

Chem With Com

Lewis Structures, Bonding, and Molecules

- Chapter 2.4 (Chemical Formulas)
- Chapter 4.4 (Lewis Symbols and Structures)
- Chapter 3.6 (The Periodic Table)
- Chapter 3.7 (Ionic and Molecular Compounds)
- Chapter 1.2 (Phases and Classifications of Matter)

Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

Lewis Symbols, Octet Rule, and Ionic Bonds

- Chapter 4.4 (Lewis Symbols and Structures)
- Chapter 3.6 (The Periodic Table)
- Chapter 3.7 (Ionic and Molecular Compounds)

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Lewis Symbols and Structures

Lewis Symbols

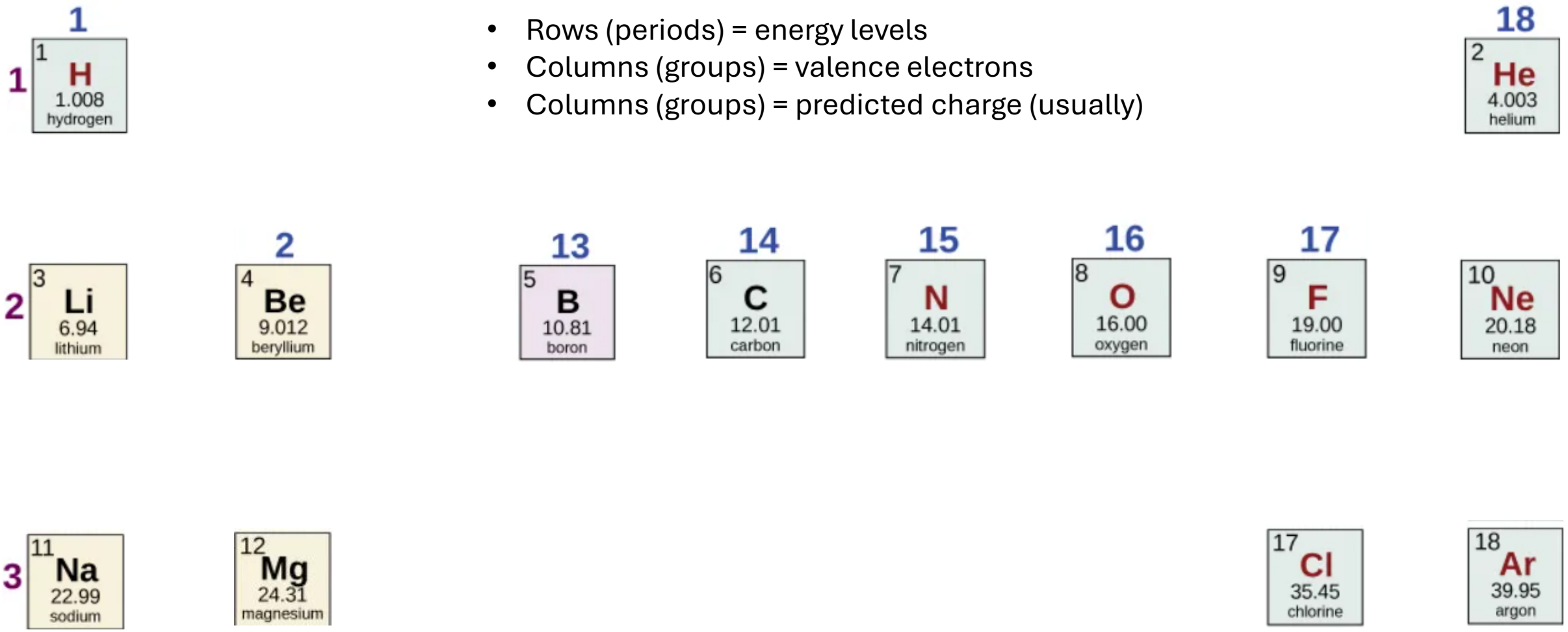
We use Lewis symbols to describe valence electron configurations of atoms and monatomic ions. A **Lewis symbol** consists of an elemental symbol surrounded by one dot for each of its valence electrons:



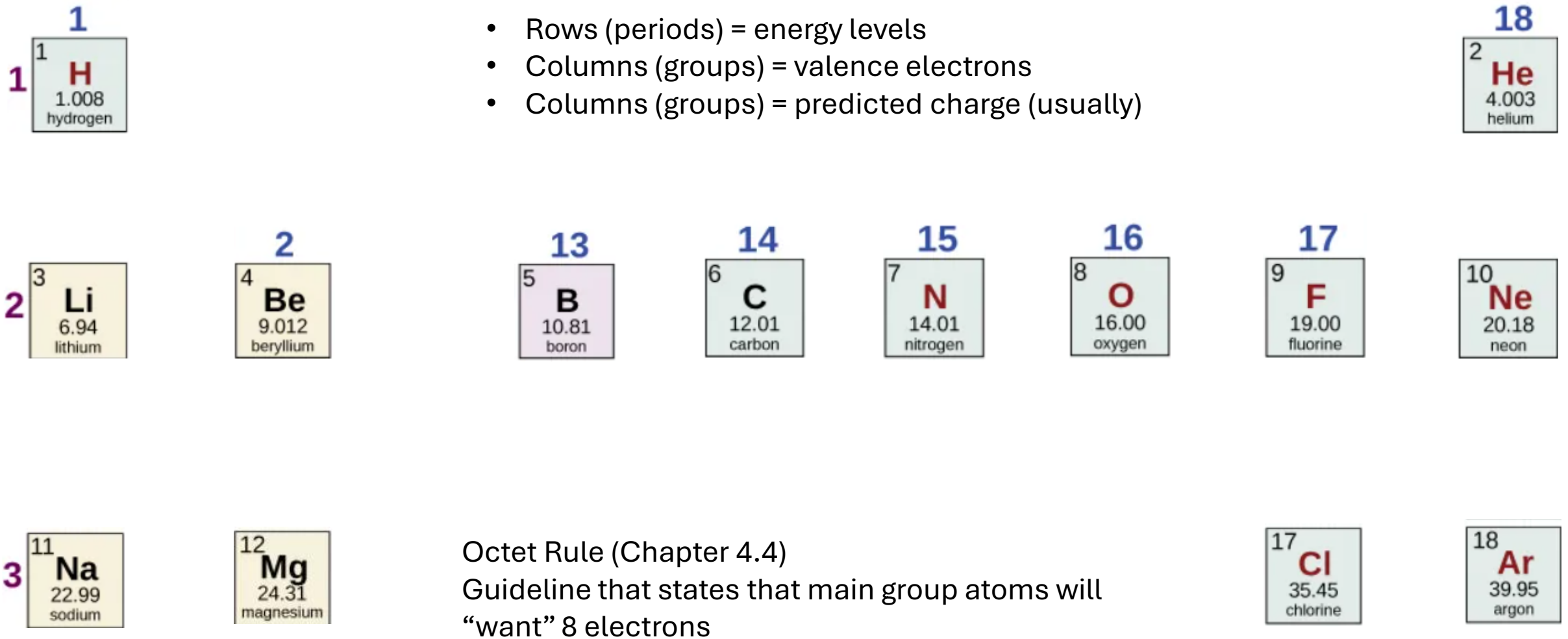
Figure 4.10 shows the Lewis symbols for the elements of the third period of the periodic table.

Ions

- Rows (periods) = energy levels
- Columns (groups) = valence electrons
- Columns (groups) = predicted charge (usually)



Lewis Symbols and Structures



- Rows (periods) = energy levels
- Columns (groups) = valence electrons
- Columns (groups) = predicted charge (usually)

Octet Rule (Chapter 4.4)
Guideline that states that main group atoms will "want" 8 electrons

Lewis Structures

Atoms	Lewis Symbol
sodium	Na·
magnesium	·Mg·
aluminum	·Al·
silicon	·Si·
phosphorus	·P·
sulfur	:S·
chlorine	:Cl·
argon	:Ar:

valence e⁻ only

- Draw the lewis structure for sodium.
- Draw the lewis structure for helium.
- Draw the lewis structure for phosphorous.
- Draw the lewis structure for calcium.

Octet Rule

octet rule

guideline that states main group atoms will form structures in which eight valence electrons interact with each nucleus, counting bonding electrons as interacting with both atoms connected by the bond



Chapter 3.6 and 4.4

Ionic Bonds (ionic compounds)

- Metal + Nonmetal
- Metal = gives away electrons, nonmetal = takes electrons

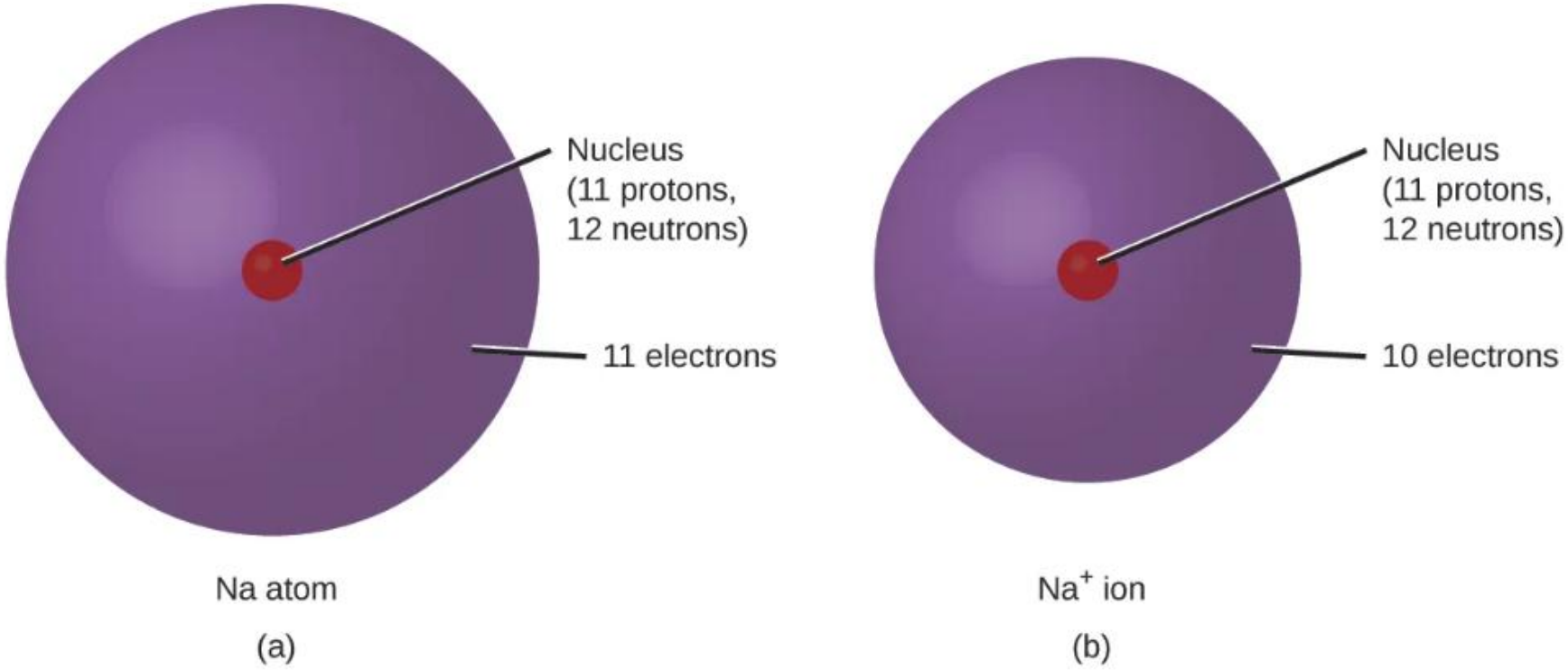
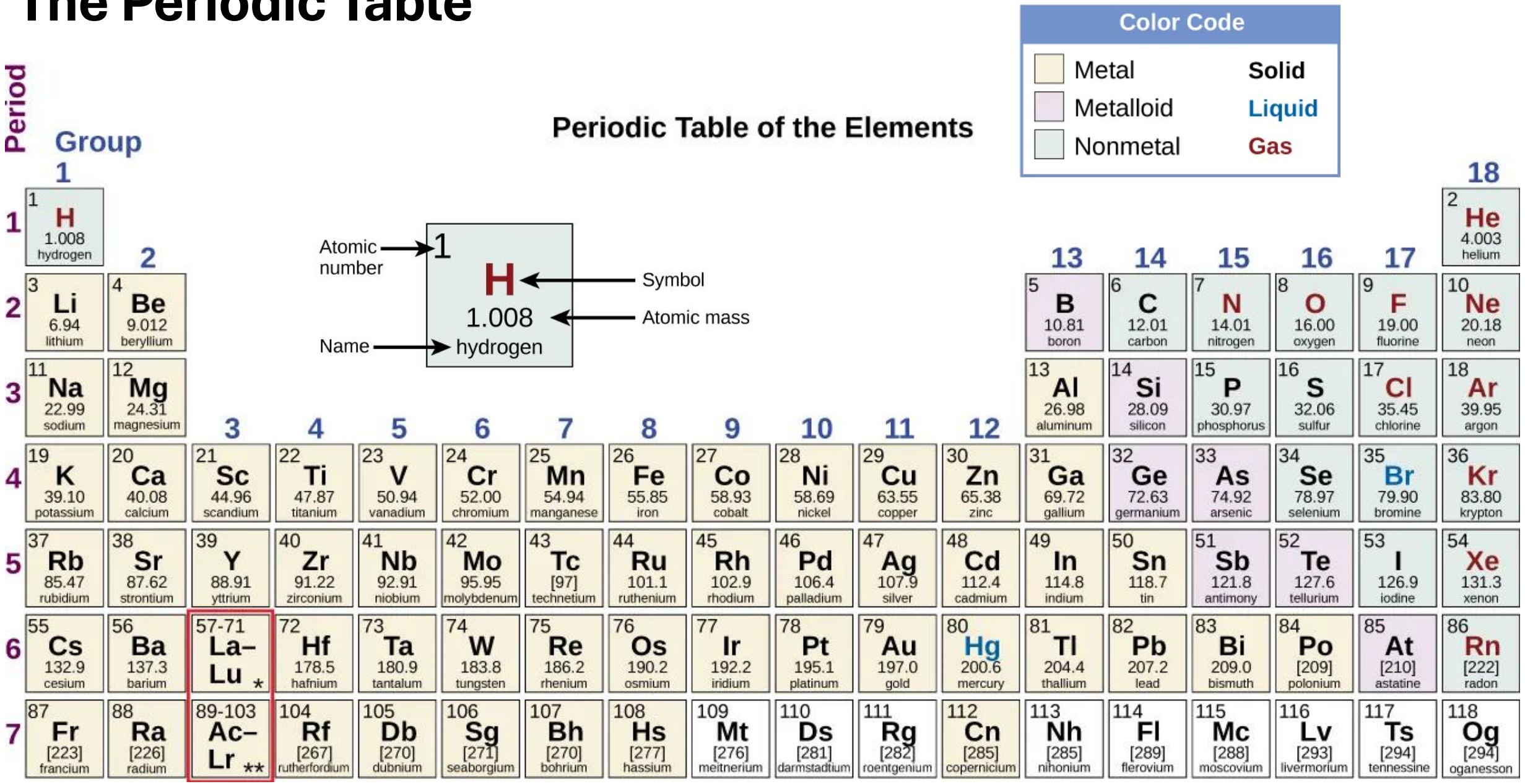
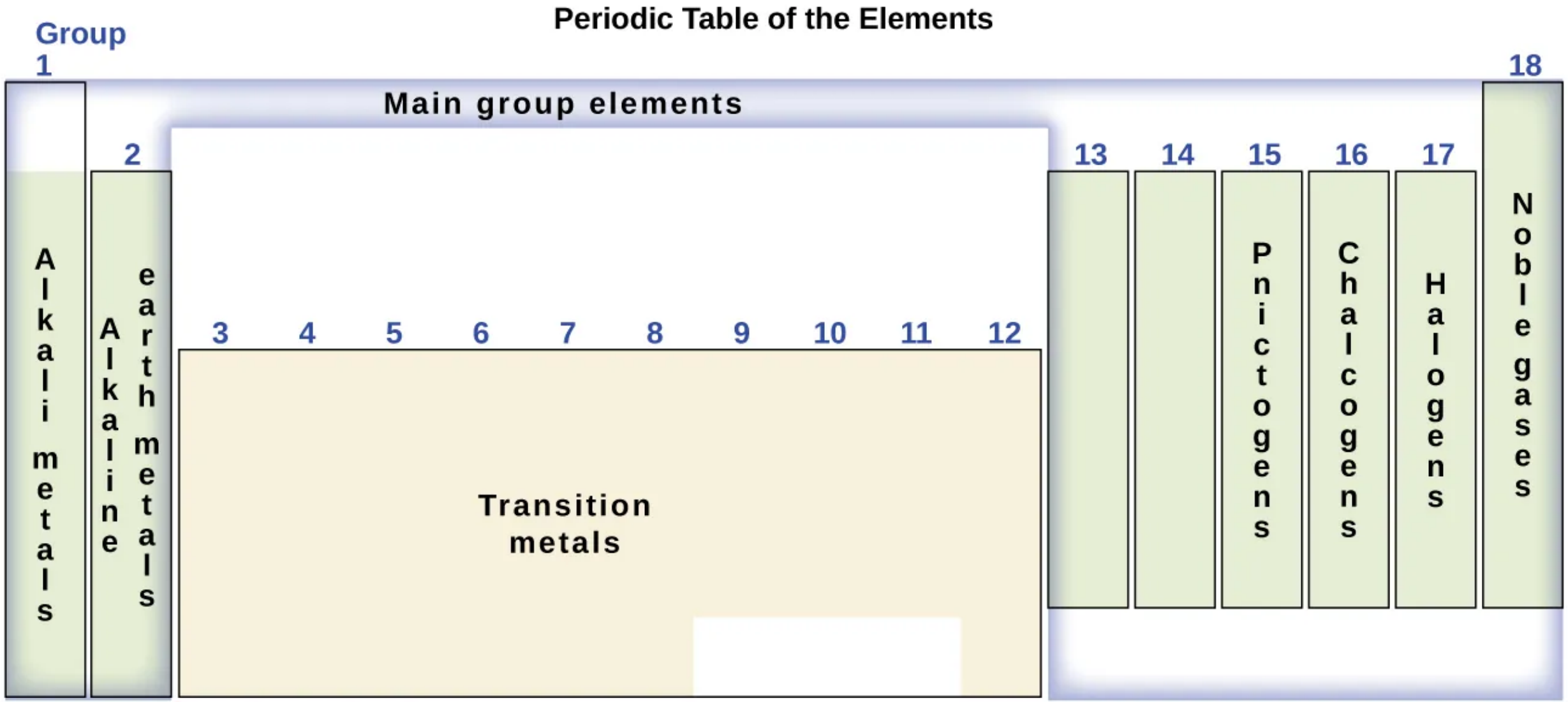


Figure 3.39 (a) A sodium atom (Na) has equal numbers of protons and electrons (11) and is uncharged. (b) A sodium cation (Na^+) has lost an electron, so it has one more proton (11) than electrons (10), giving it an overall positive charge, signified by a superscripted plus sign.

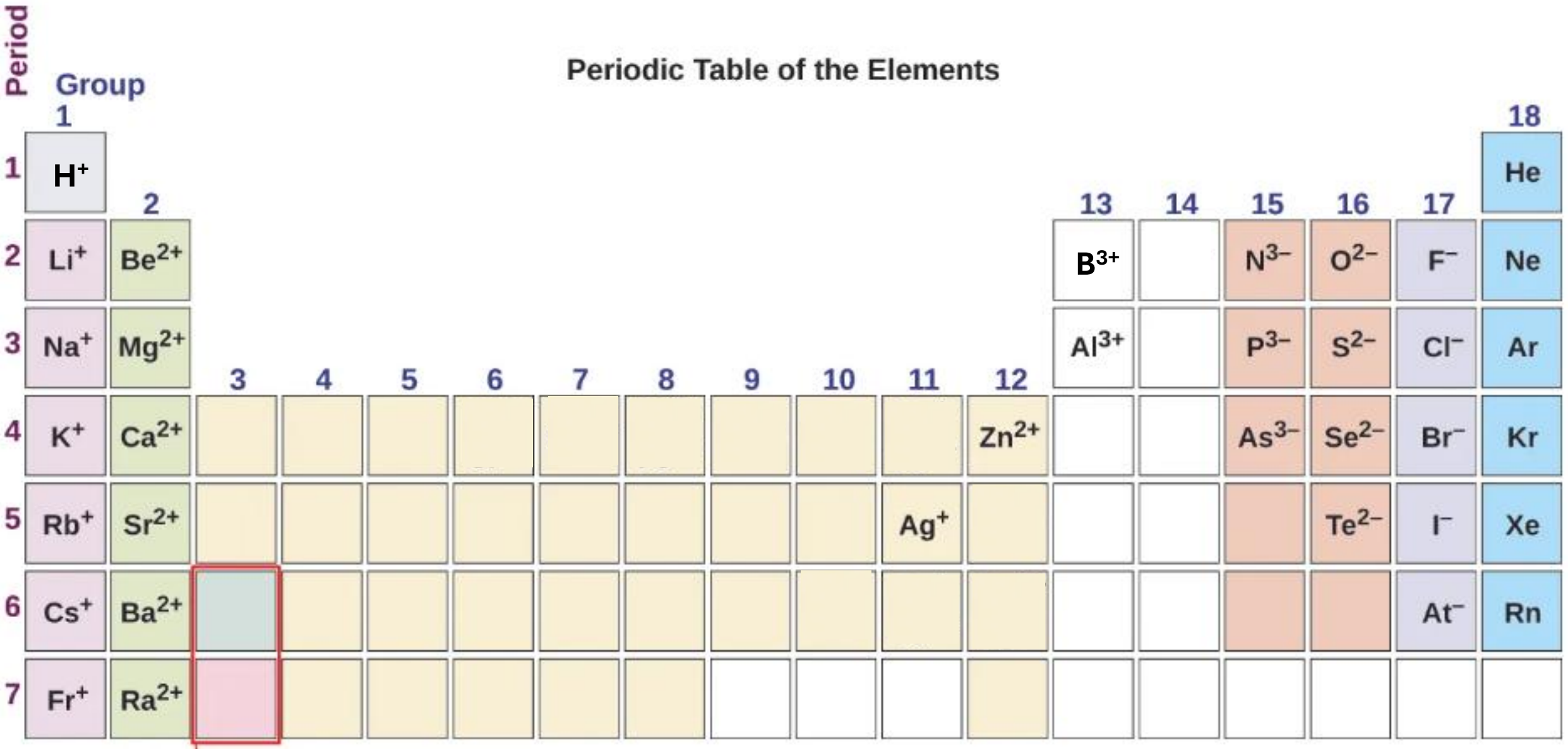
The Periodic Table



The Periodic Table



Ionic Bonds


Periodic Table of the Elements
Period
Group
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
H+
He
Li+
Be2+
B3+
N3−
O2−
F−
Ne
Na+
Mg2+
Al3+
P3−
S2−
Cl−
Ar
K+
Ca2+
Zn2+
As3−
Se2−
Br−
Kr
Rb+
Sr2+
Ag+
Te2−
I−
Xe
Cs+
Ba2+
At−
Rn
Fr+
Ra2+

Polyatomic Ions

Name	Formula
ammonium	NH_4^+
hydronium	H_3O^+
peroxide	O_2^{2-}
hydroxide	OH^-
acetate	CH_3COO^-
cyanide	CN^-
azide	N_3^-
carbonate	CO_3^{2-}
bicarbonate	HCO_3^-
nitrate	NO_3^-
nitrite	NO_2^-
sulfate	SO_4^{2-}

Name	Formula
hydrogen sulfate	HSO_4^-
sulfite	SO_3^{2-}
hydrogen sulfite	HSO_3^-
phosphate	PO_4^{3-}
hydrogen phosphate	HPO_4^{2-}
dihydrogen phosphate	$H_2PO_4^-$
perchlorate	ClO_4^-
chlorate	ClO_3^-
chlorite	ClO_2^-
hypochlorite	ClO^-
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
permanganate	MnO_4^-

Ions

Check Your Learning

Aluminum and carbon react to form an ionic compound. Predict which forms an anion, which forms a cation, and the charges of each ion. Write the symbol for each ion and name them.

Ionic Bonds

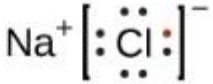
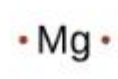
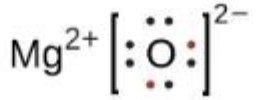
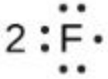
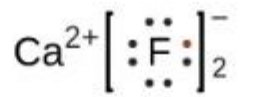
Metal		Nonmetal		Ionic Compound
	+			
sodium atom		chlorine atom		sodium chloride (sodium ion and chloride ion)
	+			
magnesium atom		oxygen atom		magnesium oxide (magnesium ion and oxide ion)
	+			
calcium atom		fluorine atoms		calcium fluoride (calcium ion and two fluoride ions)

Figure 4.11 Cations are formed when atoms lose electrons, represented by fewer Lewis dots, whereas anions are formed by atoms gaining electrons. The total number of electrons does not change.

Ionic Bonds

- Make neutral compounds
- The charges of the ions should add up to 0.
- You can’t change the charge of the ions but you can just “find” additional ions with the same charge so the charges add up to 0.

Ionic Bonds

KF

Li_2S

$BaBr_2$

Ionic Bonds

Check Your Learning

Predict the formula of the ionic compound formed between the sodium cation, Na^+, and the sulfide anion, S^{2-}.

Ionic Bonds

Check Your Learning

Predict the formula of the ionic compound formed between the lithium ion and the peroxide ion, O_2^{2-} (Hint: Use the periodic table to predict the sign and the charge on the lithium ion.)

Ionic Bonds

- Ionic compounds
  - Held together by ionic bonds (+/- charges)
  - Ionic bonds are formed by atoms giving and taking electrons
  - Occurs between metals and nonmetals
  - Usually comes apart in water

Lewis Structures and Covalent Bonds

- Chapter 4.4 (Lewis Symbols and Structures)
- Chapter 3.7 (Ionic and Molecular Compounds)

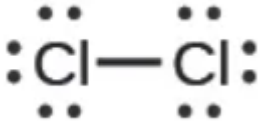
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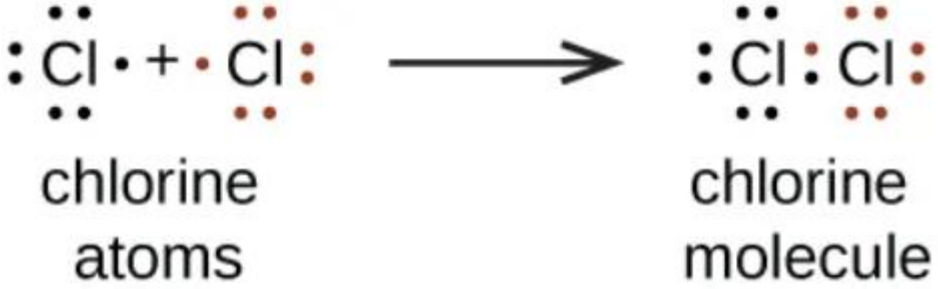
Ionic Bonds and Covalent Bonds

- Ionic compounds
  - Held together by ionic bonds (+/- charges)
  - Ionic bonds are formed by atoms giving and taking electrons
  - Occurs between metals and nonmetals
  - Usually comes apart in water.
- Molecular compounds
  - Held together by covalent bonds
  - Covalent bonds are formed by atoms sharing electrons
  - Occurs between two nonmetals
  - Usually doesn’t come apart in water

Covalent Bonds (molecular compounds)

- Nonmetal + Nonmetal
- nonmetal = takes electrons
- Two nonmetals = sharing electrons





H—H

Covalent Bonds and Lewis Structures

1. Determine the total number of valence (outer shell) electrons. For cations, subtract one electron for each positive charge. For anions, add one electron for each negative charge.
2. Draw a skeleton structure of the molecule or ion, arranging the atoms around a central atom. (Generally, the least electronegative element should be placed in the center.) Connect each atom to the central atom with a single bond (one electron pair).
3. Distribute the remaining electrons as lone pairs on the terminal atoms (except hydrogen), completing an octet around each atom.
4. Place all remaining electrons on the central atom.
5. Rearrange the electrons of the outer atoms to make multiple bonds with the central atom in order to obtain octets wherever possible.

Covalent Bonds and Lewis Structures (com's way)

- Count total valence electrons of all atoms
  - Negative charges mean add electrons, positive charges mean subtract electrons
- Draw the skeletal structure with these tips
  - symmetrical
  - H, F, Cl, Br, I on the outsides
- Place bonding electrons in pairs to connect atoms
- Put rest of electrons on the outsides in pairs following the "octet" rule
  - If an atom doesn't have all it's electrons, share your neighbor's electron pairs
- Other common things (usual but not always):
  - C = 4 bonds, 0 lone pair
  - N = 3 bonds, 1 lone pair
  - O = 2 bonds, 2 lone pairs
  - halogens = 1 bond, 3 lone pairs

Covalent Bonds and Lewis Structures

- Count total valence electrons of all atoms
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CCl_4

CH_2O

Covalent Bonds and Lewis Structures

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CO **CO_2**

Covalent Bonds and Lewis Structures

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CO_3^{2-}

NH_4^{1+}

Covalent Bonds and Lewis Structures

- Count total valence electrons of all atoms
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H_2O **NH_3**

Ionic and Molecular Compounds

Check Your Learning

Using the periodic table, predict whether the following compounds are ionic or covalent:

(a) SO_2

(b) CaF_2

(c) N_2H_4

(d) $Al_2(SO_4)_3$

Molecules, Compounds, and Chemical Formulas

- Chapter 2.4 (Chemical Formulas)
- Chapter 3.6 (The Periodic Table)
- Chapter 1.2 (Phases and Classifications of Matter)

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Chemical Formulas

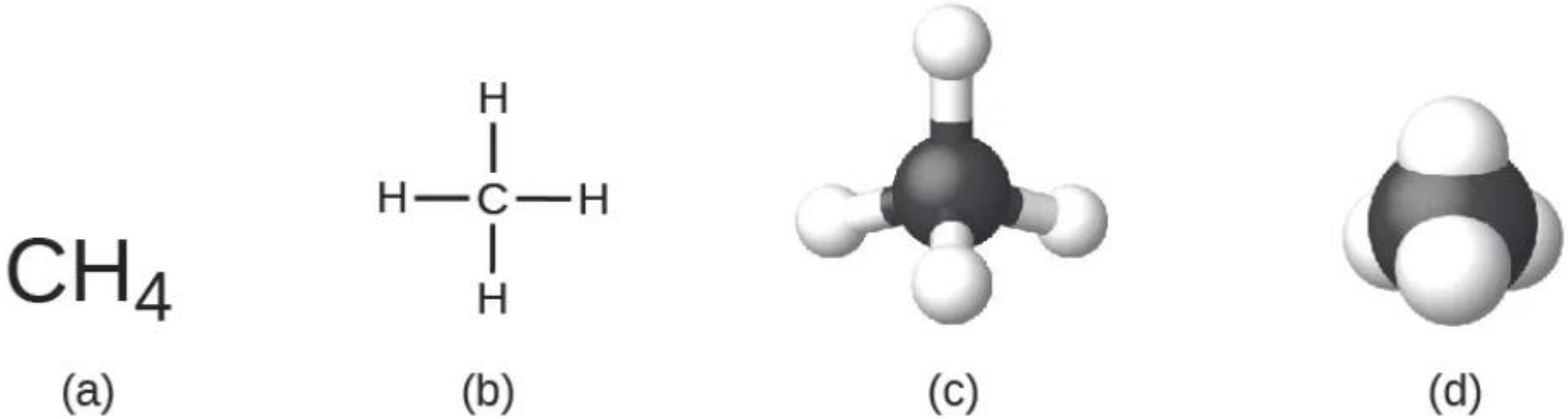


Figure 2.16 A methane molecule can be represented as (a) a molecular formula, (b) a structural formula, (c) a ball-and-stick model, and (d) a space-filling model. Carbon and hydrogen atoms are represented by black and white spheres, respectively.

Atoms and Molecules

atoms

molecules (more than one atom)

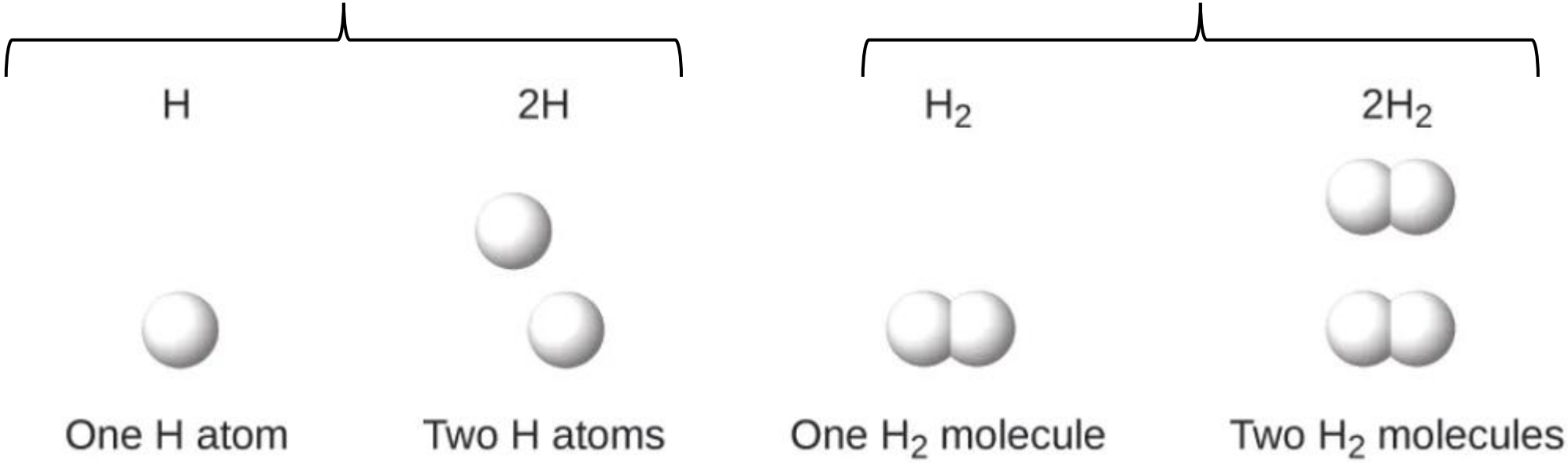


Figure 2.18 The symbols H, 2H, H_2, and $2H_2$ represent very different entities.

all elements

Molecules and Compounds

Compounds
(two or more different atoms)

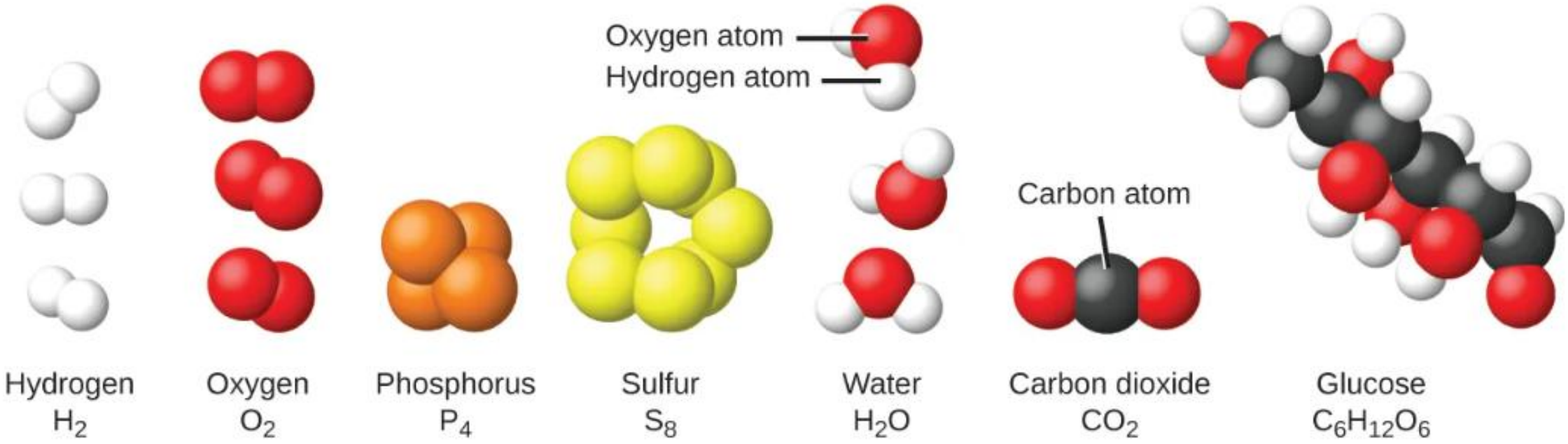


Figure 1.14 The elements hydrogen, oxygen, phosphorus, and sulfur form molecules consisting of two or more atoms of the same element. The compounds water, carbon dioxide, and glucose consist of combinations of atoms of different elements.

molecules
(more than one atom)

What are things called?

- Atoms/elements
- Molecules (more than one atom)
- Compounds (two or more different atoms)
- Molecular Element (multiple of the same atom)
- Molecular Compound (two different nonmetals)
- Ionic Compound (metal and a nonmetal)

1. What is He?
2. What is NO?
3. What is H_2O?
4. What is Fe?
5. What is H_2?
6. What is NaCl

Chemical Formulas

- Subscript numbers (small and to the bottom right is just for what is immediately to the left of it. If there are parentheses it's the number of things in the parentheses
- Number on the left of molecule is the coefficient and tells you how many total molecules there are

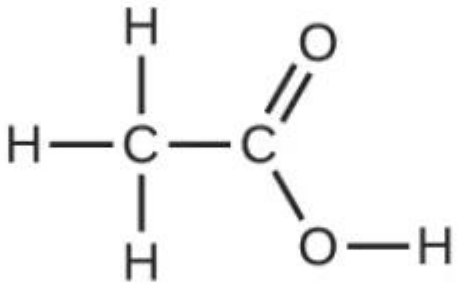
H **H_2** **H_2O**

H_2O_2 **$2(H_2O_2)$** **$2(NH_4)_2\,SO_4$**

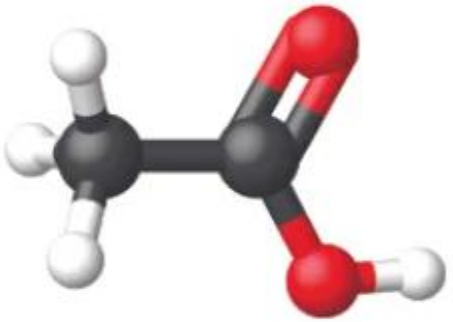
Molecular vs Empirical Formula



(a)



(b)



(c)

Figure 2.21 (a) Vinegar contains acetic acid, $C_2H_4O_2$, which has an empirical formula of CH_2O. It can be represented as (b) a structural formula and (c) as a ball-and-stick model. (credit a: modification of work by "HomeSpot HQ"/Flickr)

Molecular vs Empirical Formula

Molecular Formula

Empirical Formula

Molecular vs Empirical Formula

Check Your Learning

A molecule of metaldehyde (a pesticide used for snails and slugs) contains 8 carbon atoms, 16 hydrogen atoms, and 4 oxygen atoms. What are the molecular and empirical formulas of metaldehyde?

Isomers

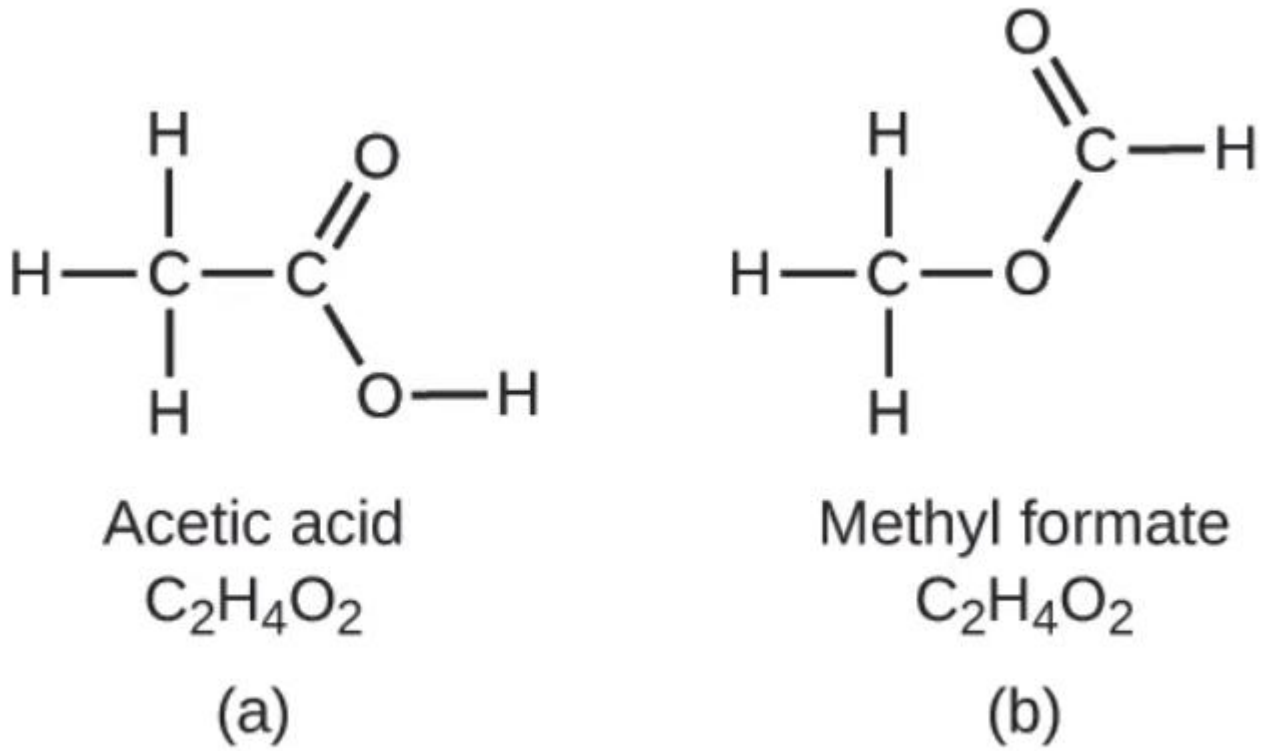


Figure 2.23 Molecules of (a) acetic acid and methyl formate (b) are structural isomers; they have the same formula ($C_2H_4O_2$) but different structures (and therefore different chemical properties).

Grams Per Mole!

H

H_2

H_2O

$2H_2O$

Element	Average Atomic Mass (amu)	Molar Mass (g/mol)	Atoms/Mole
C	12.01	12.01	6.022×10^{23}
H	1.008	1.008	6.022×10^{23}
O	16.00	16.00	6.022×10^{23}
Na	22.99	22.99	6.022×10^{23}
Cl	35.45	35.45	6.022×10^{23}

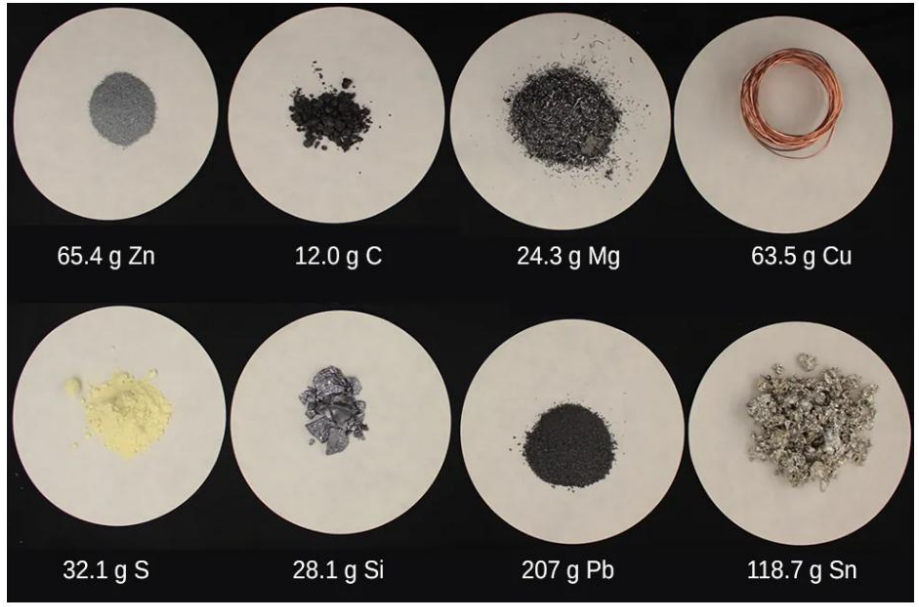
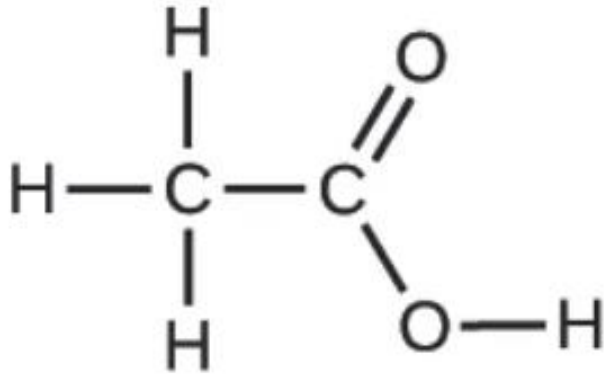


Figure 2.25 Each sample contains 6.022×10^{23} atoms —1.00 mol of atoms. From left to right (top row): 65.4 g zinc, 12.0 g carbon, 24.3 g magnesium, and 63.5 g copper. From left to right (bottom row): 32.1 g sulfur, 28.1 g silicon, 207 g lead, and 118.7 g tin. (credit: modification of work by Mark Ott)

Grams Per Mole of Molecules

Period	Group 1	2	13	14	15	16	17	18
1	1 H 1.008 hydrogen							2 He 4.003 helium
2	3 Li 6.94 lithium	4 Be 9.012 beryllium	5 B 10.81 boron	6 C 12.01 carbon	7 N 14.01 nitrogen	8 O 16.00 oxygen	9 F 19.00 fluorine	10 Ne 20.18 neon



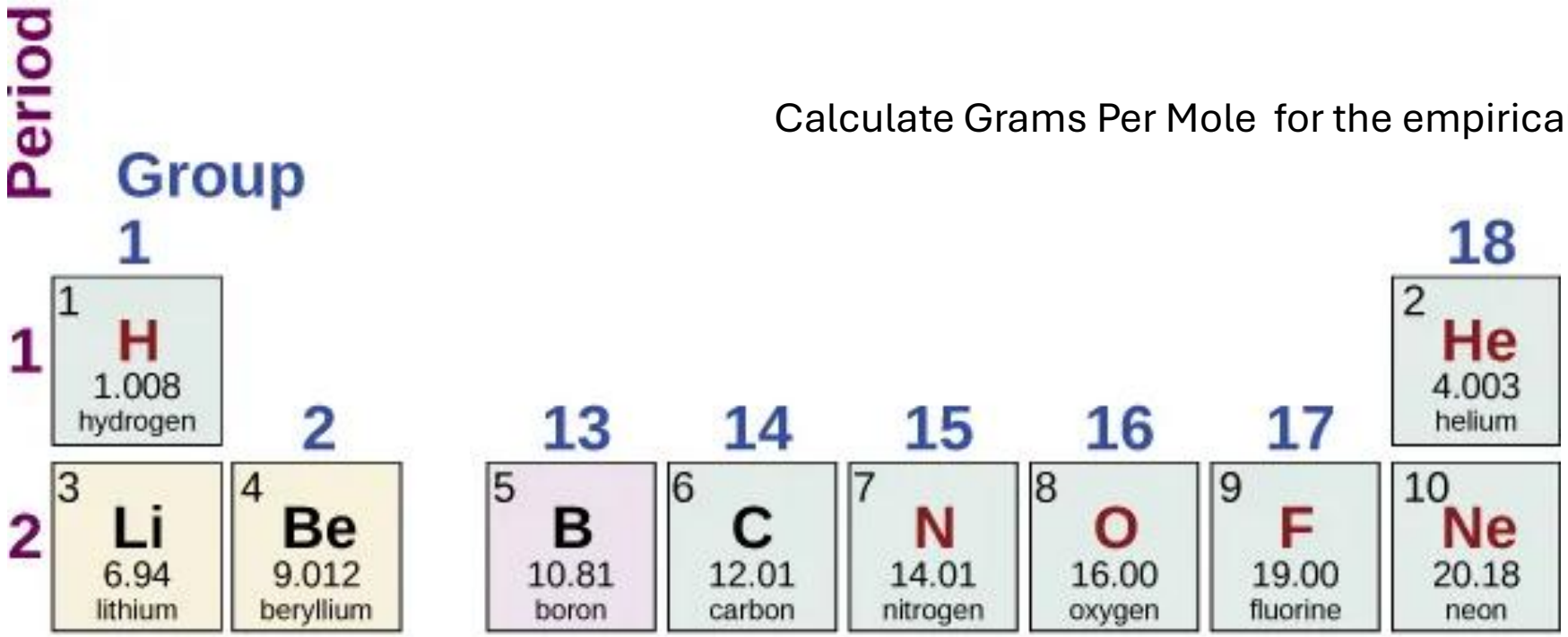
Acetic acid

$C_2H_4O_2$

Chapter 3.6 and 2.4

Grams Per Mole of Molecules

Calculate Grams Per Mole for the empirical and molecular formula.



Check Your Learning

A molecule of metaldehyde (a pesticide used for snails and slugs) contains 8 carbon atoms, 16 hydrogen atoms, and 4 oxygen atoms. What are the molecular and empirical formulas of metaldehyde?