Chapter 4  Atoms and Elements

• Elements and Symbols
• The Periodic Table
• The Atom
• Atomic and Mass Numbers
• Isotopes and Atomic Mass
• Electron Energy Levels
Review: Matter

Pure Substance
- Element
- Compound

Mixture
- Heterogeneous
- Homogeneous
Mixtures

• Homogeneous
  - alloy
  - air

• Heterogeneous
  - oil & water
Pure Substances

- Elements

- Compounds
Elements

Elements are

• Pure substances that cannot be separated into simpler substances by ordinary laboratory processes.

• The building blocks of matter.

gold    carbon    aluminum

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Sources of Some Element Names

Some elements are named for
- planets,
- mythological figures,
- minerals,
- colors,
- scientists, and
- places.

<table>
<thead>
<tr>
<th>Table 4.1</th>
<th>Some Elements and Their Names</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element</strong></td>
<td><strong>Source of Name</strong></td>
</tr>
<tr>
<td>Uranium</td>
<td>The planet Uranus</td>
</tr>
<tr>
<td>Titanium</td>
<td>Titans (mythology)</td>
</tr>
<tr>
<td>Chlorine</td>
<td><em>Chloros</em>, “greenish yellow” (Greek)</td>
</tr>
<tr>
<td>Iodine</td>
<td><em>Ioeides</em>, “violet” (Greek)</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Magnesia, a mineral</td>
</tr>
<tr>
<td>Californium</td>
<td>California</td>
</tr>
<tr>
<td>Curium</td>
<td>Marie and Pierre Curie</td>
</tr>
</tbody>
</table>
Symbols of Elements

A symbol
• Represents the name of an element.
• Consists of 1 or 2 letters.
• Starts with a capital letter.

Examples:

<table>
<thead>
<tr>
<th>1-Letter Symbols</th>
<th>2-Letter Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>C    carbon</td>
<td>Co   cobalt</td>
</tr>
<tr>
<td>N    nitrogen</td>
<td>Ca   calcium</td>
</tr>
<tr>
<td>F    fluorine</td>
<td>Al   aluminum</td>
</tr>
<tr>
<td>O    oxygen</td>
<td>Mg   magnesium</td>
</tr>
</tbody>
</table>
Symbols from Latin Names

Several symbols are derived from Latin names as shown below:

Cu, copper (cuprum)  Au, gold (aurum)
Fe, iron (ferrum)     Ag, silver (argentum)
<table>
<thead>
<tr>
<th>Name*</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Al</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
</tr>
<tr>
<td>Arsenic</td>
<td>As</td>
</tr>
<tr>
<td>Barium</td>
<td>Ba</td>
</tr>
<tr>
<td>Boron</td>
<td>B</td>
</tr>
<tr>
<td>Bromine</td>
<td>Br</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Cd</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
</tr>
<tr>
<td>Chromium</td>
<td>Cr</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Co</td>
</tr>
<tr>
<td>Copper (cuprum)</td>
<td>Cu</td>
</tr>
<tr>
<td>Fluorine</td>
<td>F</td>
</tr>
<tr>
<td>Gold (aurum)</td>
<td>Au</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H</td>
</tr>
<tr>
<td>Iodine</td>
<td>I</td>
</tr>
<tr>
<td>Iron (ferrum)</td>
<td>Fe</td>
</tr>
<tr>
<td>Lead (plumbum)</td>
<td>Pb</td>
</tr>
<tr>
<td>Lithium</td>
<td>Li</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn</td>
</tr>
<tr>
<td>Mercury (hydrargyrum)</td>
<td>Hg</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
</tr>
<tr>
<td>Nickel</td>
<td>Ni</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
</tr>
<tr>
<td>Platinum</td>
<td>Pt</td>
</tr>
<tr>
<td>Potassium (kalium)</td>
<td>K</td>
</tr>
<tr>
<td>Radium</td>
<td>Ra</td>
</tr>
<tr>
<td>Silicon</td>
<td>Si</td>
</tr>
<tr>
<td>Silver (argentum)</td>
<td>Ag</td>
</tr>
<tr>
<td>Sodium (natrium)</td>
<td>Na</td>
</tr>
<tr>
<td>Strontium</td>
<td>Sr</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S</td>
</tr>
<tr>
<td>Tin (stannum)</td>
<td>Sn</td>
</tr>
<tr>
<td>Titanium</td>
<td>Ti</td>
</tr>
<tr>
<td>Uranium</td>
<td>U</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn</td>
</tr>
</tbody>
</table>

*Names given in parentheses are Latin or Greek words from which the symbols are derived.
Pure Substances

A pure substance is classified as

• An element when composed of one type of atom.

• A compound when composed of two or more different elements combined in a definite ratio.
Elements v. Compounds v. Mixtures: Review

• Identify each of the following as an element (A), compound (B), homogeneous mixture (C), or heterogeneous mixture (D).

• carbon monoxide (CO) (B)
• oxygen (O₂) (A)
• salt mixed with sugar (D)
• salt mixed with water (C)
• oil and water (D)
A closer look at the Periodic Table
Modern Periodic Table

- Mendeleev – Father of the Periodic Table

- Periodic Law of the Elements – when elements are arranged in a particular order (increasing atomic number), elements of similar properties occur at periodic intervals

- Arranged into:
  - Groups/families – vertical columns
  - Periods – horizontal rows
Arrangement of the Periodic Table

The blocks of the periodic table:
### Periodic Table of Elements

#### Periodic Table of Elements

<table>
<thead>
<tr>
<th>Period</th>
<th>Group</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1A</td>
<td>H</td>
</tr>
<tr>
<td>2</td>
<td>2A</td>
<td>Li, Be</td>
</tr>
<tr>
<td>3</td>
<td>3B</td>
<td>Na, Mg</td>
</tr>
<tr>
<td>4</td>
<td>4B</td>
<td>K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr</td>
</tr>
<tr>
<td>5</td>
<td>5B</td>
<td>Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe</td>
</tr>
<tr>
<td>6</td>
<td>6B</td>
<td>Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn</td>
</tr>
<tr>
<td>7</td>
<td>7B</td>
<td>Fr, Ra, Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr</td>
</tr>
</tbody>
</table>

*©Lanthanides* *↑Actinides*
The Periodic Table – All Stretched Out

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>37</td>
<td>38</td>
</tr>
<tr>
<td>55</td>
<td>56</td>
</tr>
<tr>
<td>87</td>
<td>88</td>
</tr>
</tbody>
</table>
Groups and Periods

On the periodic table

- Elements are arranged according to similar properties.
- **Groups** contain elements with similar properties in vertical columns.
- **Periods** are horizontal rows of elements.
Groups and Periods (Rows)
Periodic Table
Group Numbers

• Use the letter A for the representative elements 1A to 8A and the letter B for the transition elements.

• Also use numbers 1-18 for the columns from left to right.
Names of Some Representative Elements

- Several groups of representative elements are known by common names.
Alkali Metals

Group 1A(1), the alkali metals, includes lithium, sodium, and potassium.
Halogens

Group 7A(17) the halogens, includes
• chlorine,
• bromine, and
• iodine.
Learning Check

Identify the element described by the following:
1. Group 7A (17), Period 4
   A) Br    B) Cl    C) Mn

2. Group 2A(2), Period 3
   A) beryllium   B) magnesium   C) boron

3. Group 5A(15), Period 2
   A) phosphorus   B) arsenic   C) nitrogen
Metals, Nonmetals, and Metalloids

The heavy zigzag line separates metals and nonmetals.

- **Metals** are located to the left.
- **Nonmetals** are located to the right.
- **Metalloids** are located along the heavy zigzag line between the metals and nonmetals.
Properties of Metals, Nonmetals, and Metalloids

**Metals**
- Are shiny, ductile and malleable.
- Are good conductors of heat and electricity.

**Nonmetals**
- Are dull, brittle, and poor conductors.
- Are good insulators.

**Metalloids**
- Are better conductors than nonmetals, but not as good as metals.
- Are used as semiconductors and insulators.
Comparing A Metal, Metalloid, and Nonmetal

### Table 4.3 Some Characteristics of a Metal, a Metalloid, and a Nonmetal

<table>
<thead>
<tr>
<th>Silver (Ag)</th>
<th>Antimony (Sb)</th>
<th>Sulfur (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>Metalloid</td>
<td>Nonmetal</td>
</tr>
<tr>
<td>Shiny</td>
<td>Blue-grey, shiny</td>
<td>Dull, yellow</td>
</tr>
<tr>
<td>Extremely ductile</td>
<td>Brittle</td>
<td>Brittle</td>
</tr>
<tr>
<td>Can be hammered into sheets (malleable)</td>
<td>Shatters when hammered</td>
<td>Shatters when hammered</td>
</tr>
<tr>
<td>Good conductor of heat and electricity</td>
<td>Poor conductor of heat and electricity</td>
<td>Poor conductor, good insulator</td>
</tr>
<tr>
<td>Used in coins, jewelry, tableware</td>
<td>Used to harden lead, color glass and plastics</td>
<td>Used in gunpowder, rubber, fungicides</td>
</tr>
<tr>
<td>Density 10.5 g/mL</td>
<td>Density 6.7 g/mL</td>
<td>Density 2.1 g/mL</td>
</tr>
<tr>
<td>Melting point 962°C</td>
<td>Melting point 630°C</td>
<td>Melting point 113°C</td>
</tr>
</tbody>
</table>

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Learning Check

Match the elements to the description:

1. Metals in Group 4A(14)
   - A) Sn, Pb
   - B) C, Si
   - C) C, Si, Ge, Sn

2. Nonmetals in Group 5A(15)
   - A) As, Sb, Bi
   - B) N, P
   - C) N, P, As, Sb

3. Metalloids in Group 4A(14)
   - A) C, Si, Ge
   - B) Si, Ge
   - C) Si, Ge, Sn, Pb
A closer look still
The Conjecture of Atoms

- As early as 500 B.C., Greek Philosophers proposed that all matter is made up of atoms
  - Atom:
    - The smallest individual particle of an element that maintains the properties of that element
    - *Atomos* - indivisible
• Two Quizzes on Web Campus – Ends Tuesday 11:30 pm

• Exam I – next Monday, 9/29
  – Chapters 1-4
  – Chapter 5 will be on Exam II
Dalton’s Law of Atomic Theory

1. All matter is composed of extremely small particles called atoms.

2. Atoms of a given element are identical in their physical and chemical properties.

3. Atoms of different elements differ in their physical and chemical properties.
4. Atoms of different elements combine in simple, whole-number ratios to form compounds.

5. In **chemical reactions**, atoms are combined, separated, or rearranged but never created, destroyed, or changed.
Subatomic Particles

Today, we know that atoms are made up of smaller, more fundamental particles called subatomic particles.

Protons, Electrons & Neutrons
Subatomic Particles

Atoms contains subatomic particles

- **Protons** have a positive (+) charge.
- **Electrons** have a negative (-) charge.
- Like charges *repel* and unlike charges *attract*.
- **Neutrons** are neutral.
Rutherford’s Gold-Foil Experiment

In Rutherford’s gold-foil experiment

- Positively charged particles were aimed at atoms of gold.
- Most went straight through the atoms.
- Only a few were deflected.
- Conclusion: There must be a small, dense, positively charged nucleus in the atom that deflects positive particles that come close.
Rutherford’s Gold-Foil Experiment
An atom consists

- Of a nucleus that contains protons and neutrons.
- Of electrons in the large empty space around the nucleus.
Atomic Mass Scale

On the atomic mass scale for subatomic particles

- 1 atomic mass unit (amu) is equal to 1/12 of the mass of the carbon-12 atom.
- A proton has a mass of about 1 (1.007) amu.
- A neutron has a mass of about 1 (1.008) amu.
- An electron has a very small mass (0.00055 amu).
# Particles in the Atom

## Table 4.5 Subatomic Particles in the Atom

<table>
<thead>
<tr>
<th>Particle</th>
<th>Symbol</th>
<th>Relative Charge</th>
<th>Mass (g)</th>
<th>Mass (amu)</th>
<th>Location in Atom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>$p$ or $p^+$</td>
<td>1+</td>
<td>$1.673 \times 10^{-24}$</td>
<td>1 (1.007)</td>
<td>Nucleus</td>
</tr>
<tr>
<td>Neutron</td>
<td>$n$ or $n^0$</td>
<td>0</td>
<td>$1.675 \times 10^{-24}$</td>
<td>1 (1.008)</td>
<td>Nucleus</td>
</tr>
<tr>
<td>Electron</td>
<td>$e^-$</td>
<td>1−</td>
<td>$9.110 \times 10^{-28}$</td>
<td>0.000549</td>
<td>Outside nucleus</td>
</tr>
</tbody>
</table>

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Atomic Number

The atomic number

• Is specific for each element.
• Is the same for all atoms of an element.
• Is equal to the number of protons in an atom.
• Appears above the symbol of an element in most periodic tables.

11 Na
Atomic Numbers and Protons

Examples:

• Hydrogen has atomic number 1, every H atom has one proton.
• Carbon has atomic number 6, every C atom has six protons.
• Copper has atomic number 29, every Cu atom has 29 protons.
• Gold has atomic number 79, every Au atom has 79 protons.
Atomic Models
Learning Check

State the number of protons in each.

1. A nitrogen atom
   A) 5 protons  B) 7 protons  C) 14 protons

2. A sulfur atom
   A) 32 protons  B) 16 protons  C) 6 protons

3. A barium atom
   A) 137 protons  B) 81 protons  C) 56 protons

4. A mercury atom
   A) 80 protons  B) 200 protons  C) 25 protons
Electrons in An Atom

- An atom of any element is electrically neutral; the net charge of an atom is zero.
- In an atom, the number of protons is equal to the number of electrons.

\[
\text{number of protons} = \text{number of electrons}
\]

- For example, an atom of aluminum has 13 protons and 13 electrons. The net charge is zero.

\[
13 \text{ protons} (13 +) + 13 \text{ electrons} (13 -) = 0
\]
Mass Number

The mass number

- Represents the number of particles in the nucleus.
- Is equal to the

  Number of protons + Number of neutrons

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Atomic Number</th>
<th>Mass Number</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Number of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>7</td>
<td>14</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>17</td>
<td>37</td>
<td>17</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>26</td>
<td>56</td>
<td>26</td>
<td>30</td>
<td>26</td>
</tr>
<tr>
<td>Gold</td>
<td>Au</td>
<td>79</td>
<td>197</td>
<td>79</td>
<td>118</td>
<td>79</td>
</tr>
</tbody>
</table>

Table 4.6 Composition of Some Atoms of Different Elements

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Learning Check

An atom has 14 protons and 20 neutrons.

1. Its atomic number is
   A) 14     B) 16     C) 34

2. Its mass number is
   A) 14     B) 16     C) 34

3. The element is
   A) Si     B) Ca     C) Se
Learning Check

An atom of zinc has an atomic number of 30, and mass number of 65.

1. How many protons are in this zinc atom?
   A) 30  B) 35  C) 65

2. How many neutrons are in the zinc atom?
   A) 30  B) 35  C) 65

3. What is the mass number of a zinc atom that has 37 neutrons?
   A) 37  B) 65  C) 67
Isotopes and Atomic Mass

Isotopes

• Are atoms of the same element that have different mass numbers.
• Have the same number of protons,
• but different numbers of neutrons.
Nuclear Symbol

A nuclear symbol (aka atomic symbol)

- Represents a particular atom of an element.
- Gives the mass number in the upper left corner and the atomic number in the lower left corner.

Example: An atom of sodium with atomic number 11 and a mass number 23 has the following atomic symbol:

\[ \text{mass number } 23 \rightarrow \text{Na} \]
\[ \text{atomic number } 11 \rightarrow 11 \]
Information from Nuclear Symbols

- The nuclear symbol indicates the number of protons ($p^+$), neutrons ($n$), and electrons ($e^-$) in a particular atom.

- $\text{O}^{16} \text{O}$: $8 \ p^+ \ 8 \ n \ 8 \ e^-$
- $\text{P}^{31} \text{P}$: $15 \ p^+ \ 16 \ n \ 15 \ e^-$
- $\text{Zn}^{65} \text{Zn}$: $30 \ p^+ \ 35 \ n \ 30 \ e^-$
**Nuclear / Atomic Symbols**

Charge = Number of protons - number of electrons

Mass number = number of protons + number of neutrons

Atomic number = number of protons
   Defines the element
Nuclear / Atomic Symbols

Mass number = number of protons + number of neutrons

Atomic number = number of protons

Charge = number of protons - number of electrons
Nuclear / Atomic Symbols

- Mass number = number of protons + number of neutrons
- Charge = number of protons - number of electrons
- Atomic number = number of protons
Nuclear / Atomic Symbol Notation vs. The Periodic Table Notation

\[ \text{Ca}^{2+} \]

\[ 40 \quad 20 \]

\[ \text{Ca} \]

\[ 20 \quad 40.078 \]
Learning Check

Naturally occurring carbon consists of three isotopes, $^{12}\text{C}$, $^{13}\text{C}$, and $^{14}\text{C}$. State the number of protons, neutrons, and electrons in each of the following.

<table>
<thead>
<tr>
<th></th>
<th>$^{12}\text{C}$</th>
<th>$^{13}\text{C}$</th>
<th>$^{14}\text{C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>protons</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>neutrons</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>electrons</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
Learning Check

Write the nuclear symbols for atoms with the following subatomic particles:

A. 8 p\(^{+}\), 8 n, 8 e\(^{-}\)  

\[
\text{\underline{8}}\quad \text{\underline{O}}
\]

B. 17p\(^{+}\), 20n, 17e\(^{-}\)  

\[
\text{\underline{17}}\quad \text{\underline{Cl}}
\]

C. 47p\(^{+}\), 60 n, 47 e\(^{-}\)
Learning Check

1. Which of the following pairs are isotopes of the same element?
2. In which of the following pairs do both atoms have 8 neutrons?

A. $^{15}_8X$ $^{15}_7X$
B. $^{12}_6X$ $^{14}_6X$
C. $^{15}_7X$ $^{16}_8X$
Atomic Mass

The atomic mass of an element

• Is usually listed below the symbol of each element on the periodic table.
• Gives the mass of an “average” atom of each element compared to $^{12}$C.
• Is not the same as the mass number.

Na
22.99
Isotopes of Magnesium

In naturally occurring magnesium, there are three isotopes.

Table 4.7  Isotopes of Magnesium

<table>
<thead>
<tr>
<th>Atomic symbol</th>
<th>$^{24}_{12}$Mg</th>
<th>$^{25}_{12}$Mg</th>
<th>$^{26}_{12}$Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of protons</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Number of electrons</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Mass number</td>
<td>24</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>Number of neutrons</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
</tbody>
</table>
Examples of Isotopes and Their Atomic Masses

Most elements have two or more isotopes that contribute to the atomic mass of that element.

<table>
<thead>
<tr>
<th>Element</th>
<th>Isotopes</th>
<th>Atomic Mass (Weighted Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>$^6\text{Li}, ^7\text{Li}$</td>
<td>6.941 amu</td>
</tr>
<tr>
<td>Carbon</td>
<td>$^{12}\text{C}, ^{13}\text{C}, ^{14}\text{C}$</td>
<td>12.01 amu</td>
</tr>
<tr>
<td>Fluorine</td>
<td>$^{19}\text{F}$</td>
<td>19.00 amu</td>
</tr>
<tr>
<td>Oxygen</td>
<td>$^{16}\text{O}, ^{17}\text{O}, ^{18}\text{O}$</td>
<td>16.00 amu</td>
</tr>
<tr>
<td>Sulfur</td>
<td>$^{32}\text{S}, ^{33}\text{S}, ^{34}\text{S}, ^{36}\text{S}$</td>
<td>35.45 amu</td>
</tr>
<tr>
<td>Copper</td>
<td>$^{63}\text{Cu}, ^{65}\text{Cu}$</td>
<td>63.55 amu</td>
</tr>
</tbody>
</table>
Calculating Average Atomic Mass

The calculation for the average atomic mass requires the

- Percent (%) abundance of each isotope.
- Atomic mass in amu of each isotope of that element.
- Sum of the weighted averages.

\[
\text{mass isotope}(1) \times \left(\frac{\%}{100}\right) + \text{mass isotope}(2) \times \left(\frac{\%}{100}\right) + \ldots
\]
Atomic Mass of Magnesium

The atomic mass of Mg
- Is due to all the Mg isotopes.
- Is a weighted average.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Mass</th>
<th>Abundance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{24}\text{Mg}$</td>
<td>23.985</td>
<td>78.70</td>
</tr>
<tr>
<td>$^{25}\text{Mg}$</td>
<td>24.986</td>
<td>10.13</td>
</tr>
<tr>
<td>$^{26}\text{Mg}$</td>
<td>25.983</td>
<td>11.17</td>
</tr>
</tbody>
</table>
## Calculating Atomic Mass

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Mass (amu)</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{24}\text{Mg}$</td>
<td>23.985</td>
<td>78.70/100</td>
</tr>
<tr>
<td>$^{25}\text{Mg}$</td>
<td>24.986</td>
<td>10.13/100</td>
</tr>
<tr>
<td>$^{26}\text{Mg}$</td>
<td>25.983</td>
<td>11.17/100</td>
</tr>
</tbody>
</table>

Atomic mass (average mass) Mg = 24.31 amu
Atomic Mass for Cl

- The atomic mass of chlorine is the weighted average of two isotopes $^{35}\text{Cl}$ and $^{37}\text{Cl}$. 
Calculating Atomic Mass for Cl

$^{35}\text{Cl}$ has atomic mass 34.97 (75.78%) and $^{37}\text{Cl}$ has atomic mass 36.97 (24.22%).

- The atomic mass and percent of each isotope are used to calculate the contribution of each isotope to the weighted average.

$$\frac{34.97 \times 75.78}{100} = 26.50 \text{ amu}$$

$$\frac{36.97 \times 24.22}{100} = +8.954 \text{ amu}$$

- The sum is the weighted average or atomic mass of Cl. 35.45 amu
Learning Check

Gallium is an element found in lasers used in compact disc players. In a sample of gallium, there is 60.11% of $^{69}\text{Ga}$ (atomic mass 68.93) atoms and 39.89% of $^{71}\text{Ga}$ (atomic mass 70.93) atoms.

What is the atomic mass of gallium?
Solution

\[ \text{Atomic mass Ga} = 69.72 \text{ amu} \]

\[ \begin{align*}
\text{\(69\text{Ga}\)}
\quad & 68.93 \text{ amu} \times \frac{60.11}{100} = 41.43 \text{ amu} \quad \text{(from \(69\text{Ga}\))} \\
\text{\(71\text{Ga}\)}
\quad & 70.93 \text{ amu} \times \frac{39.89}{100} = 28.29 \text{ amu} \quad \text{(from \(71\text{Ga}\))}
\end{align*} \]
Learning Check

Using the periodic table, specify the average atomic mass of each element:

A. Calcium __________ 40.08 amu
B. Aluminum __________ 26.98 amu
C. Lead __________
D. Barium __________
E. Iron __________
Electrons

• Protons and Neutrons located in the nucleus.

• Electrons are located in the space surrounding the nucleus.
  – Is there any order to how the electrons are arranged?
    • YES
  – What is the significance of that arrangement?
Energy Levels

Energy levels

- Are assigned numbers $n$ = 1, 2, 3, 4 and so on.
- Increase in energy as $n$ increases.
- Are like the rungs of a ladder with the lower energy levels nearer the nucleus.
### Energy Levels

Energy levels
- Have a maximum number of electrons equal to $2n^2$.

<table>
<thead>
<tr>
<th>Energy level electrons</th>
<th>Maximum number of electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n = 1$</td>
<td>$2(1)^2 = 2(1) = 2$</td>
</tr>
<tr>
<td>$n = 2$</td>
<td>$2(2)^2 = 2(4) = 8$</td>
</tr>
<tr>
<td>$n = 3$</td>
<td>$2(3)^2 = 2(9) = 18$</td>
</tr>
</tbody>
</table>
Valence Electrons

Valence electrons

• Determine the chemical properties of the elements.
• Are the electrons in the highest energy level.
• Are related to the Group number of the element.

Example: Phosphorus has 5 valence electrons

5 valence electrons

P Group 5A(15) 2, 8, 5
Groups and Valence Electrons

All the elements in a group have the same number of valence electrons.

Example: Elements in Group 2A(2) have two (2) valence electrons.

- Be $\quad 2, \ 2$
- Mg $\quad 2, \ 8, \ 2$
- Ca $\quad 2, \ 8, \ 8, \ 2$
- Sr $\quad 2, \ 8, \ 18, \ 8, \ 2$
### Periodic Table and Valence Electrons

<table>
<thead>
<tr>
<th>Representative Elements Group Numbers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>He</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>2,1</td>
<td>2,2</td>
<td>2,3</td>
<td>2,4</td>
<td>2,5</td>
<td>2,6</td>
</tr>
<tr>
<td></td>
<td>Na</td>
<td>Mg</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>S</td>
<td>Cl</td>
<td>Ar</td>
</tr>
<tr>
<td></td>
<td>2,8,1</td>
<td>2,8,2</td>
<td>2,8,3</td>
<td>2,8,4</td>
<td>2,8,5</td>
<td>2,8,6</td>
<td>2,8,7</td>
<td>2,8,8</td>
</tr>
</tbody>
</table>
Learning Check

State the number of valence electrons for each:

1. O
   A) 4  B) 6  C) 8

2. Al
   A) 13  B) 3  C) 1

3. Cl
   A) 2  B) 5  C) 7
Learning Check

State the number of valence electrons for each.

1. Calcium
   A) 1   B) 2   C) 3

2. Group 6A (16)
   A) 2   B) 4   C) 6

3. Carbon
   A) 2   B) 4   C) 14
Electron-Dot Symbols

An electron-dot symbol
- Shows the valence electrons around the symbol of the element.
- For Mg has two valence electrons placed as single dots on the sides of the symbol Mg.

\[ \text{Mg} \cdot \text{or} \quad \text{Mg} \cdot \text{or} \quad \text{Mg} \cdot \text{or} \quad \text{Mg} \cdot \]

or \[ \text{Mg} \cdot \quad \text{or} \quad \text{Mg} \cdot \]

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Chapter 4 – Slide 78 of 86
Writing Electron-Dot Symbols

Electron-dot symbols for
- Groups 1A(1) to 4A(14) use single dots.

Na • Mg • Al • C •

- Groups 5A(15) to 7A(17) use pairs and single dots.

P • O •
Groups and Electron-Dot Symbols

- In a group, all the electron-dot symbols have the same number of valence electrons (dots).

Example: Atoms of elements in Group 2A(2) each have 2 valence electrons.

• Be
• Mg
• Ca
• Sr
• Ba
## Periodic Table and Electron-Dot Symbols

Table 4.12  Electron-Dot Symbols for Representative Elements in Periods 1–4

<table>
<thead>
<tr>
<th>Group Number</th>
<th>1A (1)</th>
<th>2A (2)</th>
<th>3A (13)</th>
<th>4A (14)</th>
<th>5A (15)</th>
<th>6A (16)</th>
<th>7A (17)</th>
<th>8A (18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence Electrons</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>H·</td>
<td>Li·</td>
<td>Be·</td>
<td>B·</td>
<td>C·</td>
<td>N·</td>
<td>O:</td>
<td>F·</td>
<td>He·</td>
</tr>
<tr>
<td>Na·</td>
<td>Mg·</td>
<td>Al·</td>
<td>Si·</td>
<td>P·</td>
<td>S·</td>
<td>Cl·</td>
<td>Ar·</td>
<td></td>
</tr>
<tr>
<td>K·</td>
<td>Ca·</td>
<td>Ga·</td>
<td>Ge·</td>
<td>As·</td>
<td>Se·</td>
<td>Br·</td>
<td>Kr·</td>
<td></td>
</tr>
</tbody>
</table>
Learning Check

A. $X$ is the electron-dot symbol for
   1) Na  2) K  3) Al

B. $X$ is the electron-dot symbol of
   1) B  2) N  3) P
Ionization Energy

Ionization energy

- Is the energy it takes to remove a valence electron.

\[ \text{Na}(g) \quad + \quad \text{Energy (ionization)} \quad \rightarrow \quad \text{Na}^+(g) \quad + \quad \text{e}^- \]
Ionization Energy In a Group

Going up a group of representative elements,

• The distance decreases between the nucleus and the valence electrons.

• The ionization energy increases.
Learning Check

Select the element in each pair with the higher ionization energy.

A. Li or K
B. K or Br
C. P or Cl