

How Elements Form Compounds

Textbook Reference: 5.6 – 5.8, pages 188 – 194

Review of Section 5.5

In the modern Periodic Table the elements are arranged in order of increasing _____.

The elements are arranged in groups and periods.

The **vertical columns** on the periodic table are called _____, and sometimes also called _____.

Elements in the same _____ have similar chemical properties, because they have the _____ number of _____ in the outermost shell/orbit.

The electrons in the outermost shell are called _____.

The Roman numeral of the group, i.e. the group number equals the number of _____.

The chemical reactivity of an element is determined by the number of _____.

The **horizontal rows** on the periodic table are known as _____.

Each period represents an _____ or an _____ in the Bohr model and an energy level in the Quantum model of the atom.

All atoms want to become chemically / structurally stable.

An atom achieves this stability when it has a complete or a filled “outer shell,” i.e. it has **8** valence electrons, this is sometimes called an _____.

The Noble Gases (i.e. Group _____) have eight valence electrons, and are therefore chemically unreactive or _____.

(In 1962, Neil Bartlett, of the University of British Columbia produced the first noble gas compound containing xenon, platinum and fluorine, however since then a number of other noble gas compounds have also been prepared.)

The atoms of all other elements can only achieve this stability by:

1. _____ losing electrons: Groups IA, IIA, IIIA to become positively charged ions called _____,
2. _____ by gaining electrons: Groups VA, VIA, VIIA to become negatively charged ions called _____,
3. _____ by sharing electrons: Groups IVA.

Hydrogen can either gain, lose or share electron to fill its shell, to attain the stability of the Noble Gas helium.

Isoelectronic is the term used to describe atoms and ions that have the same number of electrons, (i.e. have the same energy level population).

Name 3 species that are isoelectronic with: (i) Na^{+1} _____
(ii) Cl^{-1} _____

5.6 Bonding Between Metals and Non-metals: Ionic Bonding

The electrons in the outermost energy level of an atom are the ones which participate in chemical bonding. These electrons are called _____.

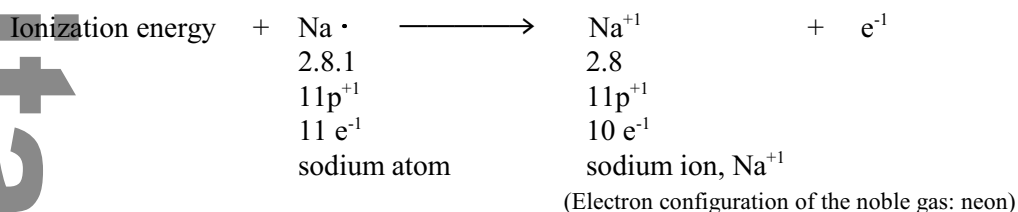
The number of valence electrons possessed by an atom determines the number of other atoms with which that atom can combine.

Thus sodium, $_{11}\text{Na}$, atomic number 11, has an electronic arrangement of _____, thus sodium has _____ valence electron.

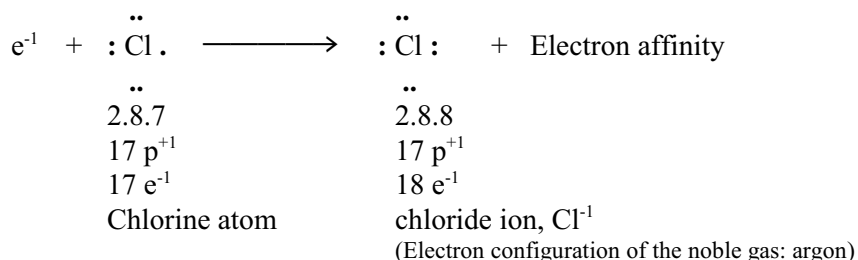
Chlorine, $_{17}\text{Cl}$, has an atomic number of 17, thus has an electronic arrangement of _____, thus chlorine has _____ valence electrons.

To illustrate the Bonding between Sodium and Chlorine

The sodium atom has an energy level population of 2.8.1 and could become isoelectronic, (i.e. have the same energy level population) as the noble gas neon, (2.8) by losing its valence electron to a chlorine atom:



The chlorine atom has an energy level population of 2.8.7 and could become isoelectronic (i.e. _____) as the noble gas argon, (2.8.8) by gaining one electron from the sodium atom:



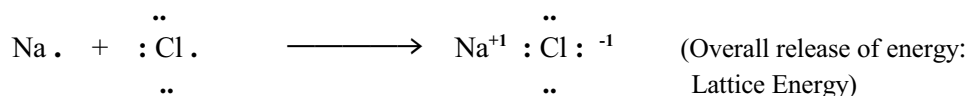
Now, both the sodium ion and the chloride ion have a stable octet of eight electrons in their outer shell and will show no further tendency to undergo chemical reaction.

The positive sodium ion, Na^{+1} and the negative chloride ion, Cl^{-1} produced attract one another, because they have opposite charges, and an **IONIC BOND** is formed.

The positively charged sodium ions and the negatively charged chloride ions are held together by 'electrostatic force of attraction'.

An ionic compound contains positive and negative ions in a ratio that make it electrically neutral.

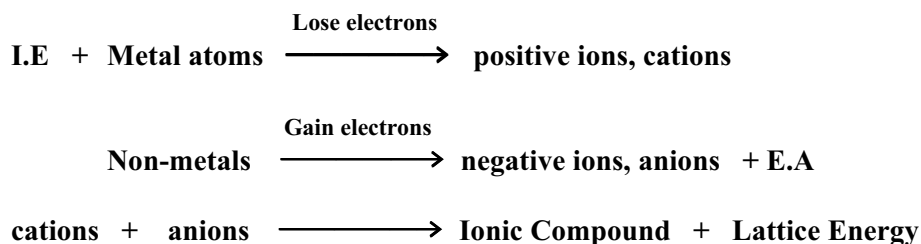
If we add these two processes together we get:



The **formula**: NaCl implies that the ratio of cation to anion is $1+ : 1-$
 NaCl would be named as: sodium chloride (metal _ non-metal- ide)

When metals react with non-metals they form ionic compounds.

Metal atoms and non-metal atoms are converted to their respective ions:



An ionic bond is the electrostatic attraction between oppositely charged ions. This attraction forms a giant crystal lattice structure, held by bonds created by the balance of electrical attraction and repulsion.

All crystal lattices are arranged so that the attractive forces between the opposite charges are maximized and the repulsive forces between ions of the same charge are minimized.

When an ionic bond is formed by electron transfer between a metal and a non-metal, all of the electrons _____ by the metal must be _____ by the non-metal.

When ionic bonds are formed, enough electrons must be transferred so that each ion produced is _____ with a noble gas,

The **alkali metals of Group IA** of the periodic table achieve a stable octet in the outer shell by _____ one electron to form a unit _____ ion, M^{+1} , (where M represents any Group IA metal); called a _____.

The **halogens in Group VIIA** of the periodic table achieve a stable octet in the outer shell by _____ one electron to form a unit _____ ion, X^{-1} , (where X represents any Group VIIA non-metal), called an _____.

To name an Ionic Binary Compound

A binary compound is a compound containing only two elements.

1. The **metal** is named **first** always.
 2. The non-metal's name is changed by adding the **suffix — IDE** to the name.
- (Note: no prefixes are used to illustrate the number of each element present.)

Anion	Suffix used for naming
F^{-1}	fluoride
Cl^{-1}	chloride
Br^{-1}	bromide
I^{-1}	iodide
O^{-2}	oxide
S^{-2}	sulphide
N^{-3}	nitride
P^{-3}	phosphide
H^{-1}	hydride

Answer the following:

1. (a) why does each lithium ion require one fluoride ion in the compound LiF?

b) Show the bonding when LiF is formed

c) name LiF

2.(a) Why does each rubidium ion require one bromide ion in the compound: RbBr.

(b) Name RbBr

To illustrate the bonding between magnesium and oxygen

A Group IIA metal, (aka: _____ metals), such as magnesium, $_{12}\text{Mg}$, has _____ valence electrons, electronic configuration: _____.

Magnesium can become isoelectronic with the noble gas _____, if it _____ valence electrons. (The energy required to lose electrons is called: _____.)

Oxygen atoms are in Group VIA, oxygen atoms, $_{8}\text{O}$ have the electronic configuration of _____. Oxygen atoms have _____ valence electrons.

Oxygen atoms would have to _____ electrons to become isoelectronic with the noble gas _____. (The gain of electrons results in the loss of energy called: _____.)

Hence, the ionic bonding between magnesium and oxygen could be represented as:

Hence, one magnesium atom could transfer _____ electrons to a single oxygen atom, and the ionic compound, **named** _____, with the **formula** _____ would form. The bonding of Mg with O results in the loss of energy: _____, hence a very stable ionic compound is formed.

Thus, **Group IIA** metals, (the alkaline- earth metals) have **two valence electrons** in their outer shell, and to achieve a stable octet of outer electrons they must **lose two electrons** to produce a dipositive ion, M^{+2} , where M represents any Group IIA metal.

To illustrate the bonding between magnesium and chlorine

Each magnesium atom transfers two valence electrons, each chlorine atom needs to gain one electron, thus _____ chlorine atoms will be required to accept the two electrons from the magnesium atom.

Each chlorine atom will accept _____ electron from the magnesium atom and will be isoelectronic with the noble gas _____.

Two _____ ions will be formed, and both will be attracted to the magnesium ion:

The formula of the compound will be _____, and the name of the compound will be _____.

Now, try to answer the following questions as true or false, if the answer is false, correct the statement:

A. When calcium combines with fluorine:

1. Each calcium atom gives up two electrons
2. Each fluorine atom receives two electrons
3. The product is an ionic bond
4. The product has an overall positive charge
5. The product contains an equal number of calcium ions and fluoride ions
6. The formula of the product is CaF
7. The name of the product is calcium difluoride.

Writing Formulas for Ionic Compounds Using the Cross-Over Rule: $M^{+a} X^{-b}$

Chemists obviously do not draw a Lewis diagram each time they want the chemical formula of the compound that contains a metal and a non-metal.

Chemists look for a shortcut.

The shortcut uses valences and is sometimes referred to as the “**Crossover Rule**”.

1. Write down the symbols of the elements (metal first)
2. Record the valence number for each element (as a superscript above the symbol of each element)
3. Crossover the valence numbers
4. Find the highest common factor to the two valences
5. Divide the valence numbers by the highest factor
6. Write the numbers as subscripts in the formula (do not write any “1” in the formula)

Examples:

1. $Al^{+3} N^{-3} \longrightarrow Al_3N_3 \longrightarrow AlN$ aluminium nitride
2. $Ba^{+2} O^{-2} \longrightarrow Ba_2O_2 \longrightarrow BaO$ Barium oxide

B. Now use the cross-over rule to predict the name and formula of the compound formed when:

	FORMULA	NAME
1. Magnesium reacts with sulphur	_____	_____
2. When barium reacts with bromine	_____	_____
3. When lithium reacts with nitrogen	_____	_____
4. When sodium reacts with sulphur	_____	_____
5. When potassium reacts with phosphorus	_____	_____
6. When aluminium reacts with oxygen	_____	_____
7. When gallium reacts with sulphur	_____	_____
8. Sodium reacts with carbon	_____	_____
9. When aluminium reacts with nitrogen	_____	_____
10. When strontium reacts with iodine	_____	_____

C. Give the chemical name for each of the following

1. Li_2S
2. CaO
3. Al_2S_3
4. K_3P
5. K_4C
6. BaI_2

D. Give the correct formula for each of the following:

1. Potassium sulphide
2. Barium nitride
3. Lithium iodide
4. Aluminium nitride
5. Magnesium bromide
6. radium chloride
7. Strontium phosphide
8. beryllium sulphide
9. Cesium fluoride
10. Rubidium sulphide
11. Francium oxide
12. Gallium sulphide

Can you see why metals react with non-metals but not with other metals.

Metals are keen to give up electrons when they react and non-metals are keen to gain these electrons.

Two metals cannot react with each other because they both want to lose electrons.

The two metals cannot come to any arrangement which satisfies both of them.

Now DO: Binary Compounds Drill Sheet I (See PAGE of the Notes)

Names and Formulas for Atoms with Variable oxidation states (valencies)

The atoms of some metals form more than one stable ion,

e.g. iron forms: Fe^{+2} and Fe^{+3} ,

tin forms: Sn^{+2} and Sn^{+4} .

copper forms: Cu^{+1} and Cu^{+2}

In such cases a **Roman numeral in parentheses**, (i.e. round brackets), is added immediately after the name of the element to indicate the oxidation number of the element.

Roman Numerals:	I	II	III	IV	V	VI	VII	VIII	IX	X
	1	2	3	4	5	6	7	8	9	10

This system of nomenclature is called the **Stock** system, (after the German chemist Alfred Stock, who first proposed it).

STOCK SYSTEM: The compounds are named as all other ionic compounds, except that a Roman Numeral is added in round brackets to indicate the oxidation state of the metal.

Example:

CuCl is copper (I) chloride, the oxidation state of copper is +1, whereas CuCl₂ is copper (II) chloride, since the oxidation state of copper is +2.

Example:

NiBr₂ Nickel (II) bromide NiBr₃ Nickel (III) bromide

Example:

FeO: Fe₂O₃

Note: Roman numerals are not used if the positive ion has only one possible oxidation number, for example, ions of elements in Group IA, Group IIA and Group IIIA.

An older method of naming such ions, referred to as the **Classical** method, in which the metals can have variable oxidation states uses the Latin name of the metal.

For the **lower oxidation number**, the suffix — **OUS** was added to the suffix of the name of the element.

For the ion of **higher oxidation number**, the suffix — **ic** was added.

Symbol	Name	Latin Name	Oxidation State	Classic Name
Cu	copper	cuprum	+1, +2	cuprous, cupric
Sn	tin	stannum	+2, +4	stannous, stannic
Au	gold	aurum	+1, +3	aurous, auric
Pb	lead	plumbum	+2, +4	
Sb	antimony	stibium		
Fe	iron	ferrum	+2, +3	
Hg	mercury	hydrargyrum	+1, +3	
As	arsenic	arsenic	+3, +5	

This system has two distinct disadvantages:

1. A given suffix does not consistently represent the same oxidation number, e.g. — ic stands for +3 in ferric but +4 in stannic ion.
2. The system has the disadvantage that it does not work at all for ions which may have more than two oxidation numbers, e.g. chromium can have oxidation numbers of +2, +3, and +6.

Because the classical system is still used by chemists, it is therefore necessary for you to learn it!!!

Now Do the following Assignment

A newly discovered metal, **M**, has an oxide of formula: **M₂O₃** .

- a. What is the oxidation number of **M** ? _____
- b. In which group of the periodic table does **M** belong? _____
- c. Give the formula of the ion formed by **M**. _____
- d. Give the formulae of the chloride and the sulphide of **M**. _____
- e. Is **M** a metal or a non-metal? Predict three physical properties for **M**.
1. _____ 2. _____ 3. _____
- f. Would you expect **M₂O₃** to be a solid, liquid or gas, justify your answer. _____
- g. Would you expect **M₂O₃** to be soluble in water? Justify your answer. _____
- h. **M** also forms a compound of the formula **M₂O₅**, Hence using both the stock and the classic system, name both **M₂O₃** and **M₂O₅**. (use the name: ottawium to represent M)

Binary Compound Drill Sheet: I

Binary Compounds containing only two types of elements. Always use the suffix “ide”. (Except for binary acids, which we will study later.)

1. Write the IUPAC chemical names for the following compounds

- a. NaCl
- b. K_2O
- c. ZnS
- d. MgO
- e. $BeBr_2$
- f. Al_2O_3
- g. Ca_2F
- h. KBr
- i. ZnI_2
- j. LiCl
- k. Ag_3N

2. Write the chemical formula of the following compounds. (Hint: using the cross-over rule.)

- a. Potassium bromide
- b. Sodium oxide
- c. Calcium chloride
- d. Potassium phosphide
- e. Lithium iodide
- f. Hydrogen sulfide
- g. Beryllium nitride
- h. Rubidium fluoride
- i. Sodium carbide
- j. Potassium sulfide
- k. Strontium hydride
- l. beryllium oxide
- m. calcium iodide
- n. Boron oxide
- o. Gallium bromide

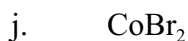
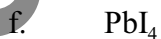
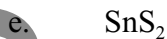
BINARY COMPOUND DRILL SHEET: II

- 1 Write the IUPAC chemical name for the following: Stock System: (IUPAC) use a Roman Numeral to represent the oxidation number of the first element (metal) in the compound.



2. Write the “IC” or “OUS” suffix chemical name of the following:

Note: The suffix “IC” is used for the higher oxidation number
The Suffix “OUS” is used for the lower oxidation number.



BINARY COMPOUND DRILL SHEET: III

1. Practice: Name each of the following. Where applicable, give both the Stock and the classical "ous - ic" names.

- a. ZnS
- b. Na₂O
- c. FeP
- d. Sb₂S₃
- e. FeCl₃
- f. Sb₂O₃
- g. CaCl₂
- h. BaO
- i. CuBr₂
- j. Hg₂O
- k. HgCl₂
- l. Cu₂O
- m. AuBr₃
- n. Sb₂S₃
- o. As₂O₃
- p. As₂O₅
- q. SnCl₄
- r. SnO
- s. MnO
- t. MnO₂
- u. PbO
- v. PbO₂
- w. SbCl₅
- x. SbCl₅

2. Write the formulas for the following compounds:

- | | | | |
|--------------------------|-------|------------------------|-------|
| 1. Iron (II) chloride | _____ | 2. Tin (II) iodide | _____ |
| 3. Vanadium (II) bromide | _____ | 4. Ferric sulphide | _____ |
| 5. Stannic bromide | _____ | 6. auric chloride | _____ |
| 7. Mercuric chloride | _____ | 8. Plumbic iodide | _____ |
| 9. Ferric phosphide | _____ | 10. Beryllium fluoride | _____ |
| 11. Sodium nitride | _____ | 12. Calcium oxide | _____ |
| 13. Beryllium oxide | _____ | 14. Calcium nitride | _____ |
| 15. Nickel (III) carbide | _____ | 16. Manganese(IV)oxide | _____ |
| 17. Vanadium (V) oxide | _____ | 18. stannous fluoride | _____ |
| 19. Cobaltic sulphide | _____ | 20. Cuprous bromide | _____ |