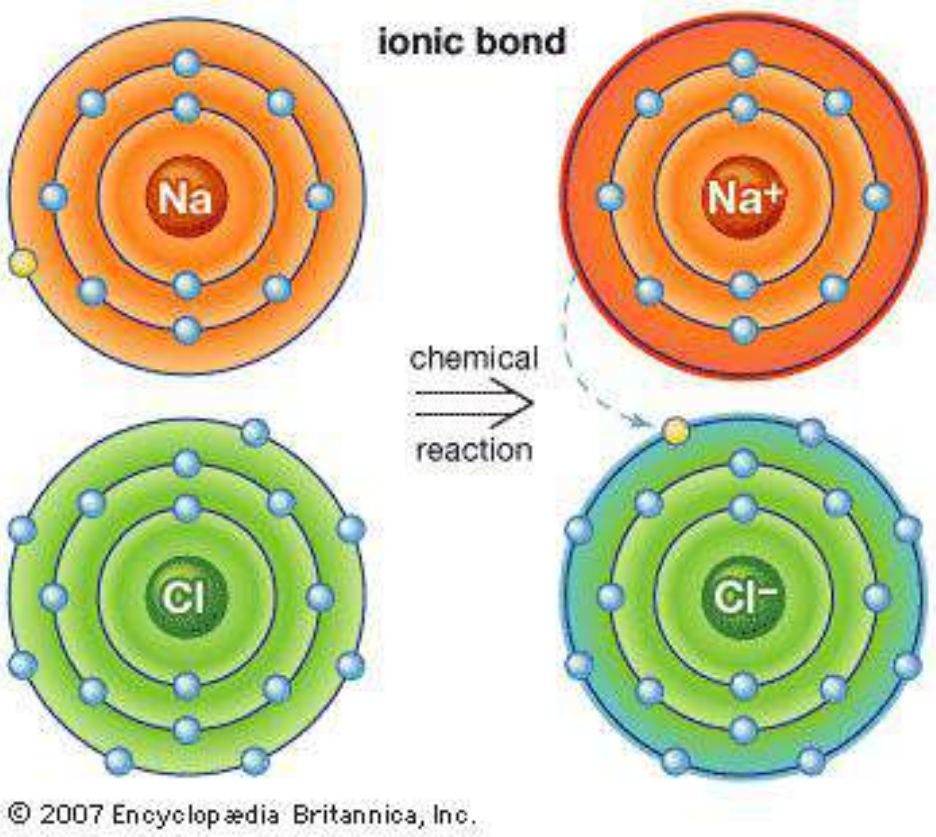
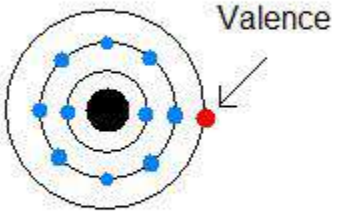
Chapter 7 – Ionic and Metallic Bonding



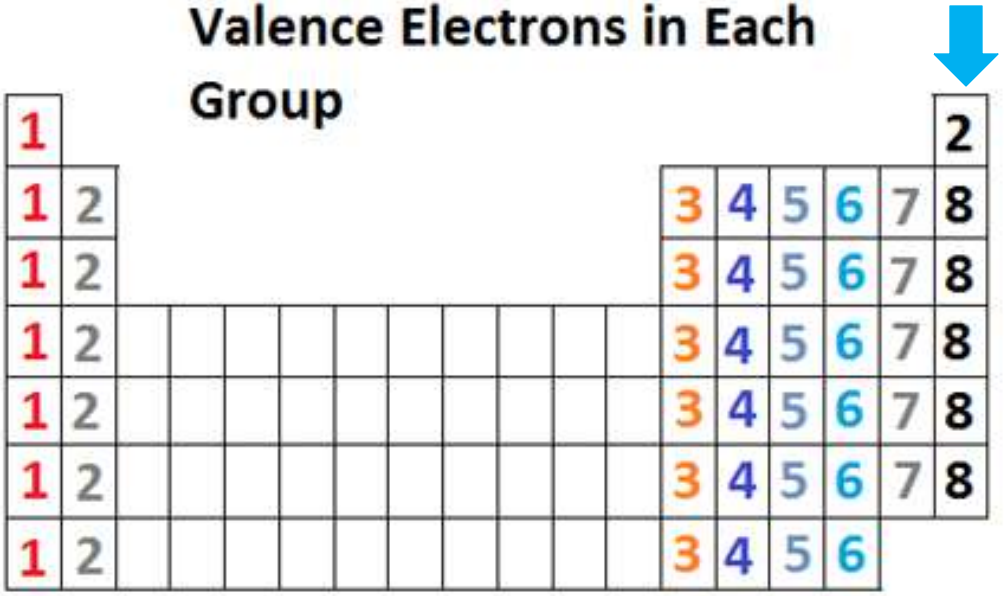
Jennie L. Borders

Section 7.1 - Ions

- Valence electrons are the electrons in the highest occupied energy level.
- Valence electrons are the only electrons involved in chemical bonding.
- Elements in the same group have the same number of valence electrons.

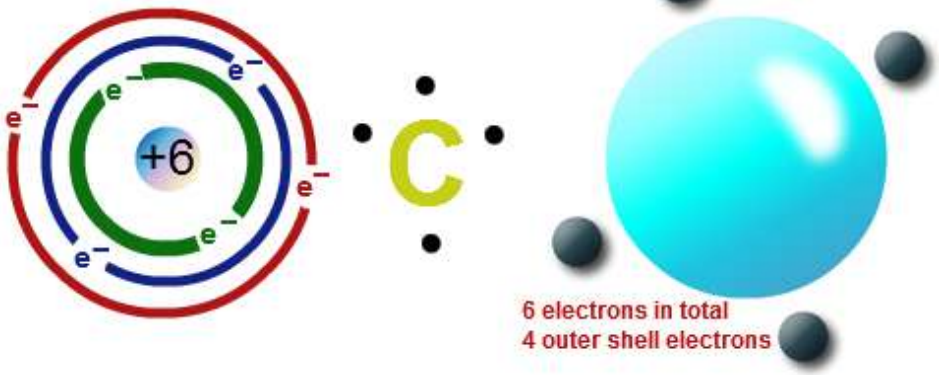


Rest are core electrons.



Electron Dot Structures

- Electron dot structures are diagrams that show the symbol of the element surrounded by the valence electrons as dots.



H•						He:
Li•	Be•	B•	•C•	•N:	•O:	:F:	:Ne:
Na•	Mg•	Al•	•Si•	•P:	•S:	:Cl:	:Ar:
K•	Ca•	Ga•	•Ge•	•As:	•Se:	:Br:	:Kr:
Rb•	Sr•	In•	•Sn•	•Sb:	•Te:	:I:	:Xe:
Cs•	Ba•	Tl•	•Pb•	•Bi:	•Po:	:At:	:Rn:
Fr•	Ra•						

Practice Problems

- Write the electron dot structure for the following elements:

P

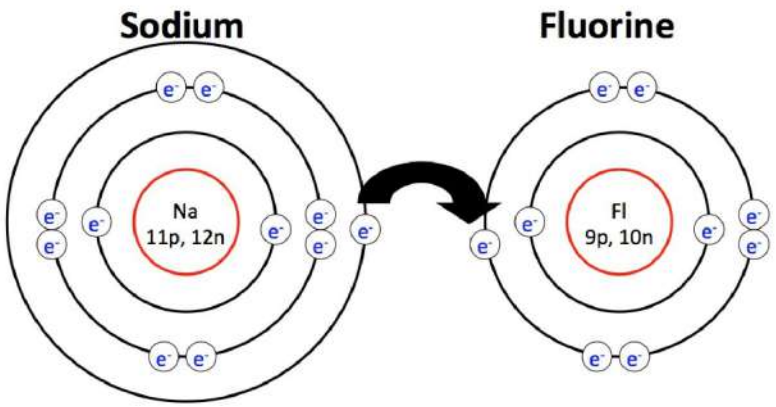
Ar

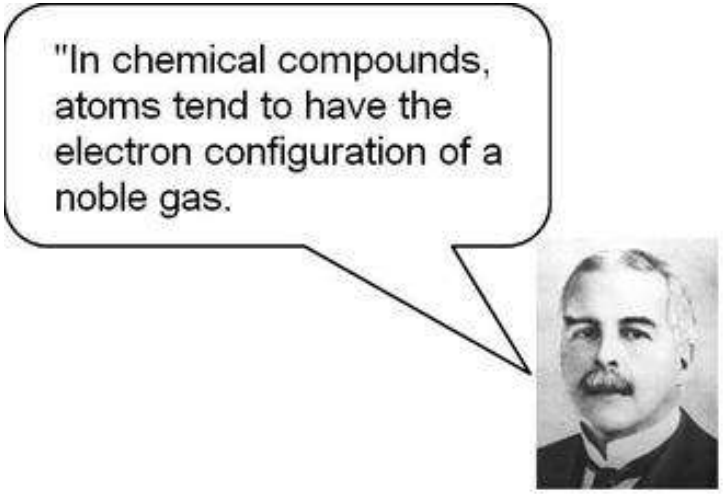
Mg

He

Octet Rule

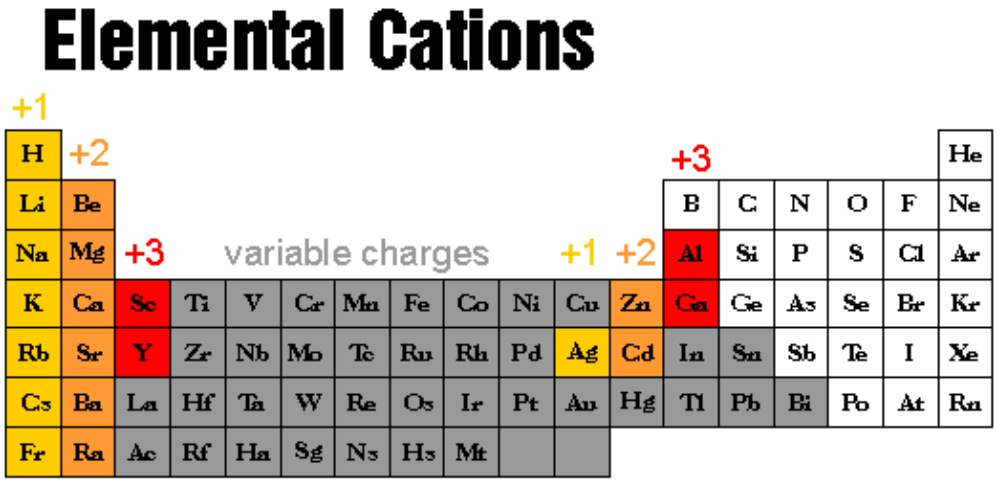
- The octet rule states that atoms tend to achieve a stable configuration when they have 8 valence electrons.
- An octet of electrons consists of full s and p sublevels.
- Metals tend to lose electrons to achieve noble-gas configuration. Nonmetals tend to gain electrons to achieve noble-gas configuration.
- Transition metals generally do no form ions that have a noble-gas configuration.





Cations

- A cation ion is a positive ion that has lost electrons.
- A loss of electrons from an atom is always an endothermic process (requires or absorbs energy).
- When writing the electron configuration for a cation, write the electron configuration for the atom and then subtract the electrons from the highest energy level.
- When you name a cation, the name of the element does not change. Ex: Ca^{+2} = calcium ion



Sample Problem

- Write the electron configuration and name for the following:
- Sr^{2+}
- Fe^{+3}

Practice Problems

- Write the electron configurations and the name for the following:
- Ga^{+3}
- Na^{+}

Anions

- Anions are negatively charged ions that have gained electrons.
- The gain of electrons is an exothermic process (loss or release of energy)
- When writing the electron configuration for anions, write the electron configuration for the atom and then add the correct number of electrons.
- When naming an anion, you change the ending of the element to –ide. Ex: Cl^- = chlor**ide** ion

Elemental Anions

		-3	-2	-1	He
B	C	N	O	F	Ne
Al	Si	P	S	Cl	Ar
Ga	Ge	As	Se	Br	Kr
In	Sn	Sb	Te	I	Xe
Tl	Pb	Bi	Po	At	Rn

Sample Problems

- Write the electron configuration and name for the following:
- P^{-3}
- F^{-}

Practice Problems

- Write the electron configuration and name for the following:
- Br^-
- S^{-2}

Sample Exercise

- Give the chemical symbol, including mass number, for each of the following ions:

  a. the ion with 22 protons, 26 neutrons, and 19 electrons

  b. the ion of sulfur that has 16 neutrons and 18 electrons

Practice Exercise

- How many protons, neutrons, and electrons does the $^{79}Se^{2-}$ ion possess?

Sample Exercise

- Predict the change expected for the most stable ion of barium and for the most stable ion of oxygen.

Practice Exercise

- Predict the charge expected for the most stable ion of aluminum and of fluorine.

Section 7.1 Assessment

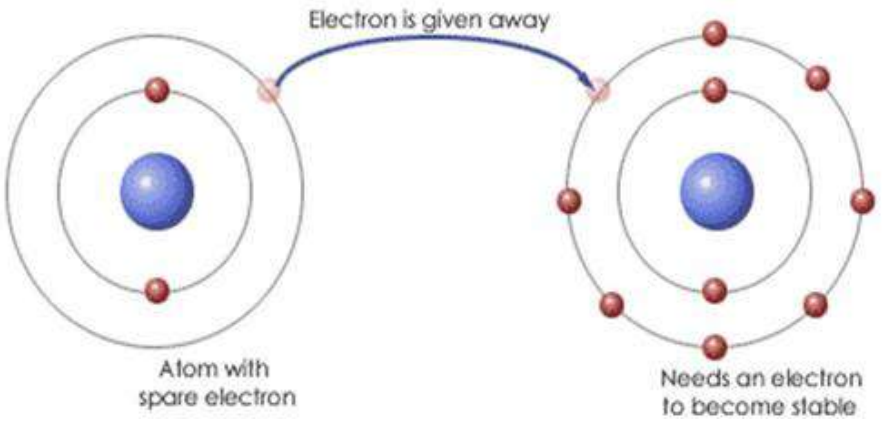
1. How can you determine the number of valence electrons in an atom of a representative element?
2. Atoms of which elements tend to gain electrons? Atoms of which elements tend to lose electrons?
3. How do cations form?
4. How do anions form?
5. How many valence electrons are in each atom?
    a. Potassium
    b. Carbon
    c. Magnesium
    d. Oxygen
6. Draw the electron dot structure for each element in question 5.

Section 7.1 Assessment

7. How many electrons will each element gain or lose in forming an ion?
    a. calcium
    b. fluorine
    c. aluminum
    d. oxygen
8. Write the name and symbol of the ion formed when
    a. a potassium atom loses one electron.
    b. a zinc atom loses two electrons.
    c. a fluorine atom gains one electron.
9. Write the electron configuration of Cd^{+2}.

Section 7.2 – Ionic Bonds and Ionic Compounds

- Compounds composed of cations and anions are called ionic compounds.
- Ionic compounds are usually composed of a metal and a nonmetal. In contrast, molecular compounds are generally composed of nonmetals only.
- Although they are composed of ions, ionic compounds are electrically neutral.
- The electrostatic forces that hold ions together are called ionic bonds.



Sample Exercise

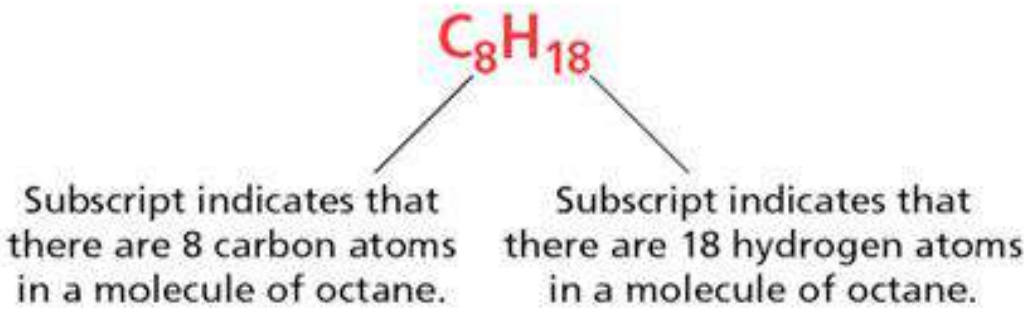
- Which of the following compounds would you expect to be ionic: N_2O, Na_2O, $CaCl_2$, SF_4?

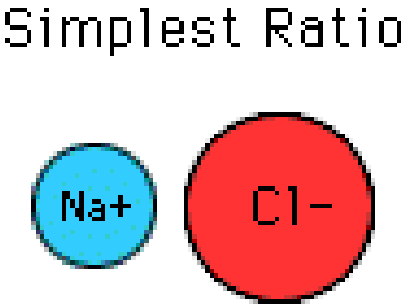
Practice Exercise

- Which of the following compounds are molecular: CBr_4, FeS, P_4O_6, PbF_2?

Formulas

- A chemical formula shows the kinds and numbers of atoms in the smallest representative unit of a substance.
- A formula unit is the lowest whole-number ratio of ions in an ionic compound.





Balancing Charges

- When you balance charges to write the formula for an ionic compound, you must make the + charge and – charge equal by adding subscripts.
- The subscripts must be in the lowest ratio to be correct.

Pb^{4+} O^{2-}

Pb^{4+} O^{2-}

Pb_2O_4

PbO_2

Mg_3^{2+} N_2^{3-}

$6 + -6 = 0$

Sample Problems

- Write the formula for the compound formed between the following elements.

- Potassium and oxygen

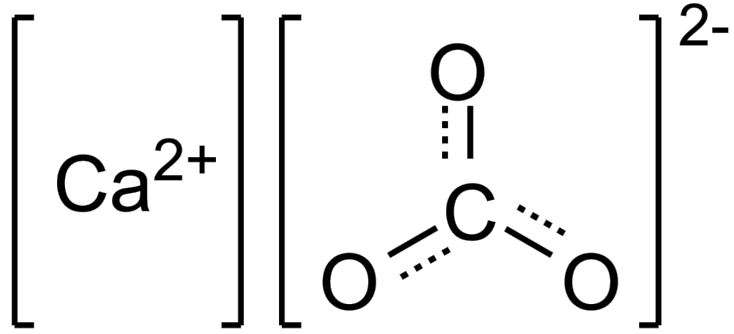
- Magnesium and nitrogen

Practice Problems

- Write the formula for the compound when the following elements combine.
- Potassium and iodine
- Aluminum and oxygen
- Calcium and chlorine
- Barium and sulfur

Polyatomic Ions

- Polyatomic ions are a group of atoms with an overall charge.
- When a compound contains a polyatomic ion, the ions are held together by ionic bonds, but the polyatomic ions is composed of covalent bonds.
- When balancing charges for polyatomic ions, you follow the same rule of cancelling the + and – charge.
- However, if you need to add a subscript to a polyatomic ion, then you have to put the polyatomic ion in parentheses. Ex: $Ca(NO_3)_2$



Common Polyatomic Ions			
$C_2H_3O_2^-$	acetate	OH^-	hydroxide
NH_4^+	ammonium	ClO^-	hypochlorite
CO_3^{2-}	carbonate	NO_3^-	nitrate
ClO_3^-	chlorate	NO_2^-	nitrite
ClO_2^-	chlorite	$C_2O_4^{2-}$	oxalate
CrO_4^{2-}	chromate	ClO_4^-	perchlorate
CN^-	cyanide	MnO_4^-	permanganate
$Cr_2O_7^{2-}$	dichromate	PO_4^{3-}	phosphate
HCO_3^-	bicarbonate	SO_4^{2-}	sulfate
HSO_4^-	bisulfate	SO_3^{2-}	sulfite
HSO_3^-	bisulfate		

Sample Problems

- Write the formula for the compound when the following ions combine:

- Sodium and phosphate

- Ammonium nitride

- Aluminum carbonate

Practice Problems

- Write the formula for the compound when the following ions combine:

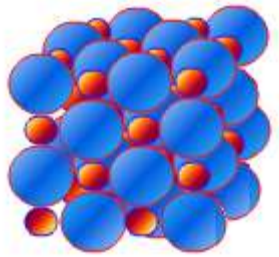
- Barium nitrate

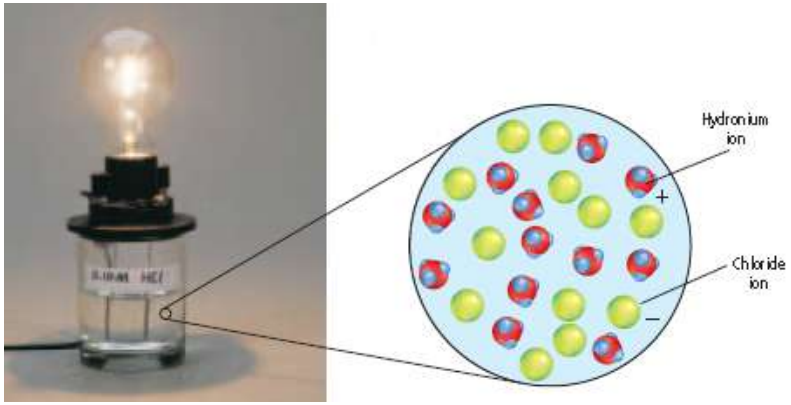
- Lithium phosphate

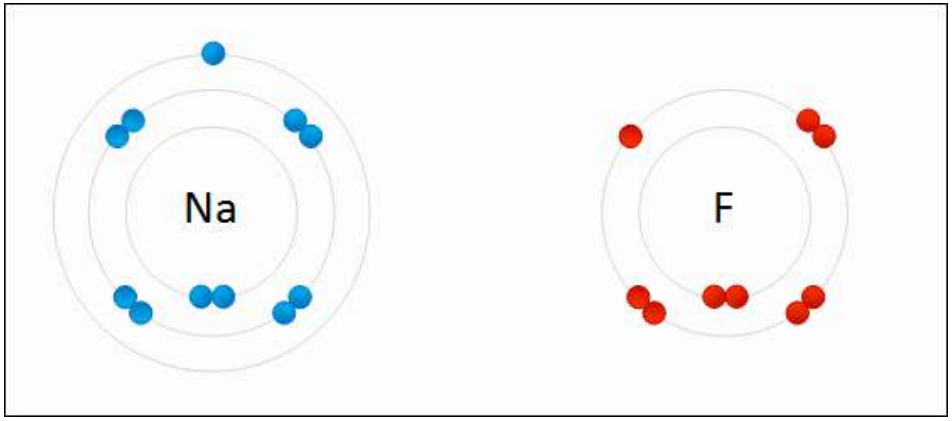
- Strontium sulfite

Properties of Ionic Compounds

- Properties of ionic compounds include the following:
- Crystalline solids
- High melting points
- Conduct electricity when molten or aqueous
- Made of metals and nonmetals
- Made of cations and anions
- Made of ionic bonds

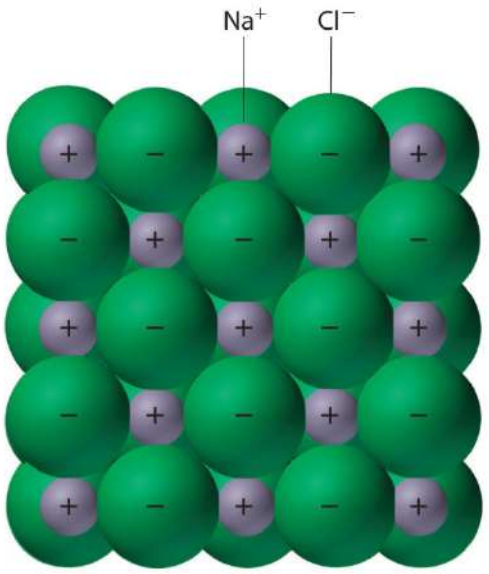






Crystals

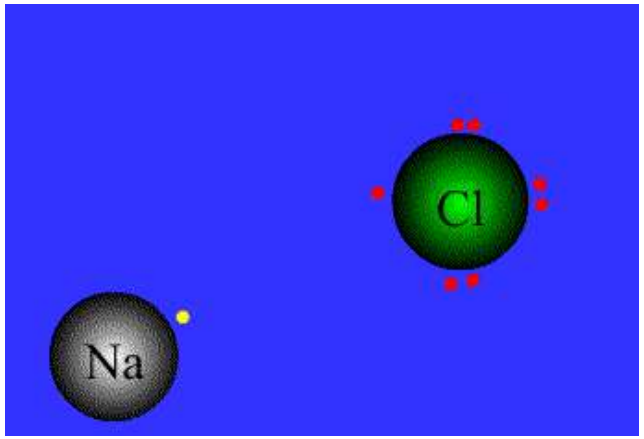
- A crystal is a substance with a 3-D repeating arrangement of particles called the crystal lattice.
- The coordination number of an ion is the number ions of opposite charge that surround the ion in a crystal.



(a) Ionic solid: strong electrostatic interactions

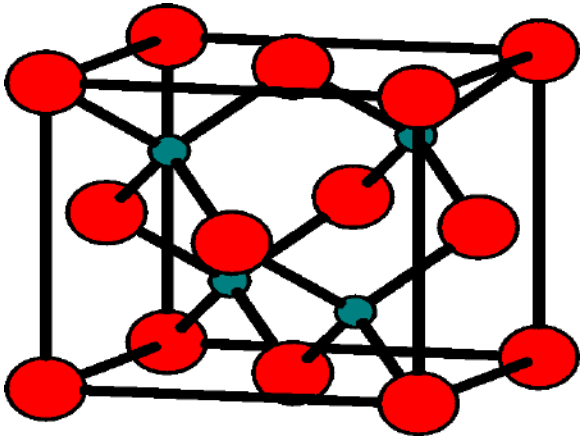
Ionic Bonding

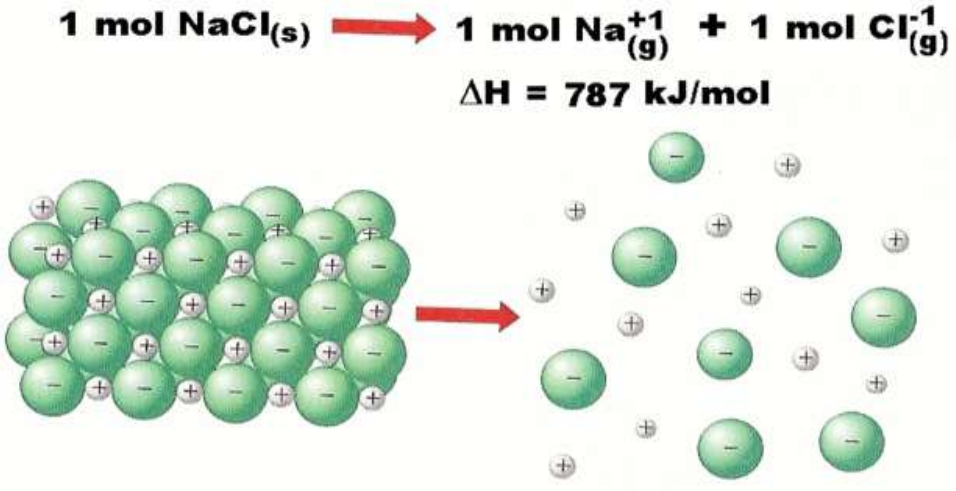
- An ionic bond involves the transfer or electrons between a cation and an anion.
- The loss of electrons is always an endothermic process.
- The gaining of electrons is generally an exothermic process.
- When ions come together, energy is released, so ionic compounds are stable.



Lattice Energy

- Lattice energy is the energy required to completely separate a mole of a solid ionic compound into its gaseous ions.
- All are large positive values, indicating that the ions are strongly attracted to one another in these solids.



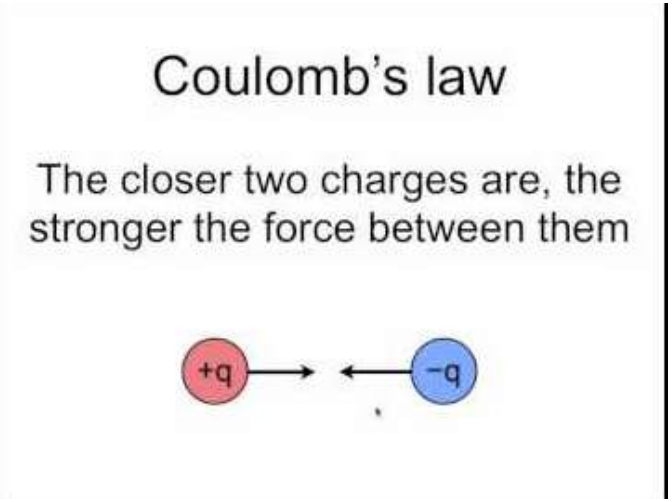


Lattice Energy

- Coulomb's law is as follows:

$$E_{el} = \frac{\kappa Q_1 Q_2}{d}$$

- Thus, for a given arrangement of ions, the lattice energy increases as the charges on the ions increase and as their radii decrease.



Sample Exercise

- Arrange the following ionic compounds in order of increasing lattice energy: NaF, CsI, and CaO.

Practice Exercise

- Which substance would you expect to have the greatest lattice energy, MgF_2, CaF_2, or ZrO_2?

Section 7.2 Assessment

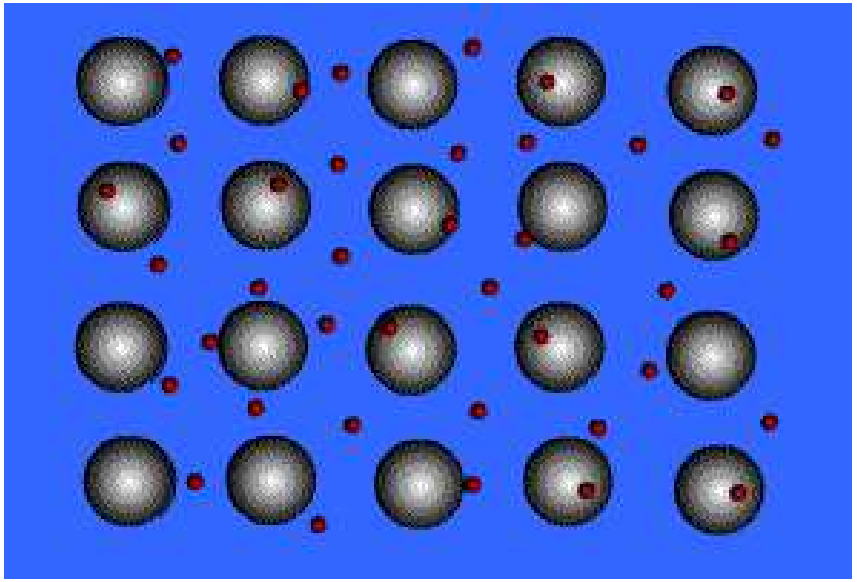
1. How can you describe the electrical charge of an ionic compound?
2. What properties characterize ionic compounds?
3. Write the correct chemical formula for the compounds formed by each pair of ions.
   a. K^{+}, S^{-2}
   b. Ca^{+2}, O^{-2}
   c. Na^{+}, O^{-2}
   d. Al^{+3}, N^{-3}

Section 7.2 Assessment

4. Write formulas for each compound.
   a. barium chloride
   b. Magnesium oxide
   c. Lithium oxide
   d. Calcium fluoride
5. Which pairs of elements are likely to form ionic compounds?
   a. Cl, Br
   b. Li, Cl
   c. K, He
   d. I, Na

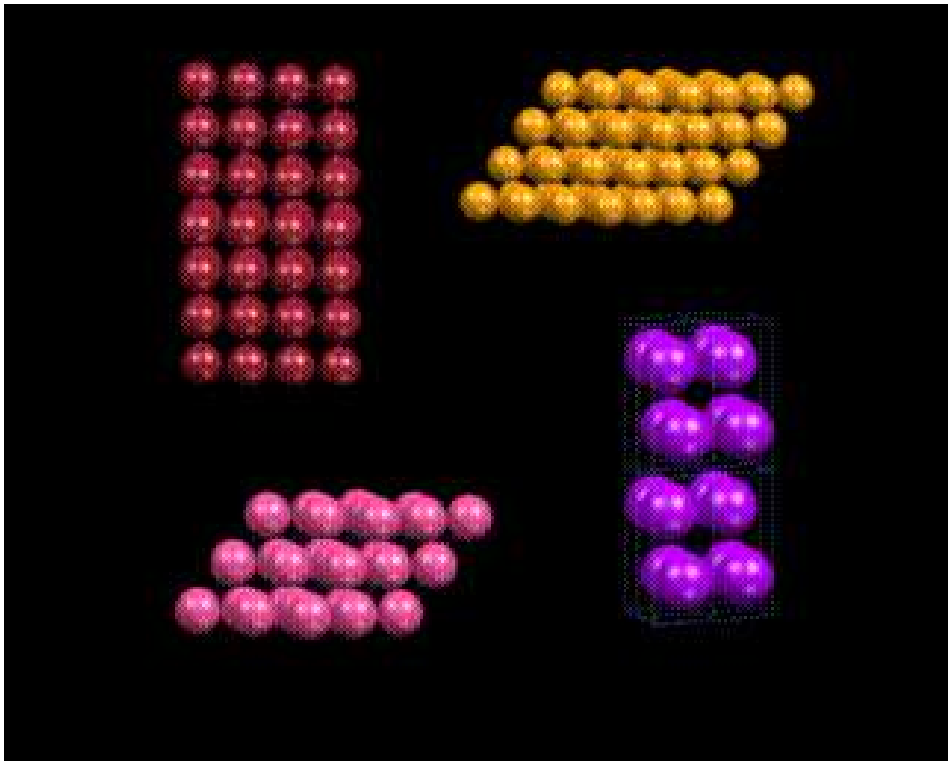
Section 7.3 – Bonding in Metals

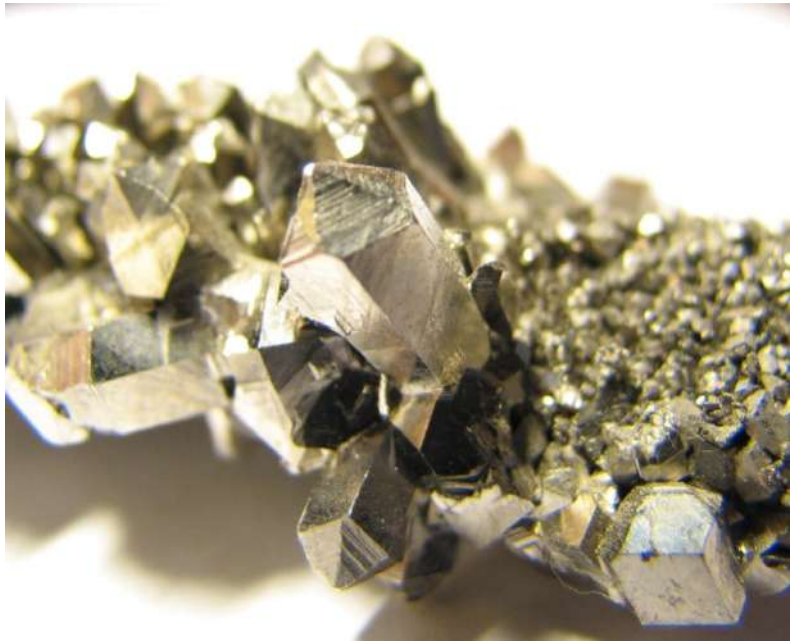
- The valence electrons of metal atoms can be modeled as a sea of electrons.
- Metallic bonds consist of the attraction of the free-floating valence electrons for the positively charged metal ions.
- Metals are good conductors and malleable because of their mobile electrons.



Metals

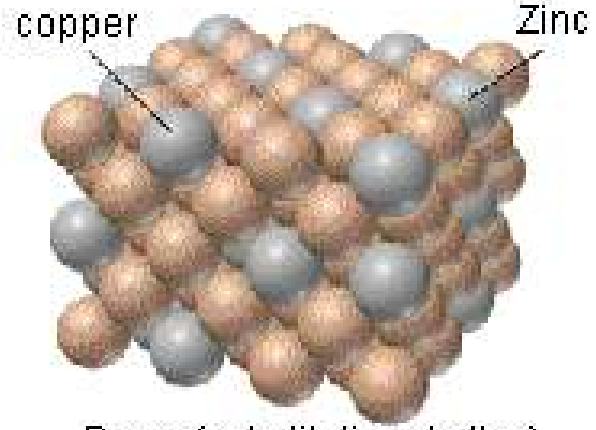
- Metals are the most simple crystals because they contain one type of element.



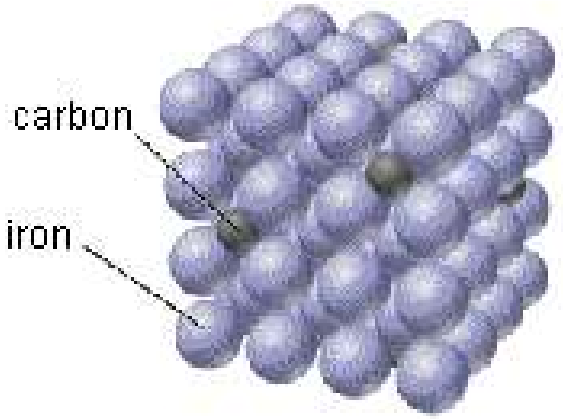


Alloys

- An alloy is a mixture with metallic properties.
- A substitutional alloy is made when atoms of one metal replace atoms of another metal.
- An interstitial alloy is made when smaller metal atoms are inserted in between larger metal atoms.



Brass (substitutional alloy)



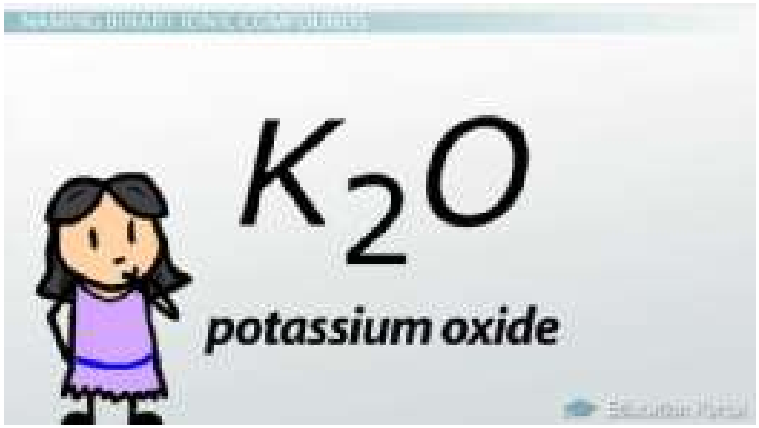
Carbon steel (interstitial alloy)

Section 7.3 Assessment

1. How do chemists model the valence electrons in metal atoms?
2. How can you describe the arrangement of atoms in metals?
3. Why are alloys more useful than pure metals?
4. Describe what is meant by ductile and malleable.

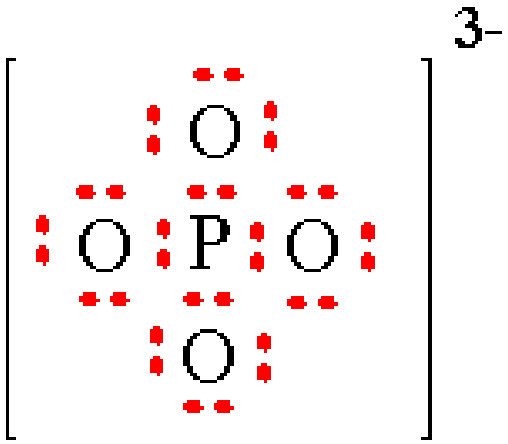
Section 9.1 – Naming with Regular Metals

- The system used in naming substances is called chemical nomenclature.
- A monatomic ion is a single atom with a charge. Ex: Na^{+} or O^{-2}
- When naming a cation, the name of the element does not change. Ex: K^{+} = potassium
- When naming an anion, the ending of the element changes to –ide. Ex: O^{-2} = ox**ide**



Polyatomic Ions

- A polyatomic ion is a group of atoms with an overall charge. Ex: SO_4^{-2}
- Most polyatomic ions end in –ate or –ite. The ending does not change when naming a compound (unless it is an acid which we will talk about later).
- The –ate suffix indicates that the polyatomic ion contains one more oxygen than the polyatomic ion with the –ite suffix. (Ex: sulfate = SO_4^{-2}, sulfite = SO_3^{-2})



Sample Problem

- Based on the formula of the sulfate ion, predict the formula for the following. Remember that sulfur and selenium are in the same group.

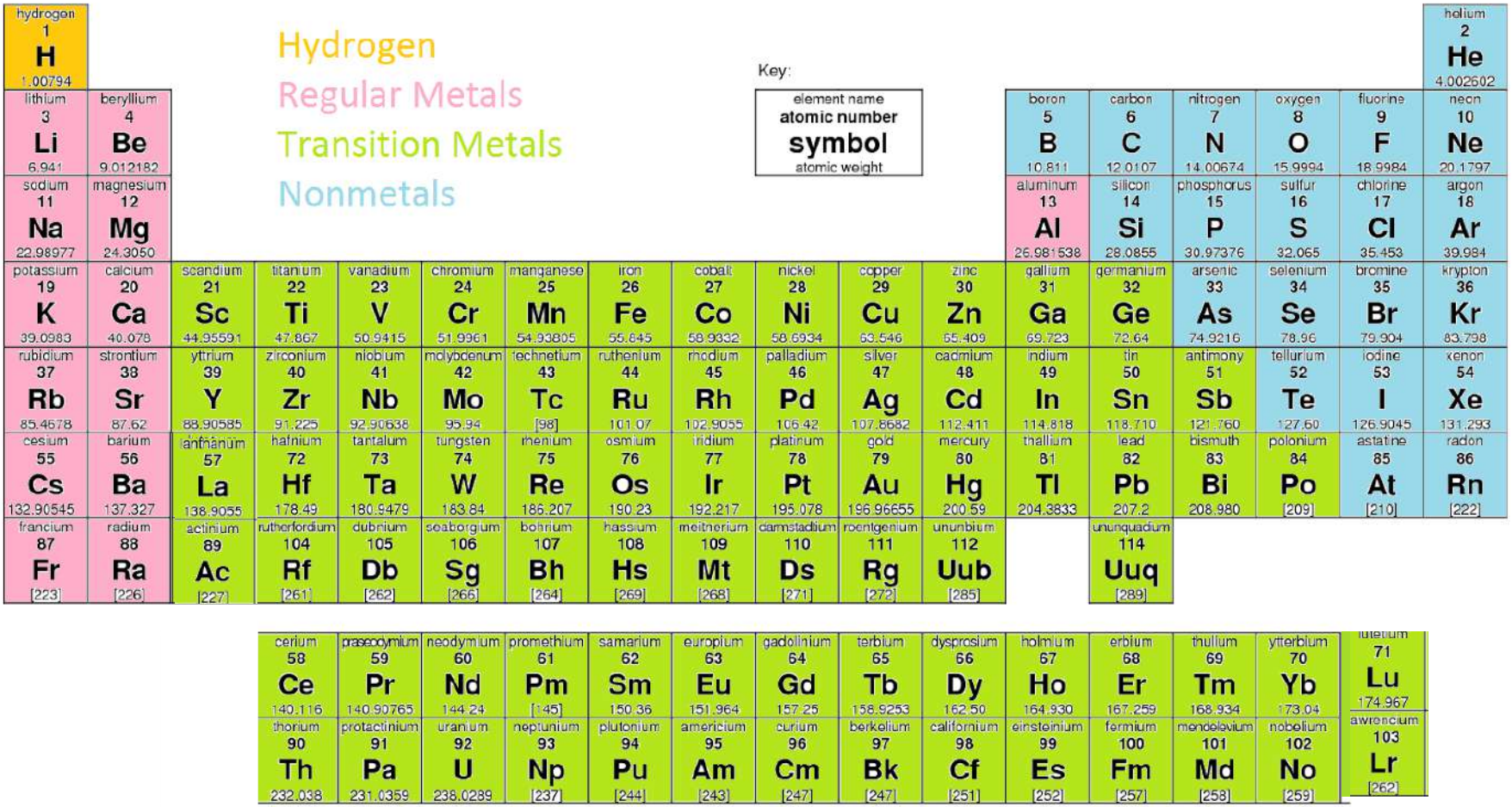
  a. the selenate ion

  b. the selenite ion

Practice Problem

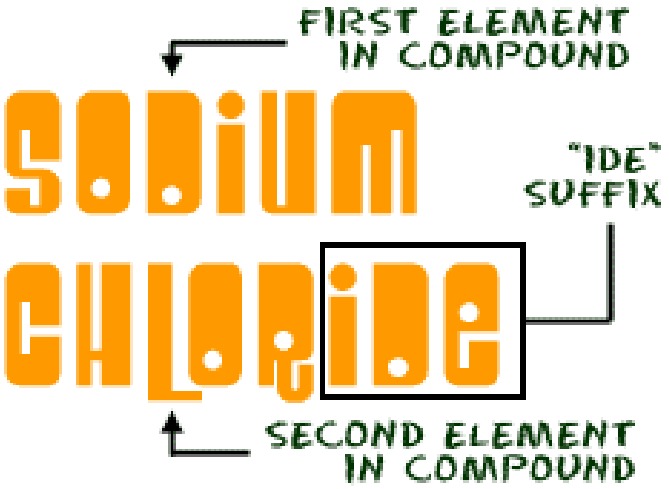
- The formula for the bromate ion is analogous to that for the chlorate ion. Write the formula for the hypobromite and perbromate ions.

Periodic Table for Naming



Naming with Regular Metals

- The regular metals are located in groups 1 and 2 (except for H). Aluminum is also a regular metal.
- When naming a compound that starts with a regular metal, you name the metal (cation) and add –ide to the nonmetal (anion). Ex: NaCl = sodium chlor**ide**
- If the anion is a polyatomic ion, then you do not change the ending. Ex: $CaCO_3$ = calcium carbonate



Sample Problems

- Name the following compounds:
- Na_2O
- $AlBr_3$
- Li_2SO_4

Practice Problems

- Name the following compounds:
- $LiNO_3$
- $Ca_2(PO_4)_3$
- $(NH_4)_2O$

Writing the Formula with Regular Metals

- When writing the formula of a compound that starts with a regular metal, you must BALANCE THE CHARGES.

- Ex: aluminum bromide

  $AlBr$

  balance charges

  $Al^{+3}Br^{-}$

  $AlBr_3$

cation	anion	compound
Ca^{+2}	Cl^{-1}	$CaCl_2$
Ba^{+2}	O^{-2}	BaO
K^{+1}	S^{-2}	K_2S
Fe^{+3}	Br^{-1}	$FeBr_3$
Cr^{+3}	O^{-2}	Cr_2O_3

Sample Problems

- Write the formula for the following compounds:
- Aluminum chloride
- Calcium acetate
- Lithium fluoride

Practice Problems

- Write the formula for the following compounds:
- Calcium hydrogen carbonate
- Aluminum oxide
- Cesium oxalate

Section 9.1 Assessment

1. What are the usual ending for the names of polyatomic ions?
2. How does a polyatomic ion differ from a monatomic ion?
3. Write the formula for these binary compounds.
    a. Beryllium chloride
    b. Cesium sulfide
    c. Sodium iodide
    d. Strontium oxide

Section 9.1 Assessment

4. Write the formula for these compounds.
    a. sodium perchlorate
    b. magnesium hydrogen carbonate
    c. calcium acetate
5. Identify any incorrect formulas. Explain your answer.
    a. $Mg_2(SO_4)_3$
    b. Rb_3As
    c. $BeCl_3$
    d. NaF

Section 9.2 – Naming with Transition Metals

- Transition metals can have multiple charges, so you cannot tell the charge based on the group it is in.
- Since transition metals can have multiple charges, we use a roman numeral to indicate the charge.
- Review of Roman Numerals

  1 = I

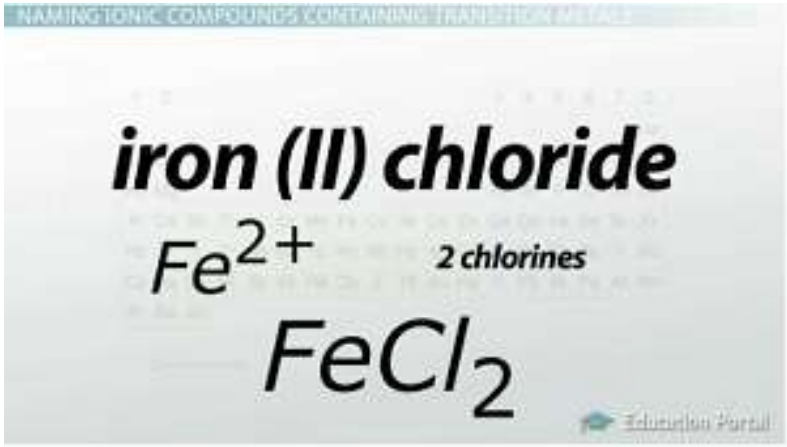
  2 = II

  3 = III

  4 = IV

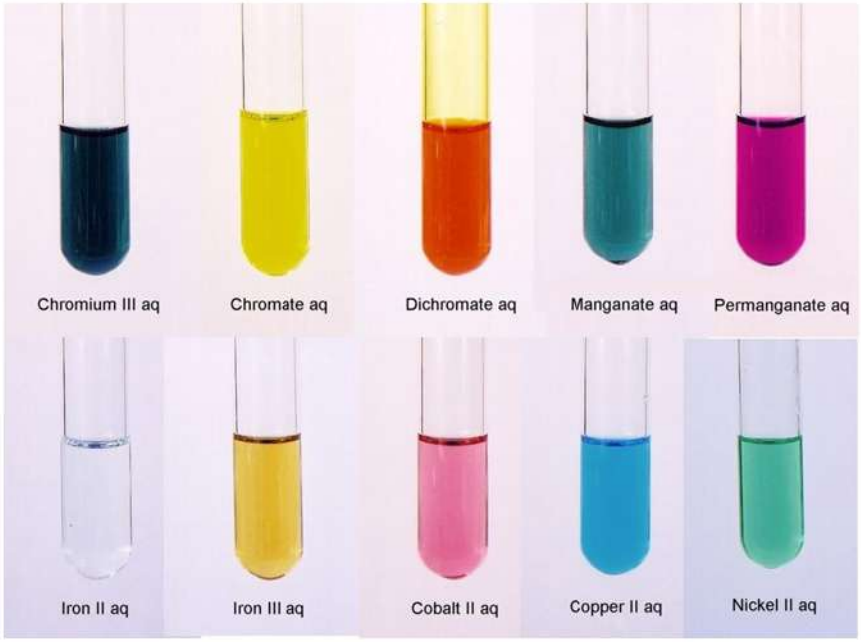
  5 = V

  **You should not use a roman numeral over 5.



Transition Metals

- Many transition metal ions exhibit colorful compounds and solution.



Transition Metals

- When naming compounds that start with a transition metal, you should balance charges to figure out the charge of the transition metal.
- Remember add –ide to the anion if it is not a polyatomic ion.

- Ex: CuO

  we know that O has a -2 charge.

  CuO^{-2}

  to cancel out a -2, Cu must be +2

  $Cu^{+2}O^{-2}$

  so the name would be copper (II) oxide.

Sample Problems

- Write the names for the following:
- Cu_2O
- $FeCl_3$
- $PbSO_4$

Practice Problems

- Write the name of the following:
- PbS_2
- $Zn(C_2H_3O_2)_2$
- Ag_3PO_3

Writing the Formulas for Transition Metals

- When writing the formula for a compound that starts with a transition metal, you must BALANCE THE CHARGES.

- Ex: vanadium (V) fluoride

VF

balance charges

$V^{+5}F^{-}$

VF_5

REMEMBER THE ROMAN NUMERAL IS NOT A SUBSCRIPT!!!!!!!!!!!!!!!!

Sample Problems

- Write the formula for the following:
- Tin (II) permanganate
- Mercury (I) oxide
- vanadium (II) hydroxide

Practice Problems

- Write the formula for the following:
- Gold (II) iodide
- Vanadium (IV) nitrite
- silver (I) nitride

Section 9.2 Assessment

1. Write the formula for chromium (III) nitrite.