarbonate)
 - nickel carbonate
- Write the names for the following compounds:
 - K_2CO_3
 - Na_2SO_4
 - $\text{Al}(\text{HCO}_3)_3$
 - AgNO_3
- What pattern do you see in the formulas of the oxyacids and the original ionic charge of the polyatomic ion? Explain, with two examples.
 - Why does this pattern make sense?
- Why is ammonium nitrate (NH_4NO_3) not written as $\text{N}_2\text{H}_4\text{O}_3$?
- Some polyatomic ions have a positive charge. The ammonium ion (NH_4^+) is an example. Give the names and formulas of the compounds formed by this ion with:
 - a chloride ion
 - a sulfate ion

Chapter 5 Review

Understanding Concepts

1. Explain the difference between the following pairs of terms. Give an example for each term:
 - (a) physical property and chemical property
 - (b) element and compound
 - (c) metal and nonmetal
 - (d) ionic compound and molecular compound
 - (e) natural substance and synthetic substance
2. For each of the following, replace the description with one or two words:
 - (a) a sample of matter that contains only one kind of atom;
 - (b) a characteristic of matter that involves the formation of a new substance;
 - (c) the starting material in a chemical reaction;
 - (d) a family of elements that includes sodium and potassium;
 - (e) the positively charged particle in the atom;
 - (f) an electrically charged atom;
 - (g) artificially made.
3. The sentences below contain errors or are incomplete. Write complete, correct versions.
 - (a) Elements and solutions are examples of pure substances.
 - (b) The melting point of a substance is an example of a chemical property.
 - (c) The chemical test for hydrogen gas is to use a glowing splint.
 - (d) Fluorine, chlorine, and iodine are members of the alkaline earth metals family.
 - (e) Negative particles called neutrons circle the nucleus of the atom.
 - (f) An atom with more electrons than protons will be a positive ion.
 - (g) A molecular compound is held together with ionic bonds.
 - (h) The chloride ion is an example of a polyatomic ion.
 - (j) Cotton, leather, and wool are examples of synthetic substances.
4. Use the periodic table at the back of this book to determine the atomic numbers and to draw Bohr diagrams for the following elements:
 - (a) aluminum
 - (b) fluorine
 - (c) magnesium
 - (d) phosphorus
5. For each of the elements in question 4:
 - (a) Draw a Bohr diagram of the stable ion that it would form.
 - (b) Write the symbol and ionic charge of the stable ion.
6. Write the name of the compound that would be formed by combining each of the following pairs of elements:
 - (a) magnesium and chlorine
 - (b) sodium and bromine
 - (c) magnesium and oxygen
 - (d) aluminum and phosphorus
 - (e) aluminum and sulfur
7. Write the formula for each of the compounds in question 6.
8. Examine the Bohr diagram in Figure 1. This diagram could represent the electronic structure of a noble gas or a stable ion. What would be the chemical symbol and ionic charge if the nucleus of the atom contained:
 - (a) 16 protons
 - (b) 18 protons
 - (c) 19 protons

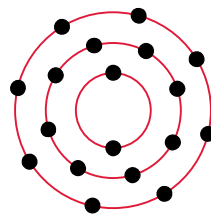


Figure 1

- (a) 16 protons
 - (b) 18 protons
 - (c) 19 protons
9. For each of the following compounds that involve elements with more than one ionic charge, write the corresponding name or chemical formula:
 - (a) CuCl
 - (b) FeI_2
 - (c) tin(IV) oxide
 - (d) lead(II) bromide
 10. For each of the following compounds that involve polyatomic ions, write the corresponding name or chemical formula:
 - (a) CuCO_3
 - (b) FeSO_4
 - (c) tin(IV) phosphate
 - (d) lead(II) nitrate

11. For each of the following molecular compounds, write the corresponding name or chemical formula:
- carbon monoxide
 - nitrogen triiodide
 - SCl_2
 - CCl_4

Applying Inquiry Skills

12. Describe four safety procedures that you followed during your investigations.
13. A student performs an experiment in which a solid white substance is added to a solution and produces a gas. When a sample of the gas is tested with limewater, the solution turns cloudy.
- What is the name and chemical formula of the gas?
 - What would be the effect of the gas on a glowing or blazing splint?
 - Suggest a reasonable possible formula for the original white solid.
14. A group of students performs an investigation to test an unknown solid. They dissolve the solid in water and then, using small samples of this solution, do separate tests for the presence of ions. Figure 2 shows their experimental results.

Procedure	Observations
¥ examined original solution	¥ solution was clear and very pale yellow
¥ added some silver nitrate solution	¥ solution turned milky white
¥ added some barium nitrate solution	¥ no change in solution
¥ added some potassium thiocyanate	¥ solution turned reddish brown

Figure 2

- What ion(s) were present in the solution? Explain.
 - What ion(s) were not present in the solution? Explain.
 - Give a possible name and formula for the unknown solid.
15. An unknown element X forms an oxide with the formula X_2O_3 .
- What is the ionic charge or valence of element X? Explain.
 - What would be the formula of the compound that element X would form with chlorine?

16. Natural and synthetic fibres have different properties (see Figure 3). Design and perform a controlled experiment to compare the characteristics of various natural and synthetic fibres. Some possible areas of study might be
- the effect of heating the fibres with an iron;
 - the fibres' solubility in solvents (e.g., acetone);
 - the fibres' ability to absorb moisture;
 - the effect of bleach on the fibres;
 - the fibres' insulating ability.

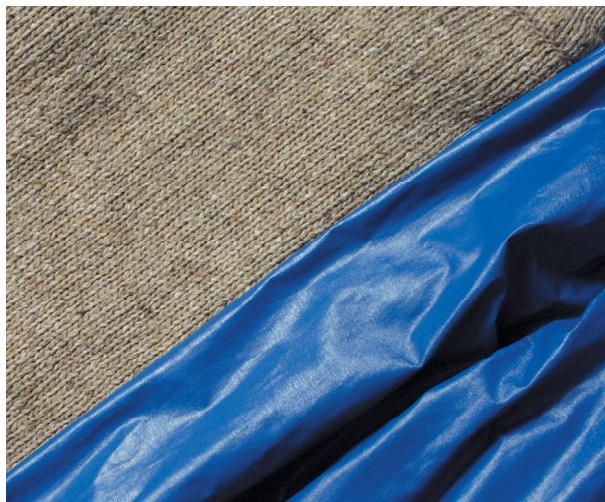


Figure 3

Making Connections

- Choose a category of household hazardous products and design a poster to be displayed in your home to encourage people to handle and dispose of these materials safely. Include HHPS or WHMIS symbols.
- Research and report on environmentally friendly alternatives to hazardous household products.
- Contact an oil company to obtain information about gasoline. Report on (a) the types of molecules present in unleaded and leaded gasoline; or (b) octane-rating and knocking.
- What natural and synthetic materials are used in modern tires? Contact a company that makes tires, and report on the substances that they use.