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- Atoms are made of protons, neutrons, and electrons.
- The number of protons in the nucleus of an atom is its atomic number ( $Z$ ).
- A neutral atom must contain the same number of positive and negative charges, so the number of protons equals the number of electrons.
- The total number of protons and neutrons in an atom is called its mass number ( $A$ ).

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Atomic number ( $Z$ ) = number of protons  
Mass number ( $A$ ) = number of protons + neutrons  
 $A - Z$  = number of neutrons

- Atoms are electrically neutral if they contain the same number of positively charged protons and negatively charged electrons.
- When the numbers of these subatomic particles are not equal, the atom is electrically charged and is called an **ion**.

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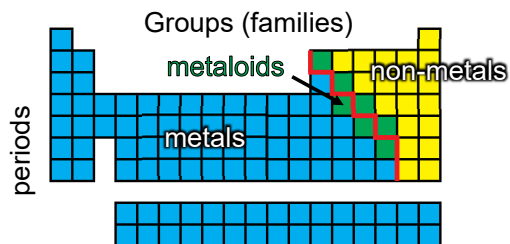
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- The periodic table arranges the elements in increasing order of their atomic numbers and groups atoms with similar properties in the same vertical column.




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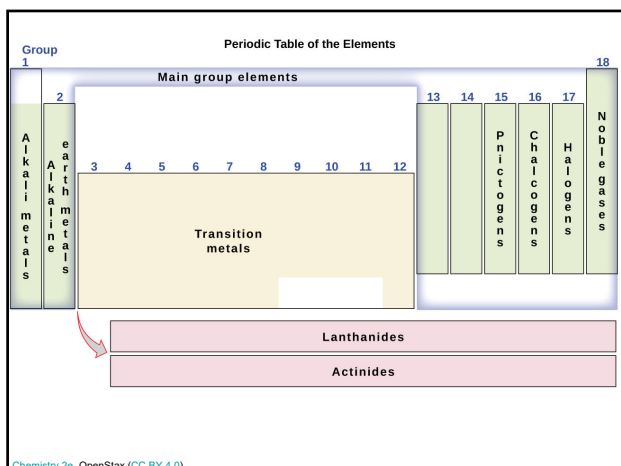
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Chemistry 2e, OpenStax (CC BY 4.0)

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- Atoms have a nucleus (containing protons and neutrons) surrounded by electrons.
  - The electrons exist at various energy levels.
- The electrons in the outermost energy level are called **valence electrons**.
  - For example, oxygen has a total of 8 electrons.
    - 2 in the first energy level
    - 6 in the second energy level
    - Therefore, oxygen has 6 valence electrons.
- The periodic table is designed such that elements in the same group have the same number of valence electrons.

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1	2	10	11	12	13	14	15	16	17	18								
1	H	He									He							
2	Li	Be									B	C	N	O	F	Ne		
3	Na	Mg									Al	Si	P	S	Cl	Ar		
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Og

Atomic No. → **H** ← Symbol  
 Name → Hydrogen  
 Valence Electron → **1**

Lanthanides: Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu  
 Actinides: Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr

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## Lewis Structures (Electron Dot Diagrams)

- A Lewis structure is a convenient shorthand way to represent an atom and its valence electrons.
- Dots are placed around the chemical symbol of an element to illustrate the valence electrons.

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## Drawing Lewis Structures

- Write the chemical symbol for the atom.
- Place dots around the outside representing the valence electrons.
  - The first 4 valence electrons are placed one on each side of the chemical symbol starting at the top and going clockwise.
  - The next 4 valence electrons are placed such that there are now two electrons on each side, again starting at the top and going clockwise.

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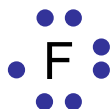
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- Draw the Lewis structure for magnesium.



- Draw the Lewis structure for fluorine.




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- The Lewis structure for the elements in the second period are as follows:




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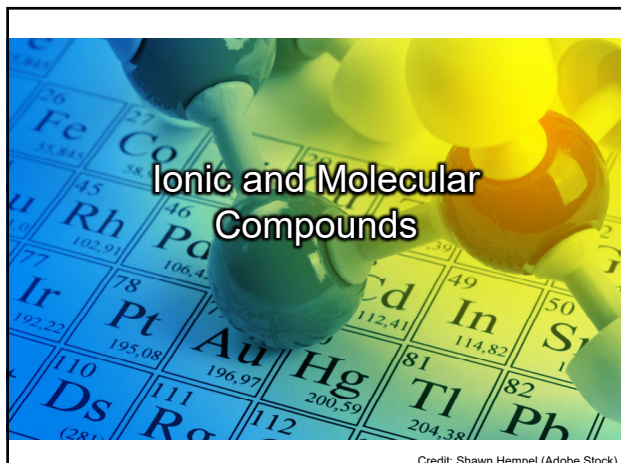
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## Ionic and Molecular Compounds

Credit: Shawn Hempel (Adobe Stock)

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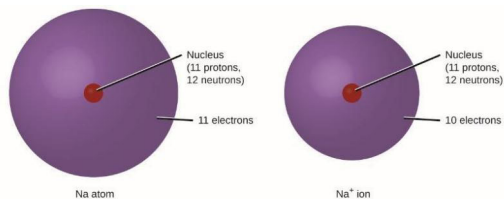
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- In ordinary chemical reactions, the nucleus of each atom (and thus the identity of the element) remains unchanged.
- During the formation of some compounds, atoms gain or lose electrons, and form electrically charged particles called **ions**.



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- You can use the periodic table to predict whether an atom will form an anion or a cation, and you can often predict the charge of the resulting ion.

- **Metals**

- **Lose** electrons
- Form **cations**
- **Positive (+)** charge

- **Non-Metals**

- **Gain** electrons
- Form **anions**
- **Negative (-)** charge

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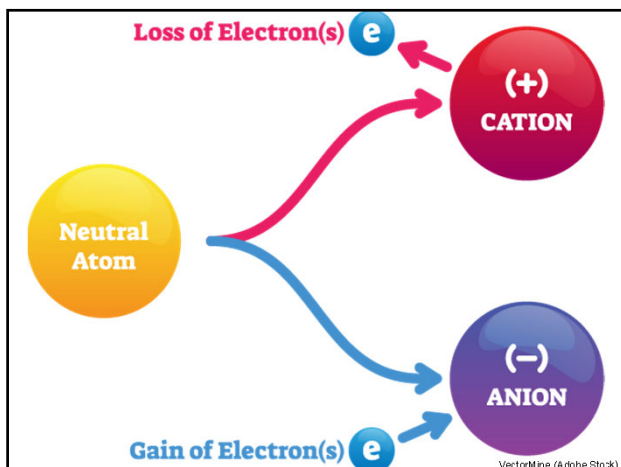
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- Most atoms lose or gain electrons to get 8 valence electrons.
- Atoms are most stable when they have 8 valence electrons.
- This is known as the **octet rule**.

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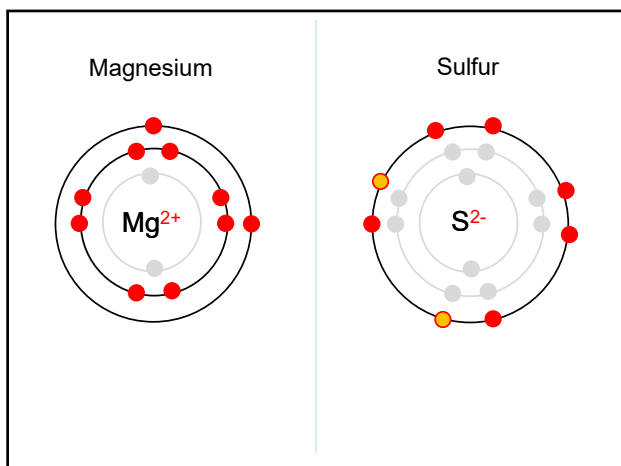
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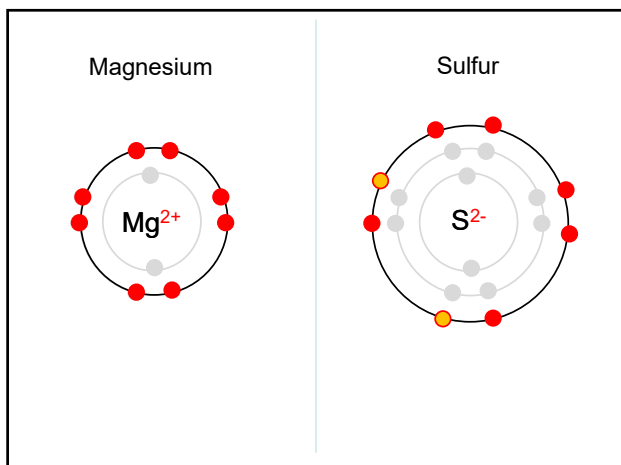
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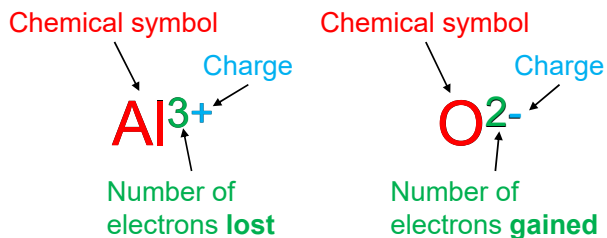


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- The symbol for an ion is the symbol for the element with the charge.



Note:

If the number of electrons lost or gained is 1, we only write the sign. Example: K<sup>+</sup>

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- Some elements exhibit a regular pattern of ionic charge when they form ions.

Periodic Table of the Elements

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Li <sup>+</sup>	Be <sup>2+</sup>																He
2	Na <sup>+</sup>	Mg <sup>2+</sup>											Al <sup>3+</sup>	C <sup>4-</sup>	N <sup>3-</sup>	O <sup>2-</sup>	F <sup>-</sup>	Ne
3	K <sup>+</sup>	Ca <sup>2+</sup>				Cr <sup>3+</sup> Cr <sup>6+</sup>	Mn <sup>2+</sup>	Fe <sup>2+</sup> Fe <sup>3+</sup>	Co <sup>2+</sup>	Ni <sup>2+</sup>	Cu <sup>+</sup> Cu <sup>2+</sup>	Zn <sup>2+</sup>			P <sup>3-</sup>	S <sup>2-</sup>	Cl <sup>-</sup>	Ar
4	Rb <sup>+</sup>	Sr <sup>2+</sup>													As <sup>3-</sup>	Se <sup>2-</sup>	Br <sup>-</sup>	Kr
5	Cs <sup>+</sup>	Ba <sup>2+</sup>									Pt <sup>2+</sup>	Ag <sup>+</sup> Cd <sup>2+</sup>			Te <sup>2-</sup>	I <sup>-</sup>	Xe	
6	Fr <sup>+</sup>	Ra <sup>2+</sup>									Au <sup>+</sup> Au <sup>3+</sup>	Hg <sup>2+</sup>				At <sup>-</sup>	Rn	

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- Cations are named by adding the word ion onto the name of the element.
  - Mg<sup>2+</sup> - magnesium ion
  - Na<sup>+</sup> - sodium ion
  - Al<sup>3+</sup> - aluminum ion
- Anions are named by adding the suffix "ide" to the first syllable of the element name.
  - N<sup>3-</sup> - nitride ion
  - O<sup>2-</sup> - oxide ion
  - Cl<sup>-</sup> - chloride ion

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- Ions formed from only one atom are called monatomic ions.
- There are also many polyatomic ions.
- These ions, which act as discrete units, are electrically charged molecules (a group of bonded atoms with an overall charge).
  - $\text{SO}_4^{2-}$  (sulfate)
  - $\text{OH}^-$  (hydroxide)
  - $\text{NO}_3^-$  (nitrate)

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### Example

- Magnesium and nitrogen 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.

$\text{Mg}^{2+}$	$\text{N}^{3-}$
cation	anion
magnesium ion	nitride ion

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### Noble Gases

- Noble gases (group 18) have 8 valance electrons.
  - Helium is an exception as it can only have 2 valance electrons.
- Noble gases usually do not form ions.

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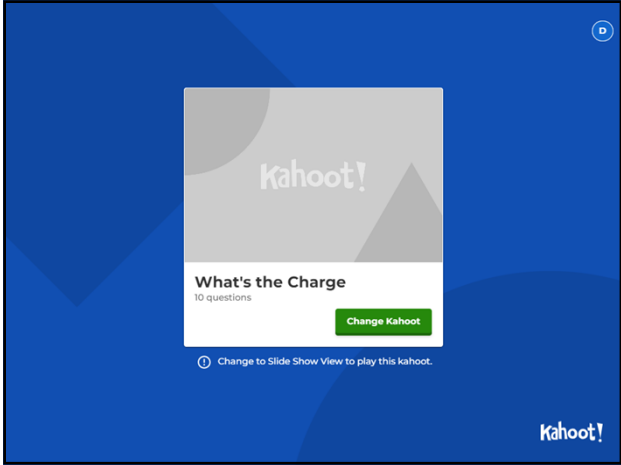
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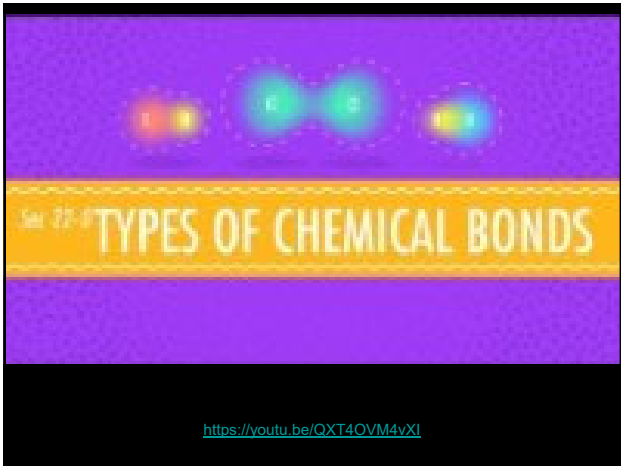
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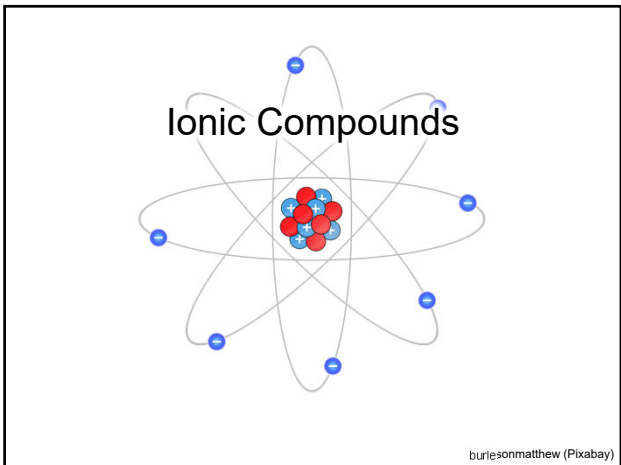
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- When an element composed of atoms that readily lose electrons (a metal) reacts with an element composed of atoms that readily gain electrons (a nonmetal), a transfer of electrons usually occurs, producing ions.
- The compound formed by this transfer is stabilized by the electrostatic attractions (ionic bonds) between the ions of opposite charge present in the compound.

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Example  
Sodium reacts with chlorine



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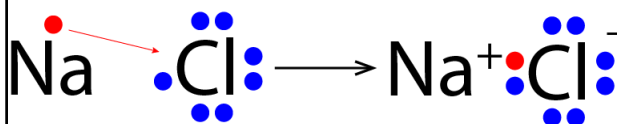
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Example  
Sodium reacts with chlorine



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- A compound that contains ions and is held together by ionic bonds is called an ionic compound.
- When a metal is combined with one or more nonmetals, the compound is usually ionic.
- You can often recognize ionic compounds because of their properties.
  - Ionic compounds are solids that typically melt at high temperatures and boil at even higher temperatures.

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- In every ionic compound, the total number of positive charges of the cations equals the total number of negative charges of the anions.
- The formula of an ionic compound must have a ratio of ions such that the numbers of positive and negative charges are equal.

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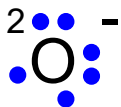
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Example

Sodium reacts with oxygen



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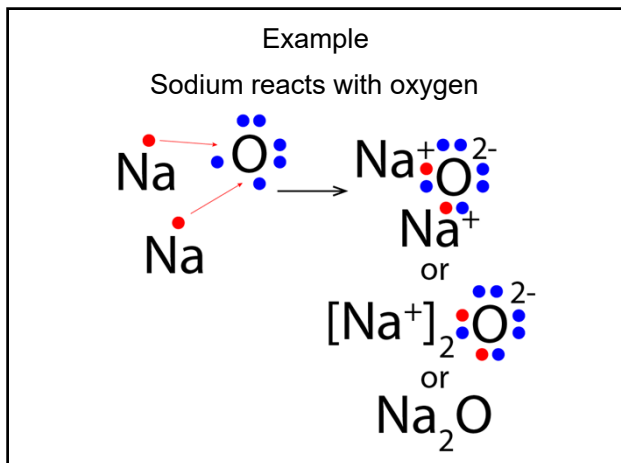
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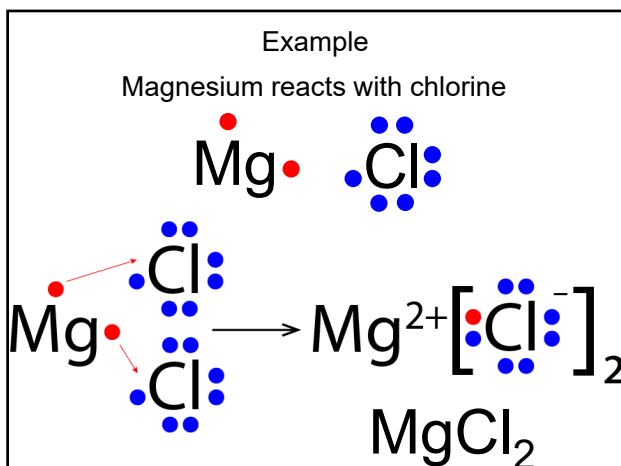
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- Many ionic compounds contain polyatomic ions as the cation, the anion, or both.
- These compounds must be electrically neutral, so their formulas can be predicted by treating the polyatomic ions as discrete units.
- We use parentheses in a formula to indicate a group of atoms that behave as a unit.

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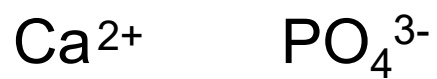
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Example

Calcium reacts with phosphate



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Predict the formula for the ionic compound formed between

sodium and sulfur.



calcium and oxygen.



potassium and iodine.



magnesium and the sulfate ion ( $\text{SO}_4^{2-}$ ).



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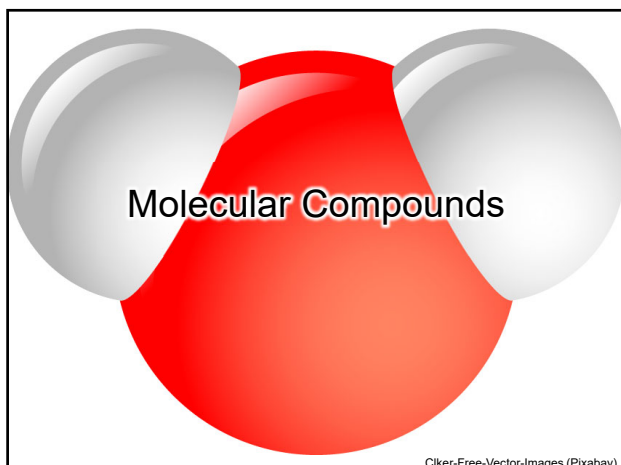
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- Many compounds do not contain ions but instead consist solely of discrete, neutral molecules.
- These molecular compounds (covalent compounds) result when atoms share electrons.
  - Each pair of shared electrons is referred to as a bond.
- Molecular compounds are usually formed by a combination of nonmetals.

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- We can often identify molecular compounds based on their physical properties.
  - Under normal conditions, molecular compounds often exist as gases, low-boiling liquids, and low-melting solids.

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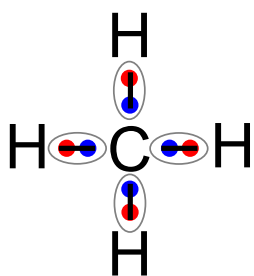
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Example



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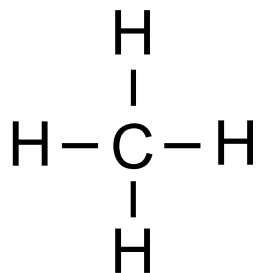
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Example



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## Diatomic Molecules

- A diatomic molecule consists of two of the same non-metal atoms.
  - Electrons are shared between the two atoms.
- Seven elements exist naturally as diatomic molecules.
  - $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{F}_2$ ,  $\text{Cl}_2$ ,  $\text{Br}_2$ ,  $\text{I}_2$ ,  $\text{H}_2$

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Are the following ionic or molecular compounds?

KI	ionic
$\text{H}_2\text{O}_2$	molecular
$\text{CHCl}_3$	molecular
$\text{Li}_2\text{CO}_3$	ionic
$\text{SO}_2$	molecular
$\text{CaF}_2$	ionic
$\text{N}_2\text{H}_2$	molecular
$\text{Al}_2(\text{SO}_4)_3$	ionic

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