Some atoms prefer to stay by themselves.  
  e.g. Aluminum is Al.  
  Iron is Fe.  
  Helium is He.  

Some atoms join other atoms by “covalent bonds”.  
  e.g. Hydrogen gas is H₂.  
  Oxygen gas is O₂.  
  Nitrogen gas is N₂.  
  Phosphorus is P₄.  
  Sulfur is S₈.  

Some atoms join with other atoms of other elements.  
  e.g. Water is H₂O.  
  Carbon dioxide is CO₂.  
  Carbon monoxide is CO.  

Some atoms are charged, and when they join together, 
they form ionic compounds.  
  e.g. Sodium chloride is NaCl.  
  Magnesium bromide is MgBr₂.  

Some atoms are charged:  
  + atoms are called cations.  
  – atoms are called anions.  
Cations and anions are attracted to each other by electrostatic attraction. (Unlike charges attract.)  
An ionic bond is the electrostatic attraction between cations and anions, forming ionic compounds.  
  e.g. Table salt is Na⁺ Cl⁻, an ionic compound, not a molecule.  

When atoms join together, they form either molecules or ionic compounds, 
depending on whether they are joined by covalent bonds or ionic bonds.  

When atoms join together by covalent bonds, they form “molecules”.  
When atoms join together by ionic bonds, they form “ionic compounds”.  

Review for yourself:  
There are 2 forms of elements: atomic and molecular. (How do we know in which form an element exists?)  
(See Nomenclature Tutorial, Unit II at my website)  

There are 2 forms of compounds: molecular and ionic. (How do we know in which form a compound exists?)  

Learn this well!  

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>nonmetal + nonmetal</td>
<td>covalent molecule (covalent bond)</td>
</tr>
<tr>
<td></td>
<td>→ molecular compound (if diff.elements combine)</td>
</tr>
<tr>
<td>metal + nonmetal</td>
<td>ionic compound (ionic bond)</td>
</tr>
<tr>
<td>metal + metal</td>
<td>alloys (metallic bond, with no fixed ratio)</td>
</tr>
<tr>
<td></td>
<td>→ metallic substance, not a compound</td>
</tr>
</tbody>
</table>

Definitions:  
A molecule is made of 2 or more atoms (of the same or different element(s)), joined by covalent bonds.  
An ionic compound is made of 2 or more charged atoms, joined by ionic bonds.  

An element is a substance that cannot be chemically broken down further into simpler substances. It can exist as single atoms or as molecules.  
A compound is a substance made of 2 or more different elements, joined by covalent bonds (as in molecules) or by ionic bonds (as in ionic compounds).
Put a check mark ✓ if the substance belongs in this group. 
Put a cross mark X if the substance does NOT belong in this group.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Atom</th>
<th>Molecule</th>
<th>Element</th>
<th>Compound</th>
<th>Ionic Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>oxygen gas (O₂)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>water (H₂O)</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>table salt (NaCl)</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>aluminum foil (Al)</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Distinguishing Amongst Formula, Structural Formula and Empirical Formula**

A **formula** states which elements and how many atoms of each element are present (only).

- e.g. H₂O: (This tells us the molecule has **two** H atoms and **one** O atom.)
- H₂O₂: (This tells us the molecule has **two** H atoms and **two** O atoms.)

A **structural formula** tells us, in addition, the **arrangement** of the atoms in a molecule.

- e.g. H₂O: structural formula = H–O–H
- H₂O₂: structural formula = H–O–O–H

(You will learn how to determine the structural formula later in the semester, in Chapter 7.)

The formula, C₂H₆O, can have more than one **structural formula**:

- ethyl alcohol: \( \text{CH}_3\text{CH}_2\text{OH} \)
- dimethyl ether: \( \text{CH}_3\text{OCH}_3 \)

A **condensed structural formula** is a shorthand version of the **structural formula**:

- CH₃CH₂OH
- CH₃OCH₃

An **empirical formula** is the formula based on **empirical data** and can only give us the **lowest ratio of atoms of each element**. [Make sure you look up the meaning of the word, empirical, in a dictionary.]

For a molecular substance, the **formula** is also called a **molecular formula**, giving the actual number of atoms of each element in each molecule. Its subscripts when reduced to the lowest ratio is its **empirical formula**. The **molecular formula** is therefore some multiple of its **empirical formula**.

- e.g. Butane gas has the molecular formula C₄H₁₀.
- What kind of formula is shown below? Ans: structural formula

```
H  H  H  H
H–C–C–C–H
H  H  H
```

Its empirical formula is C₂H₅. Its condensed structural formula is \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \).

For an ionic compound, however, the **formula** always shows the lowest ratio. Thus, its **formula** is also its **empirical formula**. (MgBr₂ is the “formula” as well as the “empirical formula,” but it is not a “molecular formula” because MgBr₂ is not molecular.)