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Chapter 7 – Ionic and Metallic Bonding

Section 7.1 – Ions

1. Valence electrons – electrons in the highest occupied energy level of an element's atoms
   a. The number of valence electrons largely determines the chemical properties of an element
   b. Valence electrons are usually the only electrons involved in chemical bonds / chemical reactions
   c. To determine the number of electrons:
      i. Group 1 – 1 valence electron
      ii. Group 2 – 2 valence electrons
      iii. Group 13 – 3 valence electrons
      iv. Group 14 – 4 valence electrons
      v. Group 15 – 5 valence electrons
      vi. Group 16 – 6 valence electrons
      vii. Group 17 – 7 valence electrons
      viii. Group 18 – 8 valence electrons

      Subtract 10 from the group number

         1. Except Helium only has 2 electrons
      ix. In the d or f block, look at electron configuration (or noble gas configuration)
         1. Look at the number of electrons in the highest energy orbital:
            a. Vanadium [Ar]$4s^2 3d^3$
               i. 2 valence electrons
            b. Platinum [Xe]$6s^1 5d^9 4f^{14}$
               i. 1 valence electron
2. Electron dot structures are diagrams that show valence electrons in atoms of an element as dots
3. Lewis Dot Structures
   a. In 1916, Gilbert Lewis described the Octet Rule, which refers to having 8 valence electrons.

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b. Electron Dot structures can also be referred to as Lewis Structures or Lewis Dot Structures.

Period	Group 1	2	13	14	15	16	17	18
1	H·							He:
2	Li·	·Be·	·B·	·C·	·N·	:O·	:F·	:Ne:
3	Na·	·Mg·	·Al·	·Si·	·P·	:S·	:Cl·	:Ar:
4	K·	·Ca·	·Ga·	·Ge·	·As·	:Se·	:Br·	:Kr:

4. Octet Rule
   a. Atoms are stable when they have 8 valence electrons
   b. When forming compounds, atoms tend to achieve the electron configuration of a noble gas
5. Atoms and Ions
   a. An atom is neutral because it has equal numbers of protons and electrons
   b. An ion forms when an atom or group of atoms gains or loses electrons
      i. Cations are positively charged ions.
         1. They are produced when an atom loses one or more valence electrons.
      ii. Anions are negatively charged ions
         1. They are produced when an atom gains one or more valence electrons.
6. Cations
   a. Group 1 Cations
      i. Atoms in Group 1 lose their 1 valence electron and are left with an octet of electrons in what is now their highest occupied energy level

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1. Sodium
   a. Na $1s^2 2s^2 2p^6 3s^1$ 1 valence electron
2. Sodium Cation
   a. Na^{+1} $1s^2 2s^2 2p^6$ 8 valence electrons
      i. Same configuration as Neon, a noble gas

ii. Group 1 ions always have a charge of +1

b. Group 2 Cations
   i. Atoms in Group 2 lose their 2 valence electrons
      1. Magnesium
         a. Mg $1s^2 2s^2 2p^6 3s^2$ 2 valence electrons
      2. Magnesium Cation
         a. Mg^{+2} $1s^2 2s^2 2p^6$ 8 valence electrons
            i. Same configuration as Neon, a noble gas
   ii. Group 2 ions always have a charge of +2

c. Transition Metal Cations
   i. The charges of cations of the transition metals may Vary.
      1. Fe^{+2} and Fe^{+3} are both possible iron cations Fe^{2+}

d. Group 13 Cations
   i. Atoms in Group 13 lose their 3 valence electrons
      1. Aluminum
         a. Al $1s^2 2s^2 2p^6 3s^2 3p^1$ 3 valence electrons
      2. Aluminum Cation
         a. Al^{+3} $1s^2 2s^2 2p^6$ 8 valence electrons
            i. Same configuration as Neon, a noble gas

e. Cations with charges of +3 or greater are uncommon

7. Anions are produced when an atom gains one or more valence electrons.
   a. Names of an anion typically end in -ide
      i. Examples: can also be written
         1. Chlorine becomes chloride (Cl^{-1}) Cl^-
         2. Oxygen becomes oxide (O^{-2}) O^{2-}
         3. Nitrogen becomes nitride (N^{-3}) N^{3-}

b. Atoms of nonmetals and metalloids form anions by gaining enough valence electrons to attain the electron configuration of the nearest noble gas.

8. Anions

a. Group 17 Anions

i. Group 17 atoms are known as Halogens

ii. Group 17 anions are called Halide Ions

1. All halogen atoms have 7 valence electrons and need to gain only 1 electron to achieve the electron configuration of a noble gas.

iii. Atoms in Group 17 gain one valence electron

1. Fluorine

a. F $1s^2 2s^2 2p^5$ 7 valence electrons

2. Fluoride

a. F^{-1} $1s^2 2s^2 2p^6$ 8 valence electrons

i. Same configuration as Neon, a noble gas

iv. Group 17 ions have a charge of -1

b. Group 16 Anions

i. Atoms in Group 16 gain 2 valence electrons

1. Oxygen

a. O $1s^2 2s^2 2p^4$ 6 valence electrons

2. Oxide

a. O^{-2} $1s^2 2s^2 2p^6$ 8 valence electrons

i. Same configuration as Neon, a noble gas

ii. Group 16 ions have a charge of -2

c. Group 15 Anions

i. Atoms in Group 15 gain 3 valence electrons

1. Nitrogen

a. N $1s^2 2s^2 2p^3$ 5 valence electrons

2. Nitride

a. N^{-3} $1s^2 2s^2 2p^6$ 8 valence electrons

i. Same configuration as Neon, a noble gas

ii. Group 15 ions have a charge of -3

d. Anions with charges of -3 or greater are uncommon

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Section 7.2 – Formation of Ionic Compounds

9. Ionic compound – compound composed of cations and anions

   a. Although they are composed of ions, ionic compounds are electrically neutral

      i. The total positive charge of the cations equals the total negative charge of the anions

   b. Anions and cations have opposite charges and attract one another by means of electrostatic forces

      i. The electrostatic forces that hold ions together in ionic compounds are called ionic bonds

   c. Ionic compound example:

      i. Sodium chloride

         1. Na Cl

Before

$$\mathrm{Na}\cdot \qquad \cdot\ddot{\underset{\cdot\cdot}{\mathrm{Cl}}}: \longrightarrow \mathrm{Na}^{+} \qquad :\ddot{\underset{\cdot\cdot}{\mathrm{Cl}}}:^{-}$$

After

$$1s^2 2s^2 2p^6 3s^1 \qquad 1s^2 2s^2 2p^6 3s^2 3p^5 \qquad 1s^2 \underbrace{2s^2 2p^6}_{\text{octet}} \qquad 1s^2 2s^2 2p^6 \underbrace{3s^2 3p^6}_{\text{octet}}$$

10. Formula Units – the formula unit shows the ratio of the atoms of each element in an ionic compound.

   a. Examples:

      i. Na Cl is the chemical formula for sodium chloride

         1. Ratio: For every 1 Na, there is 1 Cl.

      ii. $AlBr_3$ is the chemical formula for aluminum bromide

         1. Ratio: For every 1 Al, there are 3 Br

   b. Ionic compounds exist as collections of positively and negatively charged ions arranged in a repeating pattern

   c. A formula unit is the lowest whole number ratio of ions in an ionic compound

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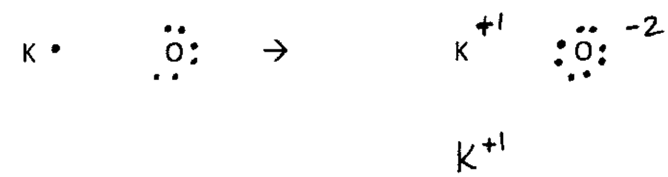
11. Predicting Formulas of Ionic Compounds

a. Potassium and oxygen

i. K Group 1 ___1___ valence electron

ii. O Group 16 ___6___ valence electrons

iii. Remember – overall charge of an ionic compound must equal ___0___



Two K

One O

Charges +1 +1 -2 = 0

$K^{+1}\ O^{-2}$

iv. Express the electron dot structure as a formula

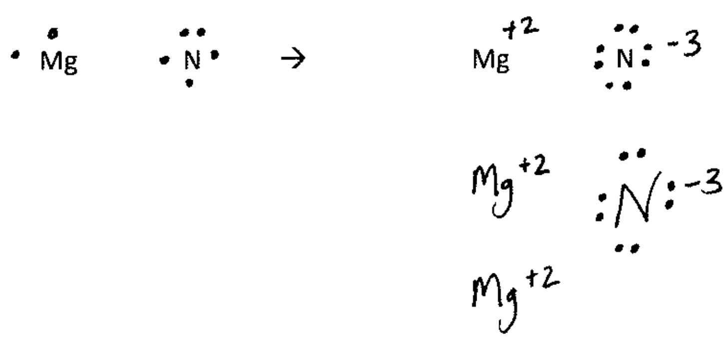
1. ___K_2O___, potassium oxide

b. Magnesium and nitrogen

i. Mg Group 2 ___2___ valence electrons

ii. N Group 15 ___5___ valence electrons

iii. Remember – overall charge of an ionic compound must equal ___0___



Three Mg

Two N

Charges +2 +2 +2 -3 -3 = 0

$Mg^{+2}\ N^{-3}$

iv. Express the electron dot structure as a formula

1. ___Mg_3N_2___, magnesium nitride

c. Calcium and fluoride

i. Ca Group 2 ___2___ valence electrons

ii. F Group 17 ___7___ valence electrons

iii. Remember – overall charge of an ionic compound must equal ___0___

• Ca • :F: → Ca^{+2} :F:$^{-1}$:F:$^{-1}$

One Ca
Two F

Charges $+2 -1 -1 = 0$

Ca^{+2} F^{-1}

iv. Express the electron dot structure as a formula

1. ___CaF_2___, calcium fluoride

12. ___Properties___ of Ionic Compounds

a. Most ionic compounds are ___crystalline___ ___solids___ at room temperature

i. The component ions are arranged in repeating ___3-Dimensional___ patterns

ii. Each ion is strongly ___attracted___ to each of its neighbors and ___repulsions___ are minimized

• opposites attract
• likes repel

+ − + −
− + − +
+ − + −

1. Each ___cation___ (+ ion) is surrounded by ___anions___ (- ions)

2. Each ___anion___ is surrounded by ___cations___

a. The large attractive forces result in a very ___Stable___ structure

b. Ionic compounds generally have ___high___ melting points

c. Ionic compounds can conduct an ___electric___ current when ___melted___ or ___dissolved___ in water

i. When dissolved, the ions are free to ___move___ about in the solution.

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d. Ionic compounds tend to be brittle

  i. If an ionic crystal is struck with a hammer, the blow tends to push the positive ions close together. The positive ions repel one another, and the crystal shatters.

e. Ionic compounds have a difference in electronegativities that is greater than ~~1.7~~ 2.0

  i. Ca and F
  1.0 4.0 $|1.0 - 4.0| = 3.0$ yes - Ionic

  ii. Li and Cl
  1.0 3.0 $|1.0 - 3.0| = 2.0$ yes - Ionic

  iii. K and O
  0.8 3.5 $|0.8 - 3.5| = 2.7$ yes - Ionic

Section 7.3 – Metallic Bonding

13. Metallic Bonds and Metallic Properties

  a. Metals consist of closely packed cations and loosely held valence electrons

  b. The valence electrons of atoms in a pure metal can be modeled as a sea of electrons

    i. The valence electrons are mobile and can drift freely from one part of the metal to another.

  c. Metallic bonds are the forces of attraction between the free-floating valence electrons and the positively charged metal ions. These bonds hold metals together.

14. Properties of Metals

  a. Metals are good conductors of electric current because electrons can flow freely in the metal

  b. Metals are ductile (can be drawn into wires) due to the mobile electrons

  c. Metals are malleable, which means they can be hammered or pressed into shapes, due to the mobile electrons

d. When a metal is subjected to pressure, the metal cations easily ___slide___ past one another

15. Alloys

a. Alloys are ___mixtures___ of two or more elements, at least one of which is a ___metal___

i. ___Brass___ – alloy of copper and zinc

ii. ___Bronze___ – copper and tin

b. Alloys are important because their properties are often superior to those of their component elements

i. ___Sterling___ ___silver___ – 92.5% silver and 7.5% copper.

1. Harder and more durable than pure silver, yet still soft enough to be made into jewelry and tableware

ii. ___Cast___ ___iron___ – 96% iron and 4% carbon

c. The most important alloys today are ___steels___

i. Most steels contain iron and carbon and a mixture of boron, chromium, manganese, molybdenum, nickel, tungsten, and vanadium.

ii. ___Stainless___ ___Steel___ includes 80.6% iron, 18% chromium, 0.4% carbon, and 1% nickel

d. Alloys can form from their component atoms in different ways

i. ___Substitutional___ alloy – if the atoms of the components in an alloy are about the ___Same___ size, they can replace each other in the crystal

ii. ___Interstitial___ alloy – if the atomic sizes are quite ___different___, the smaller atoms can fit into the interstitial spaces (___interstices___) between the larger atoms