* = should be review from previous units!

Unit Six: Ionic & Metallic Bonding

	Learning Targets	Textbook Section:
	Determine the number of valence electrons in an atom of a representative element.	7.1
	Identify the atoms of elements that tend to lose and tend to gain electrons.	7.1
*	Describe how cations form.	7.1
*	Describe how anions form.	7.1
	Explain the electrical charge of an ionic compound.	7.2
	Describe three properties of ionic compounds.	7.2
*	Convert between the count and mass of a substance.	10.1
*	Determine the molar mass of an element and of a compound. (Gram Formula Mass)	10.1
*	Describe how to convert the mass of a substance to the number of moles of a substance, and moles to mass.	10.2
	Calculate the percent by mass of an element in a compound. (percent Composition)	10.3
	Calculate the empirical formula of a compound	10.3
	Distinguish between empirical and molecular formulas.	10.3

Suggested Reading:

Chapter 7 :
- Section 7.1 (pages 192-199)
- Section 7.2 (pages 201-207)
- Section 7.3 (pages 209-212)

Chapter 10:
- Section 10.1 (pages 306-316)
- Section 10.2 (pages 317-324)
- Section 10.3 (pages 325-335)

End of Chapter Practice:

Chapter 7: 27, 28, 29, 30, 31, 32, 35, 36, 37, 38, 39, 40, 41, 43, 44, 45, 47, 49, 53, 55, 56, 58, 67

Chapter 10: 51, 52, 54, 57, 60, 61, 62, 63, 64, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77

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Valence Electrons

Mendeleev used similarities in the properties of elements to organize his periodic table. Scientists later learned that all of the elements within each group of the periodic table react in similar way because they have the same number of Valence electrons.

Valence electrons = The electrons in the highest occupied energy level of an elements atoms.

*The number of valence electrons largely determines the chemical properties of an element.

The number of valence electrons in an atom of an element is related to the element's group number in the periodic table. # = Group number

= # of valence electrons

1 1	2 2		3	4	5	6	7	8	9	10	11	12	3 13	4 14	5 15	6 16	7 17	8 18
1 H																		2 He
3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-70 *	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-102 **	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub		114 Uuq				

*Lanthanide series	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
**Actinide series	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Valence electrons are usually the only electrons involved in chemical bonds. Therefore, as a general rule, only the valence electrons are shown in electron dot structures.

Electron Dot Structures (Lewis Dot Structures)

↳ Diagrams that show valence electrons in atoms as dots.

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Practice Drawing Dot Structures:

Remember, noble gases are nonreactive in chemical reactions. That is, they are stable. In 1916, chemist Gilbert Lewis used this fact to explain why atoms form certain kinds of ions and molecules. He called his explanation the octet rule.

Octet Rule = States that in forming compounds, atoms tend to achieve electron configuration of noble gases.

An octet = a set of eight

Atoms of metals tend to ___lose___ their valence electrons, leaving a complete octet in the next-lowest energy level.

Atoms of nonmetals tend to ___gain___ their valence electrons with another nonmetal atom or atoms to achieve a complete octet.

Common Ions

Monatomic = one atom

- Representative elements typically have only one possible charge

Ca^{2+} Cl^-

Polyatomic = A charged group of bonded atoms.

- Act as one unit in an ionic bond.

NH_4^+ ← cation

OH^- ← anion

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Formation of Cations

Remember an atom is electrically neutral.

\# protons = # electrons

positive charges = negative charges

An ion forms when an atom or group of atoms lose or gains electrons.

Cations = A positively charged ion.

↓ produced when an atom loses one or more valence electrons.

$$Mg \xrightarrow{\text{loss of } 2e^-} Mg^{2+} + 2e^-$$

* The name of a cation is the same as the metal.

* Na = Sodium

* Na^+ = Sodium ion

Transition Metal Cations

The charges of cations of the transition metals may vary.

Iron (Fe)

- may lose 2 valence electrons → Fe^{2+}
- may lose 3 valence electrons → Fe^{3+}

Formation of Anions

An anion is an atom or group of atoms with a negative charge.

Anion = produced when an atom gains one or more valence electrons.

The name of an anion of a nonmetallic element is *not* the same as the element name.

* The name of an anion typically ends in -ide

- Chlorine → Cl^- = Chloride anion
- Oxygen → O^{2-} = oxide anion

Atoms of nonmetallic elements attain noble-gas electron configurations more easily by gaining electrons.

$$:\ddot{\underset{\cdot\cdot}{Cl}}\cdot + e^- \longrightarrow :\ddot{\underset{\cdot\cdot}{Cl}}:^-$$

The ions produced when atoms of halogens gain electrons are called halides.

F^-, Cl^-, Br^-, and I^- Group 17 = halogens

Stop and Review:

1. Explain how you can determine the number of valence electrons in an atom of a representative element?
   Look up the group number of that element.

2. How are cations formed?
   An atom loses valence electrons

3. How are anions formed?
   An atom gains valence electrons.

4. Atoms of which elements tend to gain electrons?
   Atoms of nonmetallic elements.
   ↳ nonmetals

5. Atoms of which elements tend to lose electrons?
   Atoms of metallic elements.
   ↳ metals

6. How many valence electrons are in each of the following atoms?

   a. potassium 1

   b. carbon 4

   c. magnesium 2

   d. oxygen 6

ers to...

Chemical Formula = Shows the numbers of atoms of each element in the smallest representative unit of a substance.

$NaCl$ $NaOH$ HCl

* Ionic compounds do not exist as single discrete units, but as collections of positively and negatively charged ions arranged in repeating patterns.

Formula Unit = The lowest whole-number ratio of ions in an ionic compound.

* For sodium chloride → ratio 1:1, Thus the formula unit is still $NaCl$. Mg Cl
* Magnesium chloride → ratio 1:2, $MgCl_2$

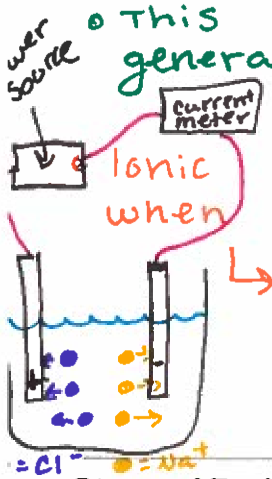
Properties of Ionic Compounds

Most ionic compounds are Crystalline solids at room temperature.

The component ions in such crystals are arranged in three-dimensional patterns. In solid sodium chloride, each sodium ion is surrounded by six chloride ions, and each chloride ion is surrounded by six sodium ions.

→ This arrangement allows for large attractive forces, which results in a very stable structure.

- This stability results in ionic compounds generally having high melting points.



Ionic compounds can conduct an electric current when melted or dissolved in water.

↳ when ions are free to move they allow electric current to flow between electrodes and through an external wire.

Stop and Review

1. How can you describe the electrical charge of an ionic compound?

   Electrically neutral

2. What properties characterize ionic compounds?
   - Solids at room temperature.
   - High melting points
   - conduct electric current when melted or dissolved in water.

3. How can you describe the arrangement of sodium ions and chloride ions in a crystal of sodium chloride?

   -

Contains positive ions and negative ions.

4. Why do ionic compounds conduct electric current when they are melted or dissolved in water?

ions are free to move.

5. Which pairs of elements are likely to form ionic compounds?

a. Cl, Br - Both are anions
b. Li, Cl Li^+ Cl^-
c. K, He - He = noble gas
d. I, Na Na^+ I^-

Metallic Bonds and Metallic Properties (SKIP)

Metals consist of closely packed cations and loosely held valence electrons. Valence electrons are mobile and can drift freely from one part of the metal to another. (The valence electrons can be modeled as a sea of electrons.)

Not Ionic Bonding

Metallic bonds= The forces of attraction between free floating valence electrons and the positively charged metal ions.

→ Hold metals together!

Properties of Metals

- Good conductors (free flowing electrons)
- Ductile (drawn into wire)
- Malleable (hammered or pressed into shapes)

* when a metal is subjected to pressure, the metal cations easily slide past one another.

Crystalline Structure of Metals - Due to "delocalized electrons"

- metal atoms are arranged in very compact and orderly patterns.

Ionic

- 3-D repeating pattern of (+) and (-) ions
  - → crystal lattice
  - Ionic solid

* When an ionic solid is subjected to pressure, the positive ions are pushed together. The positive ions repel, and the crystal shatters!

Hydrates

- A substance in which water is part of the crystal structure.
  - Feels dry to the touch
  - water is not "trapped"

Alloys

Everyday you use metallic items, such as utensils. However, very few of these objects are made out of a single kind of metal. Instead, most of the metals you encounter are alloys.

Alloys = mixtures of two or more elements, at least one of which is a metal.

Sterling Silver
- 92.5% silver and 7.5% copper
- harder and more durable than pure silver
- soft enough to made jewelry and silverware

Bronze
- seven parts copper to one part tin
- harder than copper and is easier to cast into molds

Steel
- Iron, carbon, boron, chromium, manganese, molybdenum, tungsten, and vanadium.
- corrosion resistance
- ductility
- hardness

Stainless Steel:
80.6% Fe
18.0% Cr
0.4% C
1.0% Ni

Stop and Review

1. How do chemists model the valence electrons of metal atoms?

metal cations surrounded by a sea of mobil electrons.

2. Why are alloys more useful than pure metals?

The properties of alloys are often superior to their component elements.

3. Why is it possible to bend metals but not ionic crystals?

under pressure, the cations in a metal slide past each other. The ions in ionic crystals are forced into each other by the rigid structure.

4. What is ~~a~~ hydrate?

A substance in which water is part of the crystal structure.

Gram Formula Mass

The mass (in grams) of 1 mols of an ionic compound.

- molar mass of an ionic compound.

Find the GFM of Fe_2O_3?

$$Fe = (55.85)(2) = 111.7$$
$$O = (16.00)(3) = 48.00$$
$$\boxed{159.7\ g\ Fe_2O_3}$$

Find the GFM of $(NH_4)_2S$?

$$N = (14.01)(2) = 28.02$$
$$H = (1.01)(8) = 8.08$$
$$S = (32.07)(1) = 32.07$$
$$\boxed{68.17\ g\ (NH_4)_2S}$$

Flashback → Mole Calculations!

What is the mass of 6.2 mol of $FeCl_3$?

$$6.2\ mol\ FeCl_3 \times \frac{162.2\ g\ FeCl_3}{1\ mol\ FeCl_3} = \cancel{996.4\ g}$$

1005.64

$\boxed{1.0 \times 10^3\ g\ FeCl_3}$

$\boxed{\cancel{976\ g\ FeCl_3}}$

$$Fe = (55.85)(1) = 55.85$$
$$Cl = (35.45)(3) = 106.35$$
$$162.2\ g$$

How many moles are there in 4.54 g $(NH_4)_2HPO_4$?

H: (9)(1.01) = 9.09
N: (2)(14.01) = 28.02
P: (1)(30.9) = 30.9
O: (4)(16.00) = 64.00
132.01

$$4.54\,\cancel{g}\,(NH_4)_2HPO_4 \times \frac{1\text{ mol }(NH_4)_2HPO_4}{132.01\,\cancel{g}\,(NH_4)_2HPO_4}$$

$$\boxed{0.0344\text{ mol }(NH_4)_2HPO_4}$$

Percent Composition
The relative amount of each element in a compound by mass.

$$\%\text{ Composition} = \left(\frac{\text{mass of element}}{\text{mass of compound}}\right) \times 100$$

Strategy:
1. Calculate GFM.
2. Determine mass of each element in 1 mole of the compound.
3. Calculate percent composition for each element.

Find the percent composition of $FeCl_3$.

Fe (1)(55.85) = 55.85
Cl (3)(35.45) = 106.35
162.20g

Fe = 55.85g
Cl = (3)(35.45) = 106.35g

$$\left(\frac{55.85\,\cancel{g}\text{ Fe}}{162.20\,\cancel{g}\,FeCl_3}\right) \times 100 = \boxed{34.43\%\text{ Fe}}$$

$$\left(\frac{106.35\,\cancel{g}\text{ Cl}}{162.20\,\cancel{g}\,FeCl_3}\right) \times 100 = \boxed{65.57\%\text{ Cl}}$$

Empirical Formula
Lowest whole number ratio of atoms in a compound.

Strategy:
1. Assume you have 100 g of the compound.
   a. Change all the percent compositions to grams.
2. Convert grams of each element to moles
3. Divide moles of each element by the smallest amount of moles.
4. Change the ratio to a whole number if necessary.
   a. You may need to multiply!
5. Write empirical formula.

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Find the empirical formula for each of the following.

1^{st} metal – 2^{nd} nonmetal

1. 26.8% F and 73.2% Pd

26.8% F → 26.8g F

73.2% Pd → 73.2g Pd

$26.8g\ F \times \frac{1\ mol}{19.00g\ F} = 1.41\ mol\ F$

$73.2g \times \frac{1\ mol}{106.42g\ Pd} = 0.688\ mol\ Pd$

$\frac{1.41}{0.688} = 2.05\,(F) \rightarrow 2$ $\quad \frac{0.688}{0.688} = 1\,(Pd)$

$\cancel{F_2Pd}$

$\boxed{PdF_2}$

2. 70.0% Mn and 30.0% O

70.0% Mn → 70.0g Mn

30.0% O → 30.0g O

$70.0g\ Mn \times \frac{1\ mol}{54.94g\ Mn} = 1.27\ mol\ Mn$

$30.0g\ O \times \frac{1\ mol}{16.00g\ O} = 1.88\ mol\ O$

$\frac{1.88}{1.27} = 1.48\,(O)$ → $1.5 \times 2 = 3$ $\quad \frac{1.27}{1.27} = 1\,(Mn)$ → $1 \times 2 = 2$

$\boxed{Mn_2O_3}$

3. 39.7% K, 27.9% Mn, and 32.4% O

39.7% K → 39.7g K

27.9% Mn → 27.9g Mn

32.4% O → 32.4g O

$39.7g\ K \times \frac{1\ mol}{39.10} = 1.02\ mol\ K$

$27.9g\ Mn \times \frac{1\ mol}{54.94g\ Mn} = 0.508\ mol\ Mn$

$32.4g\ O \times \frac{1\ mol}{16.00\ O} = 2.03\ mol\ O$

$\frac{1.02}{0.508} = 2.0\,(K)$ $\quad \frac{0.508}{0.508} = 1\,(Mn)$ $\quad \frac{2.03}{0.508} = 3.99\,(O) \rightarrow 4$

$\boxed{K_2MnO_4}$