

Module 2: What is a “Chemical Species”?

Chemical Formulas

Fundamentals of Chemistry Open Course

1. State and apply the laws of chemical combination.
2. State and apply the tenets of the modern atomic theory.
3. Visualize the subatomic particles that constitute the atom using a simple planetary model; count subatomic particles using atomic number (Z) and mass number (M).
4. Represent an atom or ion using an atomic symbol.
5. Represent the number ratios of atoms in a compound using a chemical formula.
6. Visualize and distinguish between submicroscopic models of molecular and ionic compounds.
7. Use the periodic table to efficiently find information about a chemical element.
8. Recognize key collections of elements on the periodic table.
9. Determine the name of a binary ionic compound from the chemical formula and *vice versa*.
10. Determine the name of a simple molecular compound from the chemical formula and *vice versa*.

What is a “Chemical Species”?

- Compounds contain atoms of two or more elements engaged in **bonds**; a collection of bonded atoms is called a **molecule**.
- What is the smallest unit of matter that defines a pure substance? It may be an atom, monatomic or polyatomic ion, or molecule. These substance-defining particles are examples of **chemical species**.
- The word “species” is used in cases when the particle of interest may be an atom, ion, or molecule, depending on the context.

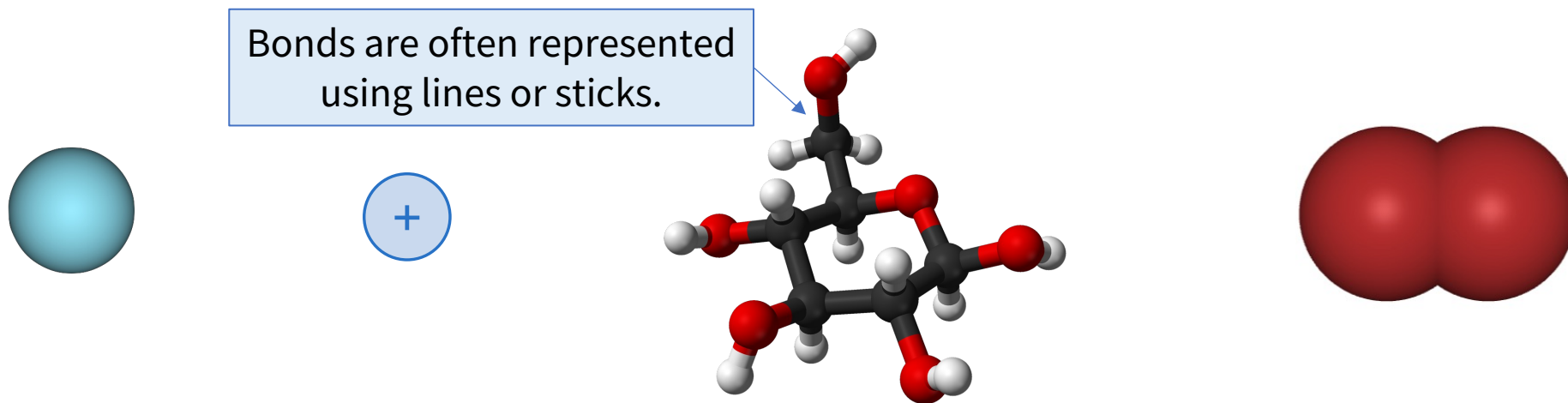
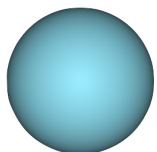


Figure. The term “species” may refer to an atom, ion, or molecule. The [CPK coloring scheme](#) is used here.

- A **chemical formula** lists the number(s) and type(s) of atoms or ions that constitute the defining species of a substance.
- Element symbols indicate the types of atoms in the substance; subscripts with each symbol indicate the number of that type of atom.
- Groupings of atoms that repeat multiple times in a substance are enclosed in parentheses; a subscript after the closing parenthesis indicates the count of that grouping of atoms in the substance.

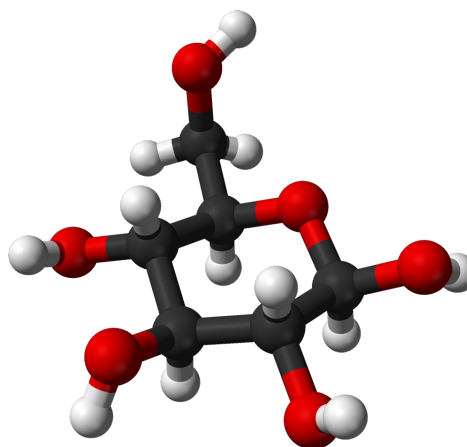
Ar



Na⁺



C₆H₁₂O₆



Br₂

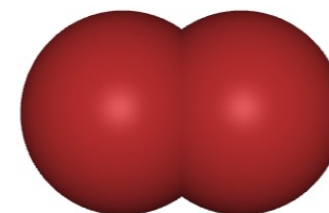
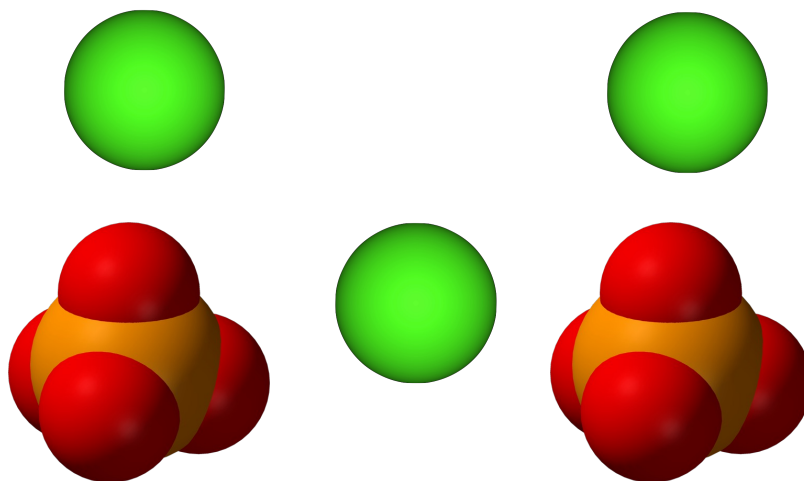


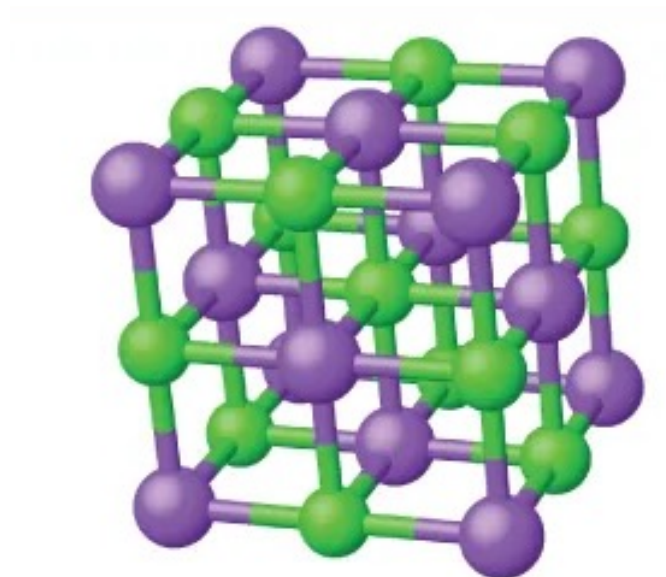
Figure. Chemical formulas list the number and types of atoms in a chemical species.

Example. Calcium phosphate is a compound that contains three calcium cations (Ca^{2+} , green) and two phosphate anions (PO_4^{3-} , orange and red) in a formula unit or “molecule.” What is the chemical formula of calcium phosphate?



- Ionic compounds and covalent network solids do not contain discrete molecules but do consist of repeating units with just a few atoms. The repeating unit in an ionic or covalent network compound is called a **formula unit**.
- Chemical formulas for these compounds refer to the formula unit.
- The distinction between “discrete molecule” and “formula unit” is important when visualizing substances at the submicroscopic level (more in the next section).

Example. The formula unit in sodium chloride, an ionic solid, is NaCl.



How can we measure the number ratios of atoms in a compound, particularly given their extremely small size?

Many practical ionic salts have formulas like “ $\text{CuSO}_4 \cdot 6\text{H}_2\text{O}$.” What does the dot signify?
How do we visualize these compounds?

There are [known compounds](#) with fractional or decimal number ratios of atoms. How is this possible?