

Module 2: What is a "Chemical Species"? Atomic Theory and Symbols

Fundamentals of Chemistry Open Course

Learning Objectives | Module 2



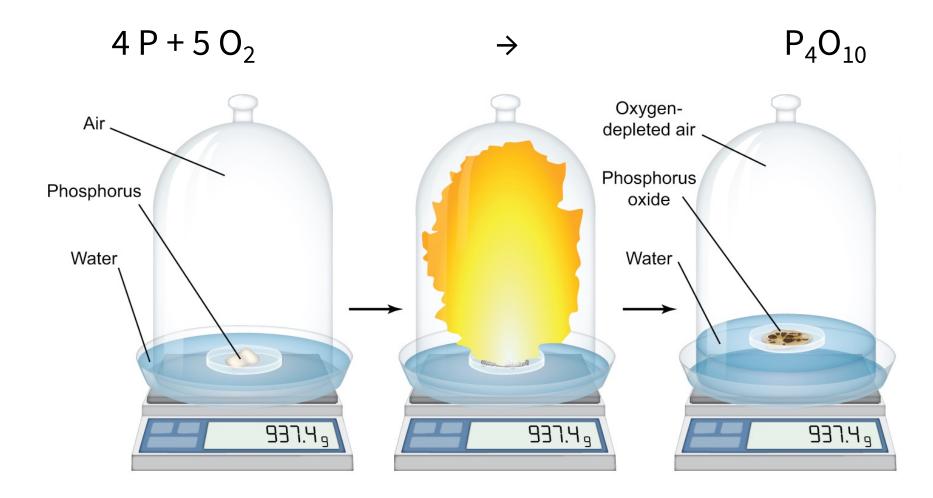
- 1. State and apply the laws of chemical combination.
- 2. State and apply the tenets of the modern atomic theory.
- 3. Visualize the subatomic particles that constitute the atom using a simple planetary model; count subatomic particles using atomic number (*Z*) and mass number (*M*).
- 4. Represent 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*.

Laws of Chemical Combination



The law of conservation of mass: the total mass of all matter is constant during a chemical reaction; atoms are
neither created nor destroyed during chemical reactions.

Example. When phosphorus is burned in air in a closed container, the total mass of material remains constant.



Laws of Chemical Combination



• **The law of definite proportions:** all samples of a compound, regardless of the source or size, contain the same proportions of the elements that constitute the compound.

Example. Potassium carbonate contains potassium, carbon, and oxygen in a ratio of 56.6:8.7:34.7 by mass.







Laws of Chemical Combination



• **The law of multiple proportions:** when elements combine in multiple proportions to form different compounds, the different proportions are related by whole-number ratios.

Example. There are three oxides of sulfur. The mass ratios in these compounds are related by whole-number factors.

Oxide A contains sulfur and oxygen in a 2:1 ratio by mass.

Oxide B contains sulfur and oxygen in a 1:1 ratio by mass.

Oxide C contains sulfur and oxygen in a 1:2 ratio by mass.

Atomic Theory



• The laws of chemical combination and other observations gave rise to the **atomic theory**.

Tenets of the atomic theory:

- 1. Matter is composed of exceedingly small particles called atoms. An atom is the smallest unit of an element that can participate in a chemical change.
- 2. An element consists of only one type of atom, which has a mass that is characteristic of the element and is the same for all atoms of that element. A macroscopic sample of an element contains an incredibly large number of atoms, all of which have identical chemical properties.
- 3. Atoms of one element differ in properties from atoms of all other elements.
- 4. A compound consists of atoms of two or more elements combined in small whole-number ratios.
- 5. Atoms are neither created nor destroyed during a chemical change but are instead rearranged to yield substances that are different from those present before the change.

Subatomic Particles



- The atom contains three types of subatomic particles:
 - Protons are positively charged and sit at the center of the atom in the nucleus.
 Neutrons also reside in the nucleus but have neutral charge.
 - **Electrons** are negatively charged, are much lighter than protons and neutrons, and surround the nucleus.

Particle	Charge (e)	Mass (g)	Mass (u)	Location
Proton	+1	1.67×10^{-24}	1.0073	In the nucleus
Neutron	0	1.67×10^{-24}	1.0073	In the nucleus
Electron	-1	9.11×10^{-31}	5.49×10^{-4}	Outside the nucleus

The elementary charge e is 1.6×10^{-19} Coulombs. One atomic mass unit (u or amu) is 1.67×10^{-24} grams.

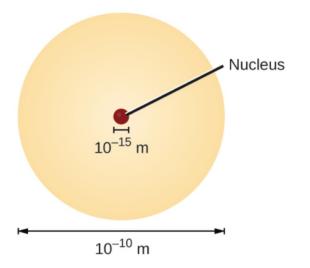






Figure. If the atom were blown up to be as large as a football stadium, the nucleus would be the size of a blueberry.

Atomic Number and Mass Number: Counting Subatomic Particles



- **Atomic number (Z):** the number of protons in the nucleus *or* the number of electrons in the neutral atom
- Mass number (M): the number of protons plus the number of neutrons in the nucleus
- Atomic number defines the elements. All atoms of a given element have the same number of protons in the nucleus.
 Atoms with different numbers of protons in their nuclei correspond to different elements.
- Atoms of a given element may have equal numbers of protons (equal Z) but different numbers of neutrons (unequal M). Such atoms are called **isotopes**.

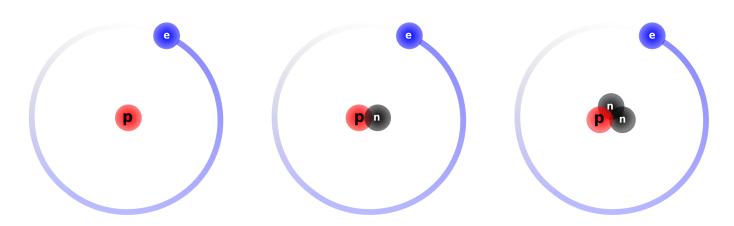
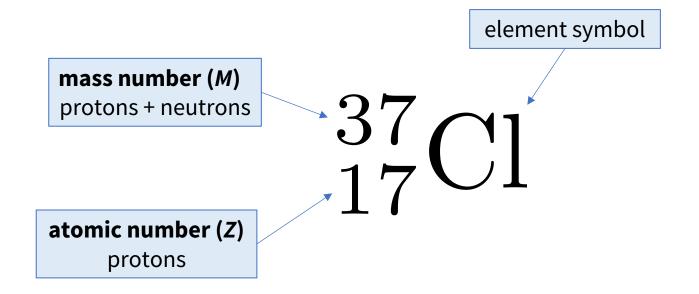


Figure. The three isotopes of hydrogen have equal atomic numbers but unequal mass numbers.

Atomic Symbols



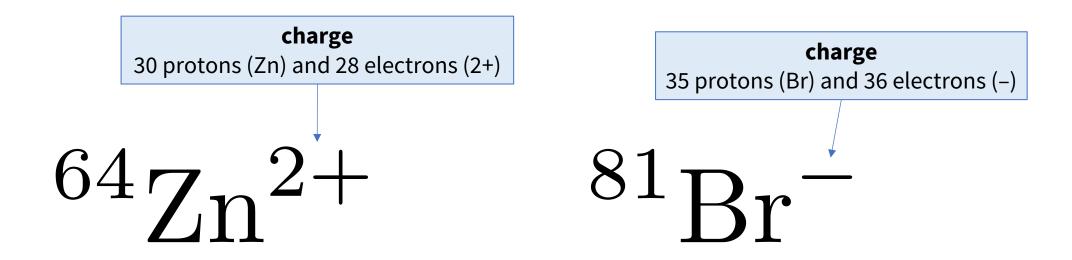
- Each element has an **element symbol** of one or two letters used to signify atoms of the element or a bulk sample of the element.
- In an **atomic symbol**, superscripts and subscripts to the left of the element symbol are used to specify the mass number and atomic number (redundant with the element symbol).
- The number of neutrons is equal to the difference between the mass number and atomic number.



Representing Ions



- Charged particles containing different numbers of protons and electrons are called ions.
 - Cations contain fewer electrons than protons and net positive charge.
 - Anions contain more electrons than protons and net positive charge.
- Ions may consist of a single atom (monatomic ions) or multiple atoms bonded together (polyatomic ions).
- Charge is indicated with a superscript to the right of the element symbol or formula: 3-, 2-, -, +, 2+, 3+, etc.



Lingering Questions



• How do we think about atomic mass in a macroscopic sample of an element with multiple isotopes?

• Do the charges of monatomic ions formed by the elements follow any sort of pattern?

How similar are the properties of isotopes? Do they display the same chemistry?

• Do electrons really "orbit" the nucleus like planets around the sun? What does an electron really "look like"?