LECTURE

2

2^{nd} semester

Academic Year 2025

CHEMICAL BONDING

CHEMISTRY

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OUTLINE

- Type of Chemical bonding
- Nomenclature of compounds
- Ionic Bond
- Electronegativity scale
- Covalent bond
- Lewis structure
- Formal charge
- Molecular Shapes
- Intermolecular forces
- Covalent crystal
- Metallic bond

What is Chemical bond?

Chemical bond is attraction that holds atoms or ions together in compounds → Compounds

NaCl, CO

Types of Chemical Bonding

1) ***Ionic bonding*** → ***Ionic bonding*** involves the ***transfer*** of electrons and is usually observed when a ***metal*** bonds to a ***nonmetal***.

2) ***Covalent bonding*** involves the ***sharing*** of electrons and is usually observed when a ***nonmetal*** bonds to a ***nonmetal***.

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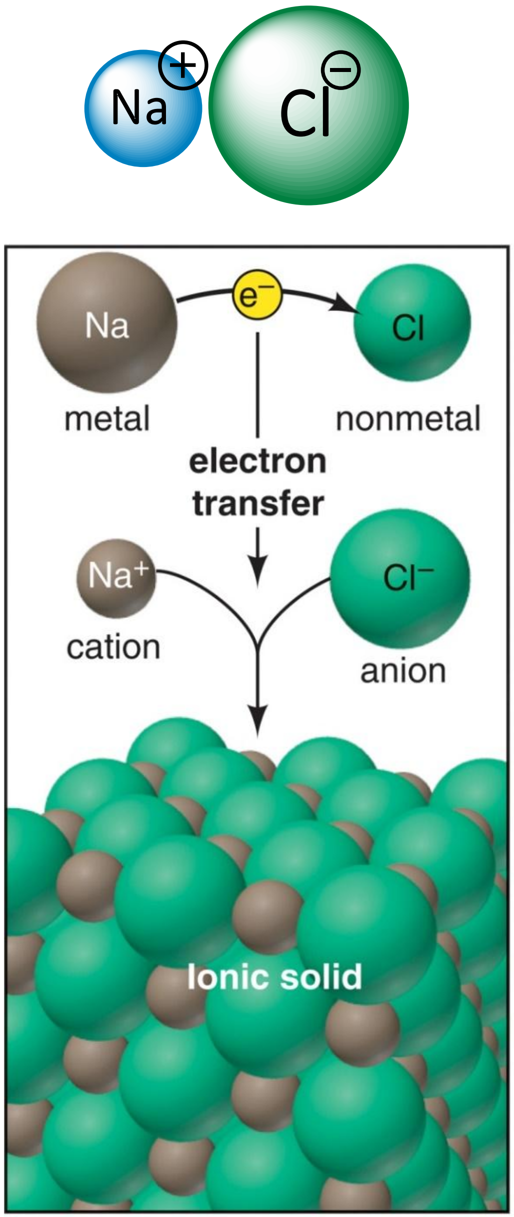
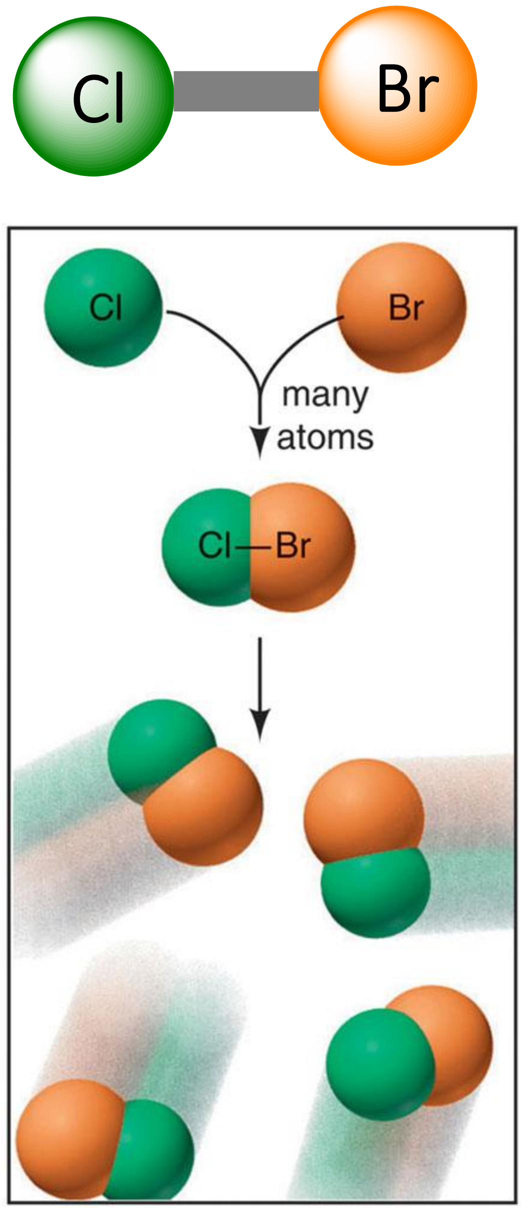


A Ionic bonding



B Covalent bonding

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METALS AND METALS

FORM

METALLIC

BONDS!

METALS AND NON-METALS

FORM

IONIC

BONDS!

NON-METALS AND NON-METALS

FORM

COVALENT

BONDS!

https://chemstory.wordpress.com/category/uncategorized/page/2/ (accessed on May 2017)

จำแนกว่าสารต่อไปนี้

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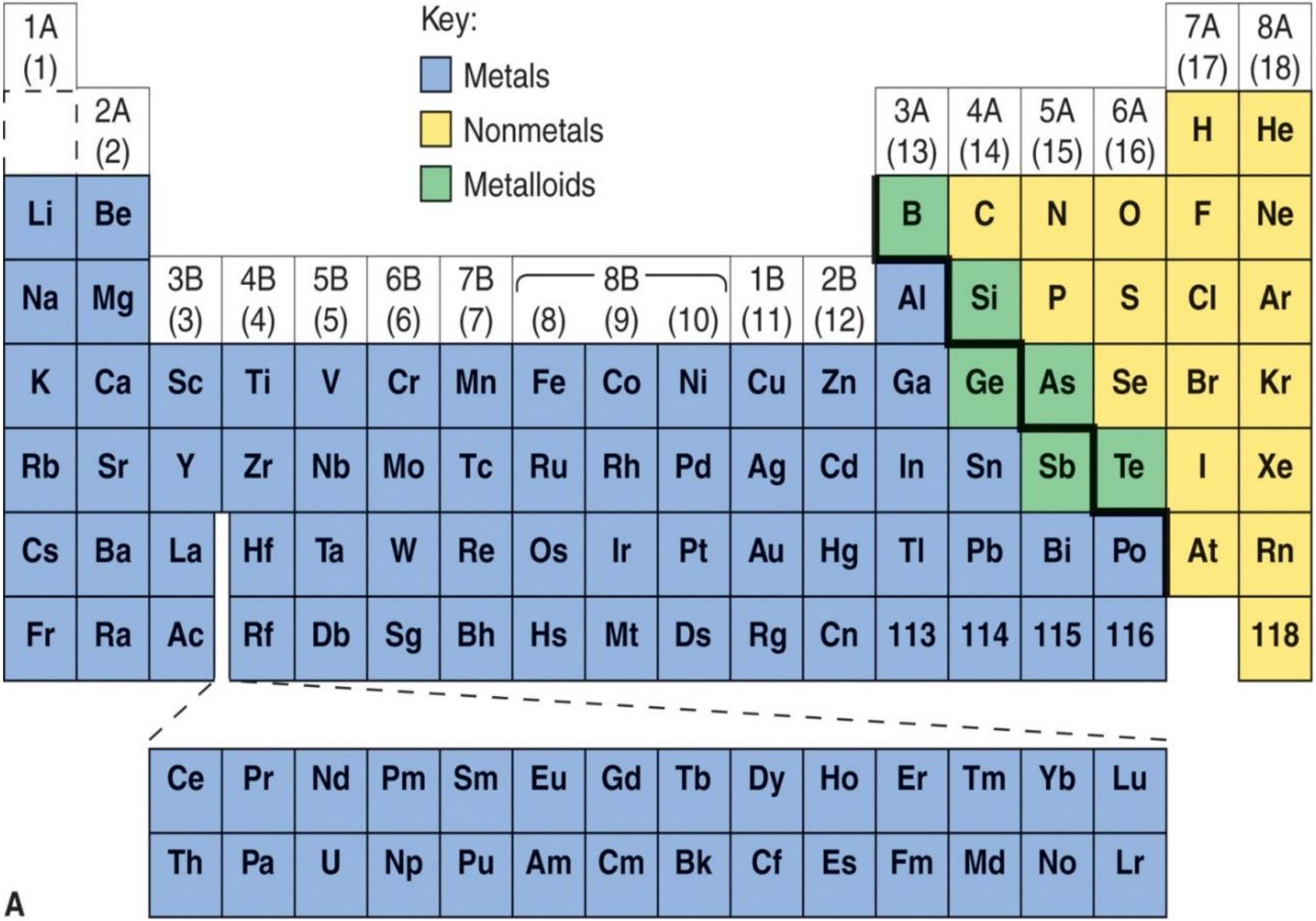

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Sample Problem 2.1 **Determining Ionic Compounds**

PROBLEM: Classify each of the following compounds as ionic or covalent compound.

Substances	Ionic	Covalent
(a) NaF		
(b) CCl_4		
(c) MgO		
(d) SO_2		
(e) P_2O_5		
(f) CH_3OH		
(g) K_2O		

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

General properties of ionic and covalent compounds

Ionic

Ionic compounds have **high melting and boiling points**

Ionic compounds are usually **soluble in water**

Ionic compounds **conduct electricity, when melted or dissolved in water**.

Covalent

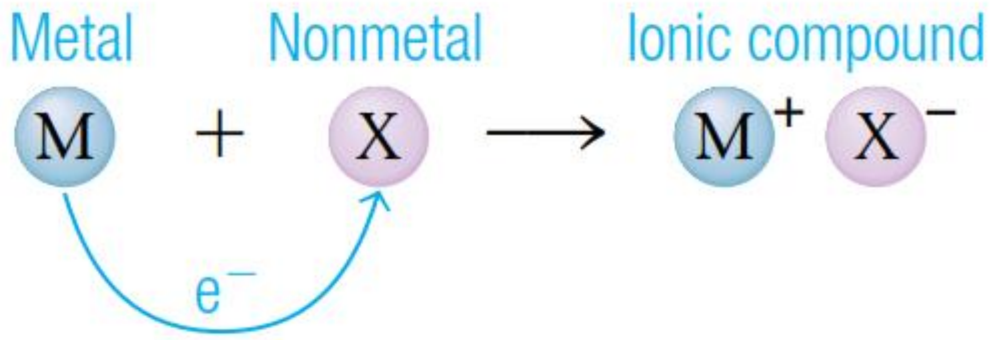
Molecular covalent compounds have **low melting and boiling points**

Covalent compounds tend to be **insoluble in water**

Covalent compounds do **not conduct electricity**.

Ionic Bond

- ❑ **Ionic compounds** results from a metal reacts with a nonmetal
- ❑ ***Ionic bonding*** is the attraction between oppositely charged ions



- ✓ **metal** atom **loses** one or more electrons and becomes a cation (+ charge).
- ✓ **nonmetal** atom **gains** one or more of the electrons lost by the metal atom and becomes an anion (⊖ charge).

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Naming of Ions

Predicting the Number of Electrons lost or Gained

Metals lose electrons

Group 1A	→	+ 1 cation		Li^{+} Na^{+}
Group 2A	→	+ 2 cation		Mg^{2+}
Group 3A	→	+ 3 cation		Al^{3+}

Nonmetals gain electrons

Group 5A	→	−3 anion	(5-8)	N^{3-}
Group 6A	→	−2 anion	(6-8)	O^{2-}
Group 7A	→	−1 anion	(7-8)	F^{-} , Cl^{-} , Br^{-} ,

Some common monatomic ions of the elements

Period	1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	8B (9)	8B (10)	1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1	H^+																H^-	
2	Li^+														N^{3-}	O^{2-}	F^-	
3	Na^+	Mg^{2+}											Al^{3+}			S^{2-}	Cl^-	
4	K^+	Ca^{2+}				Cr^{2+} Cr^{3+}	Mn^{2+}	Fe^{2+} Fe^{3+}	Co^{2+} Co^{3+}		Cu^+ Cu^{2+}	Zn^{2+}					Br^-	
5	Rb^+	Sr^{2+}									Ag^+	Cd^{2+}		Sn^{2+} Sn^{4+}			I^-	
6	Cs^+	Ba^{2+}										Hg_2^{2+} Hg^{2+}		Pb^{2+} Pb^{4+}				
7																		

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Common Monatomic Ions

Charge	Cations Formula	Name
+1	H^+	hydrogen
	Li^+	lithium
	Na^+	sodium
	K^+	potassium
	Cs^+	cesium
	Ag^+	silver
+2	Mg^{2+}	magnesium
	Ca^{2+}	calcium
	Sr^{2+}	strontium
	Ba^{2+}	barium
	Zn^{2+}	zinc
	Cd^{2+}	cadmium
+3	Al^{3+}	aluminum

Charge	Anions Formula	Name
-1	H^-	hydride
	F^-	fluoride
	Cl^-	chloride
	Br^-	bromide
	I^-	iodide
-2	O^{2-}	oxide
	S^{2-}	sulfide
-3	N^{3-}	nitride

those in boldface are most common

Determining Formulas of Ionic Compounds

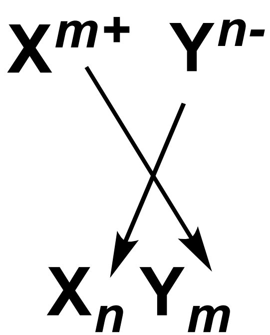
General rules for writing ionic formula;

1) Recognize which element is the metal (+) and non-metal (-)

   !!! metal is always written first

2) Write down the ion with their charges, e.g. X^{m+} Y^{n-}

3) Move the values ***m*** and ***n*** diagonally without the charges



NOTE

- The subscript 1 is understood from the presence of the element symbol alone (that is, we do not write Ca_1Br_2).
- Reduce the subscripts to the smallest whole numbers that retain the ratio of ions.

  Ca^{2+} O^{2-} give Ca_2O_2 reduce to CaO

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Sample Problem 2.6

Determining Formulas of Binary Ionic Compounds

PROBLEM: Write empirical formulas for the following compounds

(a) magnesium and nitrogen

(b) strontium and fluorine

(c) Silver and iodine

(d) sulfur and cesium

(e) oxygen and potassium

SOLUTION:

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Nomenclature of Ionic compounds

- The name of the cation is written first, followed by that of the anion.

  - ✓ The name of the cation is the same as the name of the metal.

    Many metal names end in *-ium.*

  - ✓ The name of the anion takes the root of the nonmetal name and adds the suffix -***ide***.

Metal (cation)

nonmetal (anion)

$CaBr_2$

Calcium bromide

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Sample Problem 2.5

Determining Formulas of Binary Ionic Compounds

PROBLEM: Name the ionic compound formed from **Sample problem 2.6**

PLAN: Use the periodic table to decide which element is the metal and which the nonmetal. The metal (cation) is named first and we use the -*ide* suffix on the nonmetal name root.

SOLUTION:

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Sample Problem 2.5A **Determining Formulas of Binary Ionic Compounds**

PROBLEM: For the following ionic compounds, give the name and periodic table group number of each element present:

.

a) magnesium oxide	MgO
(b) silver bromide	
(c) lithium chloride	
(d) aluminum oxide	
(e) silver oxide	
(f) potassium nitride	

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Metals With Several Oxidation States

Element	Ion Formula	Systematic Name	Common Name
Chromium	Cr^{2+}	chromium(II)	chromous
	Cr^{3+}	**chromium(III)**	chromic
Cobalt	Co^{2+}	cobalt(II)	
	Co^{3+}	cobalt(III)	
Copper	**Cu^{+}**	**copper(I)**	cuprous
	Cu^{2+}	**copper(II)**	cupric
Iron	**Fe^{2+}**	**iron(II)**	ferrous
	Fe^{3+}	**iron(III)**	ferric
Lead	**Pb^{2+}**	**lead(II)**	
	Pb^{4+}	lead(IV)	
Mercury	Hg_2^{2+}	mercury (I)	mercurous
	Hg^{2+}	**mercury (II)**	mercuric
Tin	**Sn^{2+}**	**tin(II)**	stannous
	Sn^{4+}	tin(IV)	stannic

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Sample Problem 2.7

Determining Names and Formulas of Ionic Compounds of Elements That Form More Than One Ion

PROBLEM: Give the systematic names for the formulas or the formulas for the names of the following compounds:

(a) tin(II) fluoride **(b)** AlI_3 **(c)** iron(II) oxide

(d) CoS **(e)** Cu_2S **(f)** Zinc(II) chloride

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Some Common Polyatomic Ions

Formula	Name	Formula	Name
		Cations	
NH_4^+	**ammonium**	**H_3O^+**	**hydronium**
		Common Anions	
CH_3COO^-	**Acetate**	**CO_3^{2-}**	**carbonate**
CN^-	cyanide	**HCO_3^-**	**bicarbonate**
OH^-	**hydroxide**	CrO_4^{2-}	chromate
ClO^-	hypochlorite	**$Cr_2O_7^{2-}$**	**dichromate**
ClO_2^-	chlorite	O_2^{2-}	peroxide
ClO_3^-	**chlorate**	**PO_4^{3-}**	**phosphate**
NO_2^-	nitrite	HPO_4^{2-}	hydrogen phosphate
NO_3^-	**nitrate**	SO_3^{2-}	sulfite
MnO_4^-	**Permanganate**	**SO_4^{2-}**	**sulfate**

*Bold face ions are most common. **(partial table)**

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Sample Problem 2.8

Determining Names and Formulas of Ionic Compounds Containing Polyatomic Ions

PROBLEM: Give the systematic names for the formulas or the formulas for the names of the following compounds:

(a) Magnesium sulfate **(b)** $KMnO_4$ **(c)** $FeSO_4$

(d) Potassium carbonate **(e)** Ammonium sulfate **(f)** $Ca(NO_3)_2$

(f) Sodium phosphate

SOLUTION:

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Ionic Reactions

Writing Equations for Aqueous Ionic Reactions

The molecular equation

shows all of the reactants and products as intact, undissociated compounds

reactants → *product*

$$AgNO_3(aq) + KCl(aq) \rightarrow \mathbf{AgCl(s)} + KNO_3(aq)$$

precipitation

the "**plus (+)**" sign means "**reacts with**"

the **arrow** means "**to yield**."

(*s*) for solid

(*g*) for gas

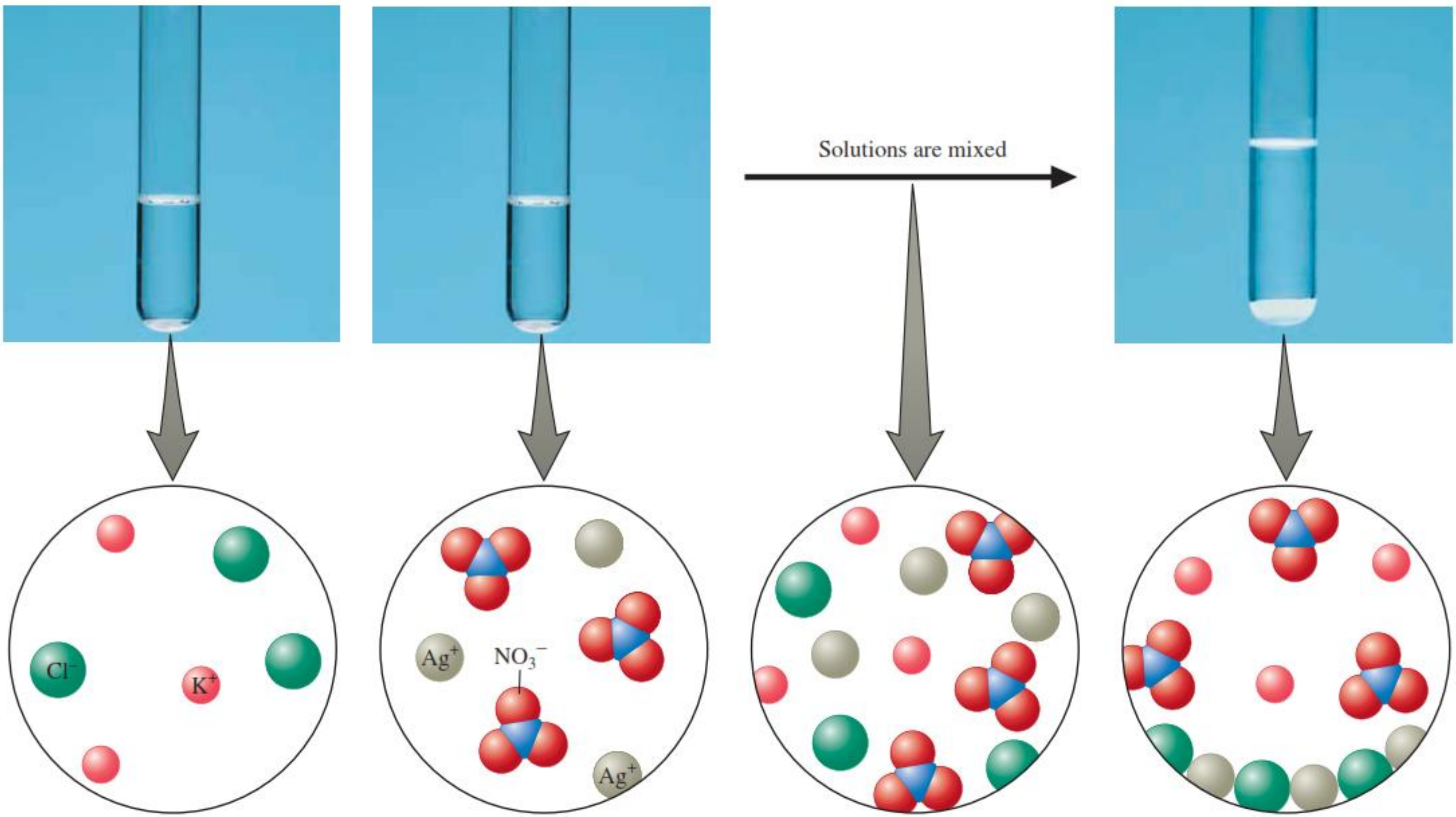
(*l*) for liquid

(*aq*) for aqueous solution (solution in water)

Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

KCl

$AgNO_3$



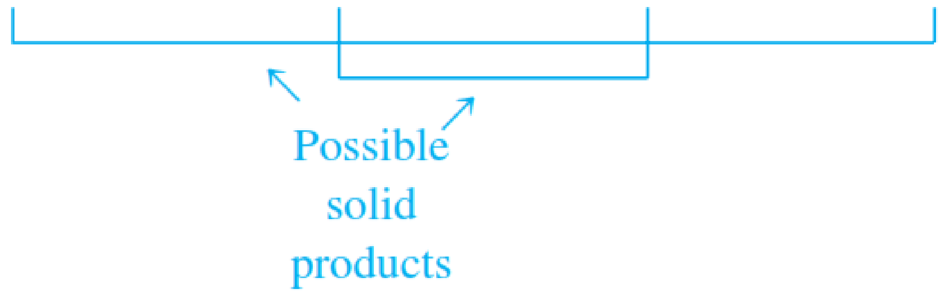
Zumdahl, S. S., & Zumdahl, S. A. (2006). *Chemistry*: Cengage Learning.

Predicting (Ionic) Reaction Products

- In determining the products, we took the cation from one reactant and combined it with the anion of the other reactant.

$$AgNO_3(aq) + KCl(aq) \rightarrow$$

$$Ag^+ + NO_3^- + K^+ + Cl^- \longrightarrow AgCl(s) + KNO_3(aq)$$



This reaction shows ions exchanging partners → *double-displacement reaction*

Zumdahl, S. S., & Zumdahl, S. A. (2006). *Chemistry*: Cengage Learning.

Sample Problem 2.11

Predicting Reaction Products

PROBLEM: Predict what will happen when the following pairs of solutions are mixed.

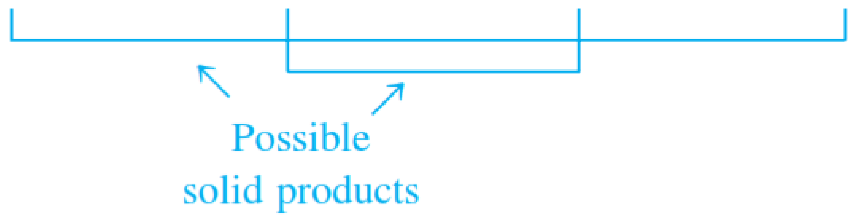
(a) KNO_3 (aq) and $BaCl_2$ (aq)

(b) Na_2SO_4(aq) and $Pb(NO_3)_2$(aq)

(c) KOH (aq) and $Fe(NO3)_2$ (aq)

Solution (a) KNO_3 (aq) and $BaCl_2$ (aq)

$$K^+ + NO_3^- + Ba^{2+} + Cl^- \longrightarrow KCl + Ba(NO_3)_2$$



Sample Problem 2.11

Predicting Reaction Products

continue:

(b) $Na_2SO_4(aq)$ and $Pb(NO_3)_2(aq)$

(c) $KOH\ (aq)$ and $Fe(NO_3)_2\ (aq)$

Sample Problem 2.11A

Predicting Reaction Products

PROBLEM: Predict what will happen when the following pairs of solutions are mixed.

(a) Iron(III) chloride(aq) + Cesium phosphate(aq)

(b) Ammonium carbonate(aq) + potassium sulfide(aq)

Solution

Table 4.1 Solubility Rules For Ionic Compounds in Water

Soluble Ionic Compounds

1. All common compounds of Group 1A(1) ions (Li^+, Na^+, K^+, etc.) and ammonium ion (NH_4^+) are soluble.

2. All common nitrates (NO_3^-), acetates (CH_3COO^- or $C_2H_3O_2^-$) and most perchlorates (ClO_4^-) are soluble.

3. All common chlorides (Cl^-), bromides (Br^-) and iodides (I^-) are soluble, ***except*** those of Ag^+, Pb^{2+}, Cu^+, and Hg^{2+}.

Insoluble Ionic Compounds

1. All common metal hydroxides are insoluble, ***except*** those of Group 1A(1) and the larger members of Group 2A(2)(beginning with Ca^{2+}).

2. All common carbonates (CO_3^{2-}) and phosphates (PO_4^{3-}) are insoluble, ***except*** those of Group 1A(1) and NH_4^+.

3. All common sulfides are insoluble *except* those of Group 1A(1), Group 2A(2) and NH_4^+.

Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

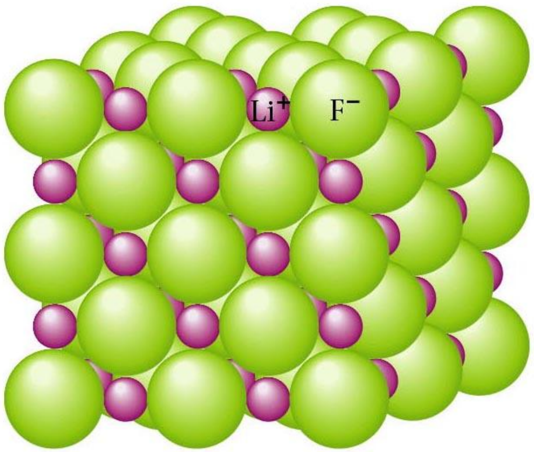
Sample Problem 2.12

PROBLEM: Classify the following ionic compounds as soluble or insoluble:

Ionic compounds	soluble	insoluble
(a) Na_3PO_4		
(b) $CaCO_3$		
(c) K_2CO_3		
(d) $Zn(NO_3)_2$		
(e) CuS		
(f) $MgCl_2$		
(g) LiOH		

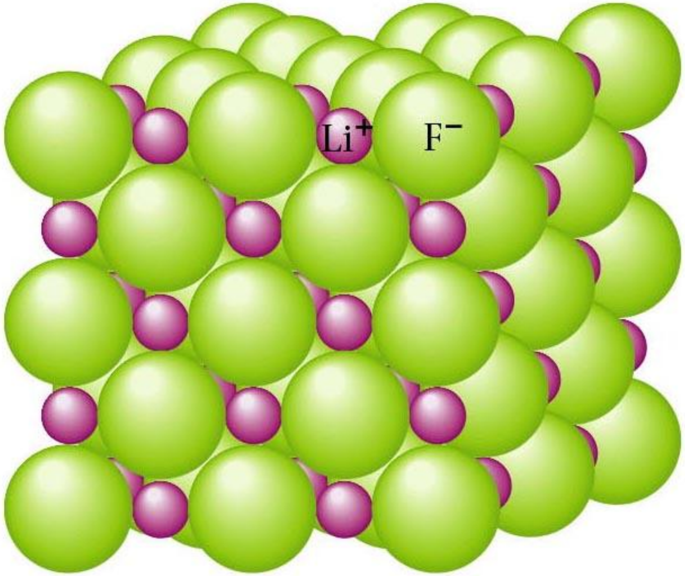
Structures & Properties

of Ionic Compounds



Structures of Ionic Compounds

- LiF (MxNy) is simplest formula
- The actual solid contains huge and equal numbers of Li^+ and F^- ions packed together in a way that maximizes the attractions of the oppositely charged ions.



This structure represents the ions as packed spheres.

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Properties of Ionic Compounds

1) Have high melting points and boiling points

(all are solids at room temp.)

2) Hard, but brittle solids

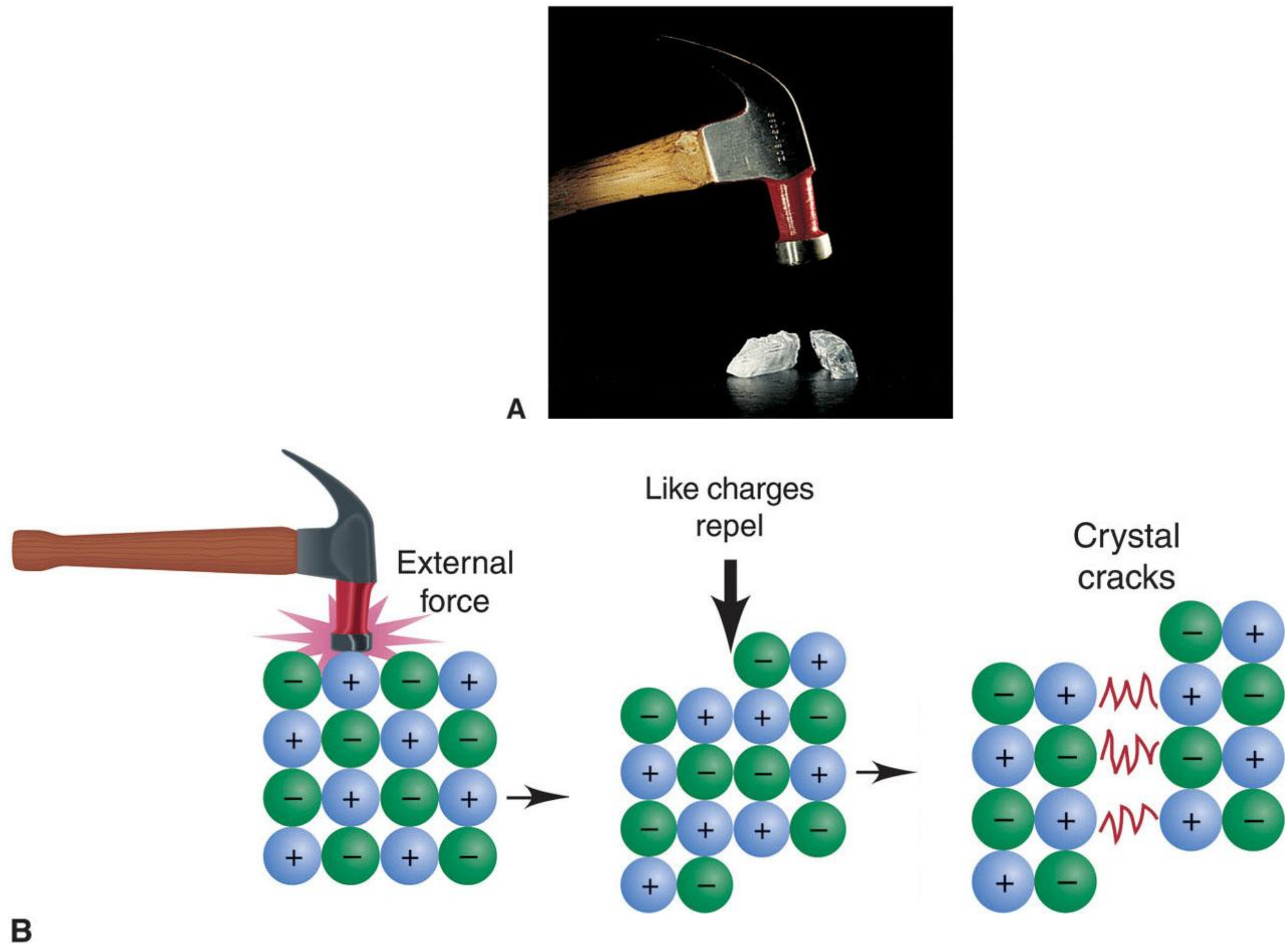
3) Conduct electricity in as liquids, but not as solids

Table 9.1 Melting and Boiling Points of Some Ionic Compounds

Compound	mp (°C)	bp (°C)
CsBr	636	1300
NaI	661	1304
$MgCl_2$	714	1412
KBr	734	1435
$CaCl_2$	782	>1600
NaCl	801	1413
LiF	845	1676
KF	858	1505
MgO	2852	3600

Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

Why ionic compounds crack.



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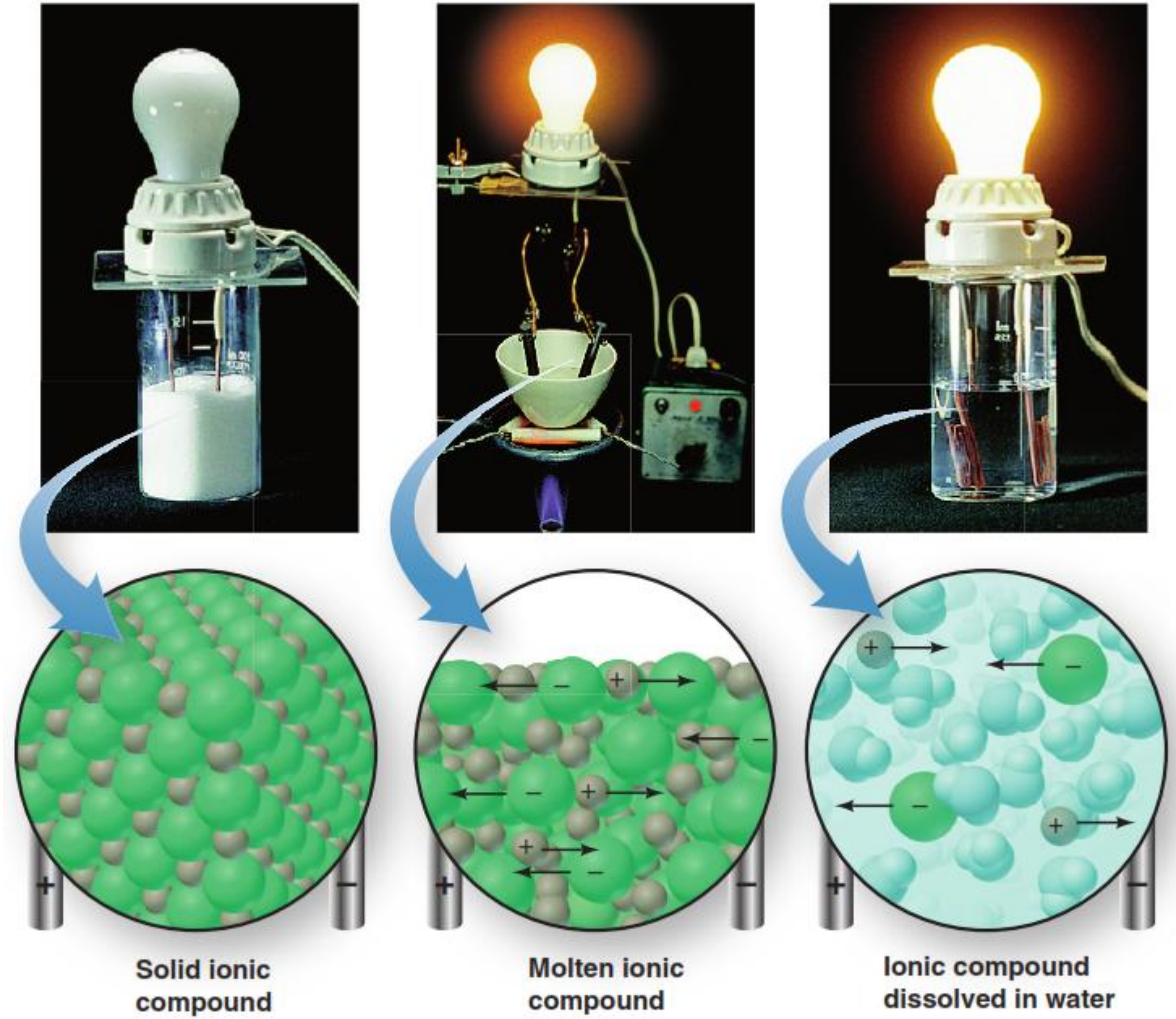
Electrical Conductance and Ion Mobility



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Sample Problem 2.9

Problem ข้อใดต่อไปนี้ไม่ใช่คุณสมบัติของสารประกอบไอออนิก

A) high melting point

B) high boiling point

C) brittleness

D) poor electrical conductor when solid

E) poor electrical conductor when molten

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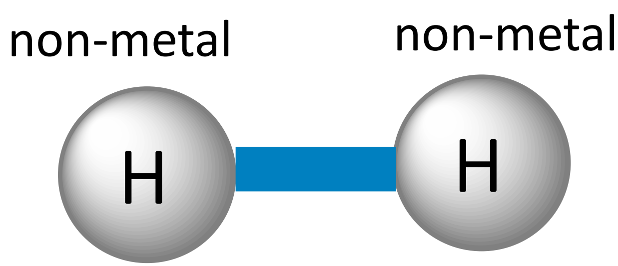
Naming Covalent Compounds

Naming Covalent Compounds

A binary covalent compound is typically formed by the combination of two **non-metals**.

Ex SO_2, H_2O, CO_2 , NO_2



Covalence bonding

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Naming Covalent Compounds

1) the element with the ***lower*** group number in the periodic table is ***first*** in the name and formula. Its name remains unchanged.

2) The element that is second is named using the root with the suffix ***–ide***.

3) Numerical prefixes indicate the number of atoms of each element present

CO_2 : carbon dioxide

SO_3 : Sulfur trioxide

N_2O_5 : dinitrogen pentoxide

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Table 2.6 Numerical Prefixes for Hydrates and Binary Covalent Compounds

Number	Prefix	Number	Prefix	Number	Prefix
1	mono-	4	tetra-	8	octa-
2	di-	5	penta-	9	nona-
3	tri-	6	hexa-	10	deca-
		7	hepta-		

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Sample Problem 2.10

Determining Names and Formulas of Binary Covalent Compounds

PROBLEM: **(a)** What is the formula of nitrogen trifluoride?

(b) What is the name of PCl_5?

(c) What is the name of $\mathbf{Cl_2O_7}$?

(d) What is the name of $\mathbf{N_2O_3}$

(e) Give the name and formula of the compound whose molecules each consist of two N atoms and four O atoms.

SOLUTION:

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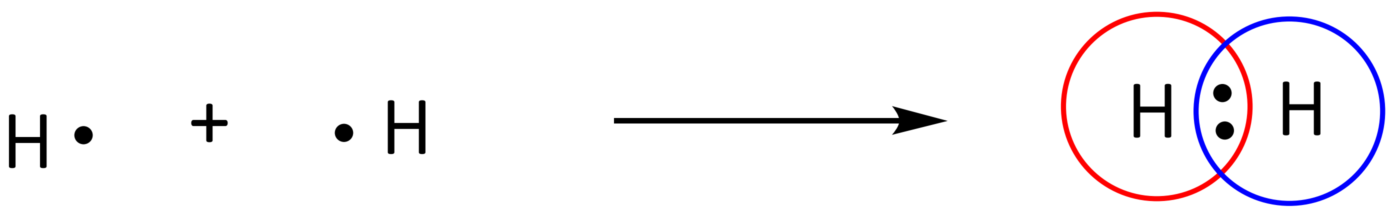
Covalent Bonding

- Formation of Covalent bond
- Type of covalent bond
- Bond Energy
- Electronegativity
- Lewis structure
- Shapes of molecules

Formation of Covalent bond

Covalent bonding is a chemical bond in which two or more electrons are shared by two non-metal atoms.

Covalent compound results when a non-metal reacts with a non-metal



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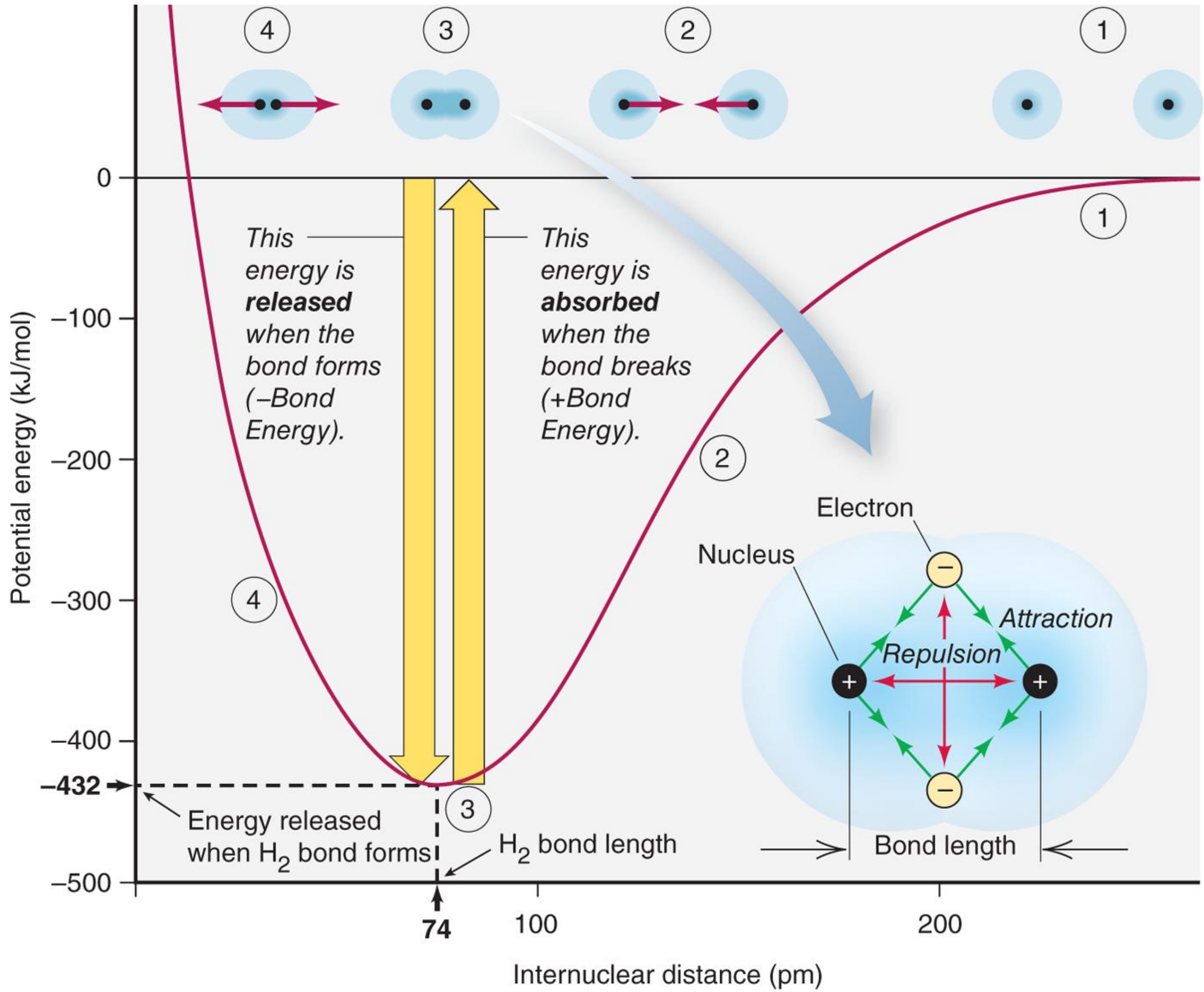
Covalent bond formation in H_2



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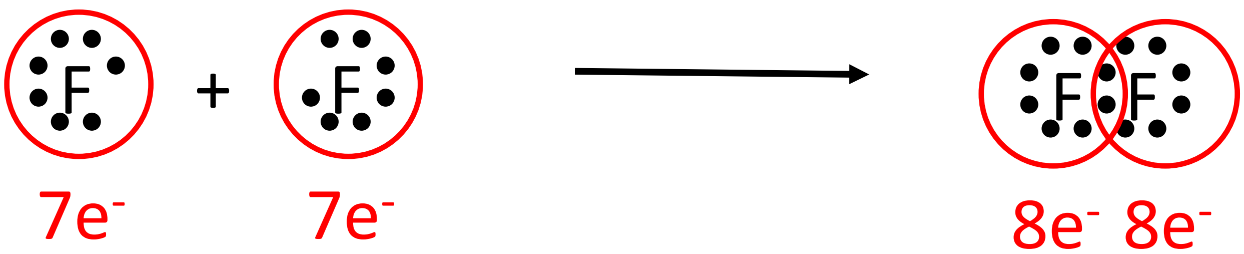
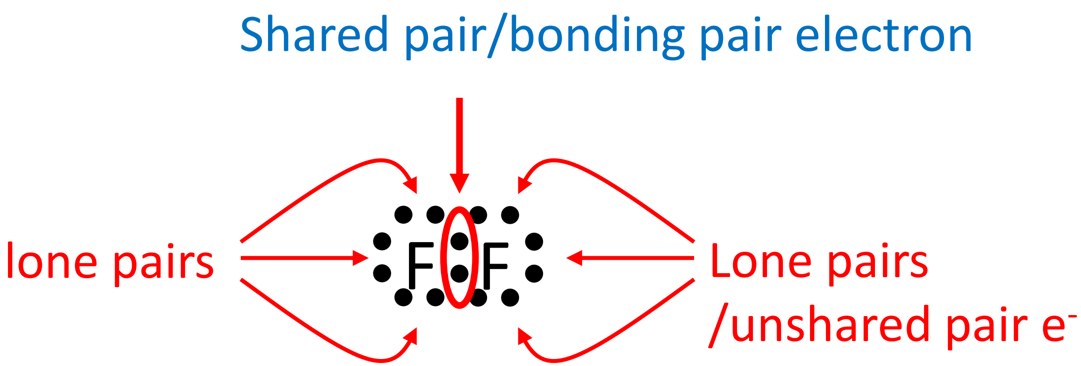
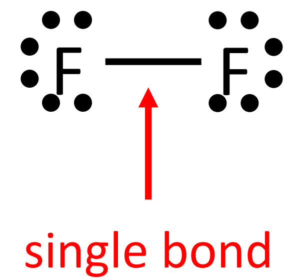
Bonding Pairs and Lone Pairs

Why should two atoms share electrons?

To achieve a full outer (valence) level of electrons





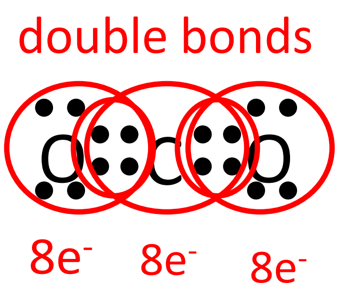


Chang, R. (2010). *Chemistry*: McGraw-Hill.

Types of Covalent bond

1) **Single bond, *two atoms*** *are held together by one electron pair.*

2) **Double bond** – two atoms share two pairs of electrons



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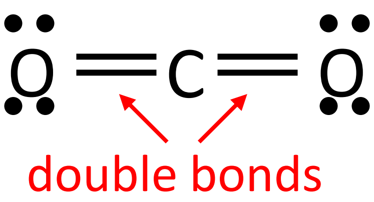
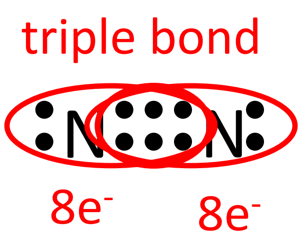


3) Triple bond – two atoms share three pairs of electrons



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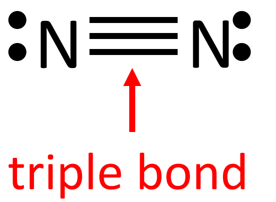
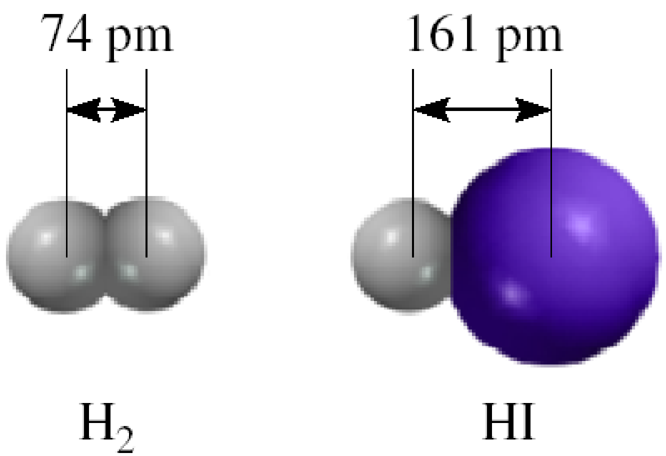


Chang, R. (2010). *Chemistry*: McGraw-Hill.

Bond lengths

The ***bond length*** is the distance between the nuclei of the bonded atoms.



Bond Lengths:

Triple bond < Double Bond < Single Bond

TABLE 9.2

Average Bond Lengths of Some Common Single, Double, and Triple Bonds

Bond Type	Bond Length (pm)
C—H	107
C—O	143
C=O	121
C—C	154
C=C	133
C≡C	120
C—N	143
C=N	138
C≡N	116
N—O	136
N=O	122
O—H	96

Chang, R. (2010). *Chemistry*: McGraw-Hill.

Bond Energy

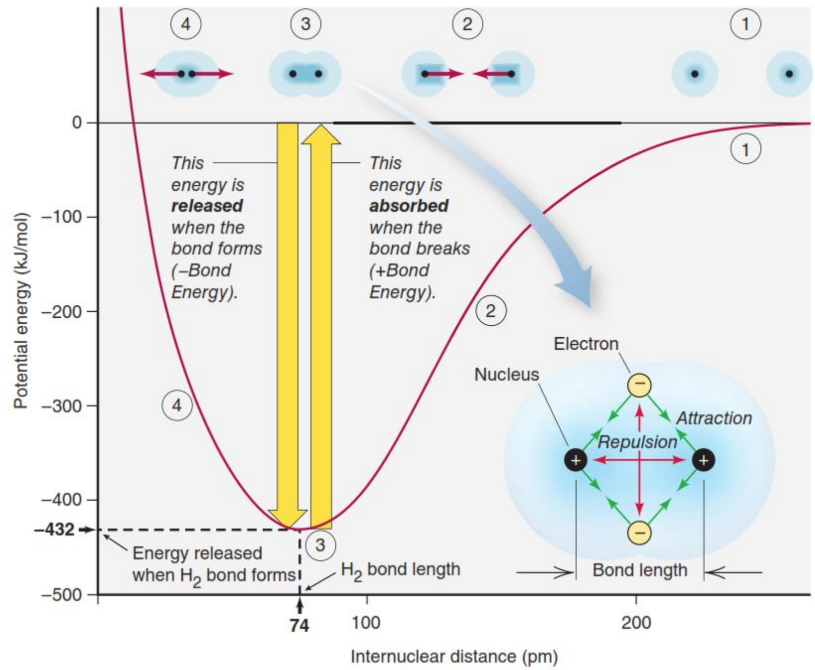
- The ***bond energy*** (BE) is the energy needed to overcome the attraction between the nuclei and the shared electrons.
- The ***stronger*** the bond the ***higher*** the bond energy.

Bond Lengths:

Triple bond **<** Double Bond **<** Single Bond

Bond Energy:

Triple bond **>** Double Bond **>** Single Bond



Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

Table 9.3 The Relation of Bond Order, Bond Length, and Bond Energy

Bond	Bond Order	Average Bond Length (pm)	Average Bond Energy (kJ/mol)
C—O	1	143	358
C═O	2	123	745
C≡O	3	113	1070
C—C	1	154	347
C═C	2	134	614
C≡C	3	121	839
N—N	1	146	160
N═N	2	122	418
N≡N	3	110	945

Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

Sample Problem 4.1

คำถามทบทวนบทเรียน (6 ข้อ)

1): ระยะห่างระหว่างนิวเคลียสของอะตอม 2 อะตอม เรียกว่าอะไร

A) พลังงานพันธะ B) ความยาวพันธะ C) เส้นผ่าศูนย์กลางโมเลกุล

D) รัศมีโคเวเลนต์ E) อิเล็กตรอนคู่ร่วมพันธะ

2) พันธะชนิดใด มีความยาวพันธะมากที่สุด

A) พันธะเดี่ยว B) พันธะคู่ C) พันธะสาม

D) พันธะไอออนิก E) พันธะระหว่างคาร์บอนอะตอม

3) จงเลือกพันธะที่แข็งแรงมากที่สุด

A) C—S B) C—O C) C═C D) C≡N E) C—F

Sample Problem 4.1 **คำถามทบทวนบทเรียน**

4) พันธะ**เดี่ยว** ประกอบด้วยอิเล็กตรอนคู่ร่วมพันธะกี่**คู่** **(คำถาม ถามว่ากี่คู่ ไม่ใช่กี่อิเล็กตรอน)**

A) 1 B) 2 C) 3

D) 4 E) 6

5) พันธะคู่ ประกอบด้วยอิเล็กตรอนคู่ร่วมพันธะกี่**คู่** **(คำถาม ถามว่ากี่คู่ ไม่ใช่กี่อิเล็กตรอน)**

A) 1 B) 2 C) 3

D) 4 E) 6

6) พันธะสาม ประกอบด้วยอิเล็กตรอนคู่ร่วมพันธะกี่**คู่** **(คำถาม ถามว่ากี่คู่ ไม่ใช่กี่อิเล็กตรอน)**

A) 1 B) 2 C) 3

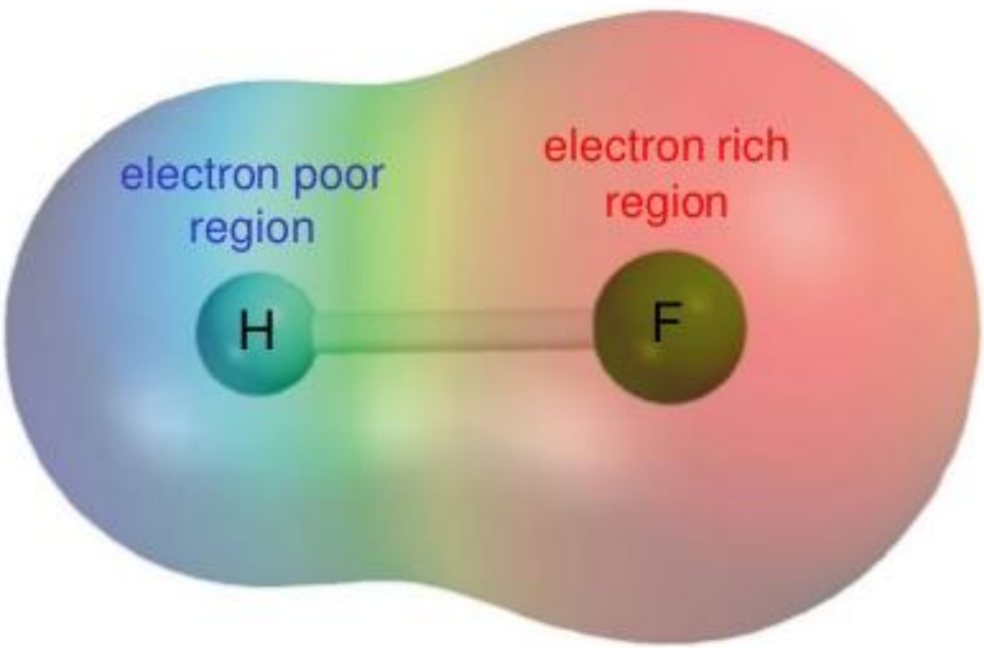
D) 4 E) 6

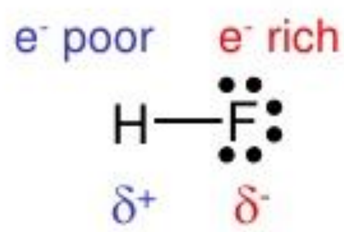
การเขียนโครงสร้างลิวอิส

- Electronegativity
- Lewis structure
- Formal Charge and Lewis structures

Electronegativity (EN)

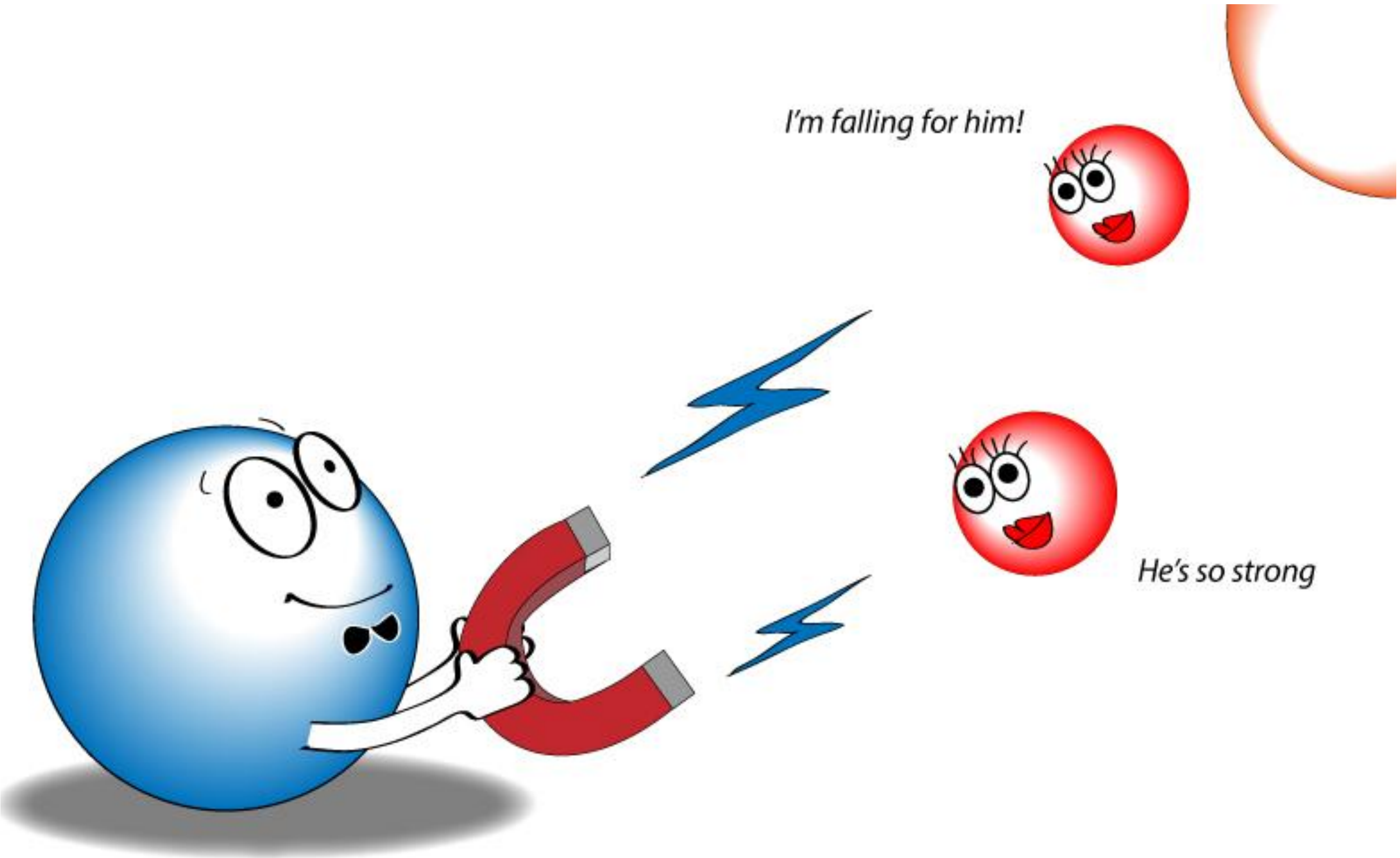
EN is the a measure of an atom's ability to attract the shared electrons of a covalent bond to itself.

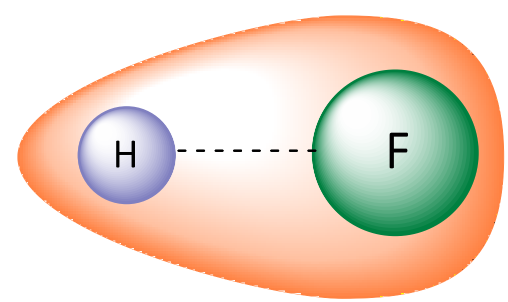




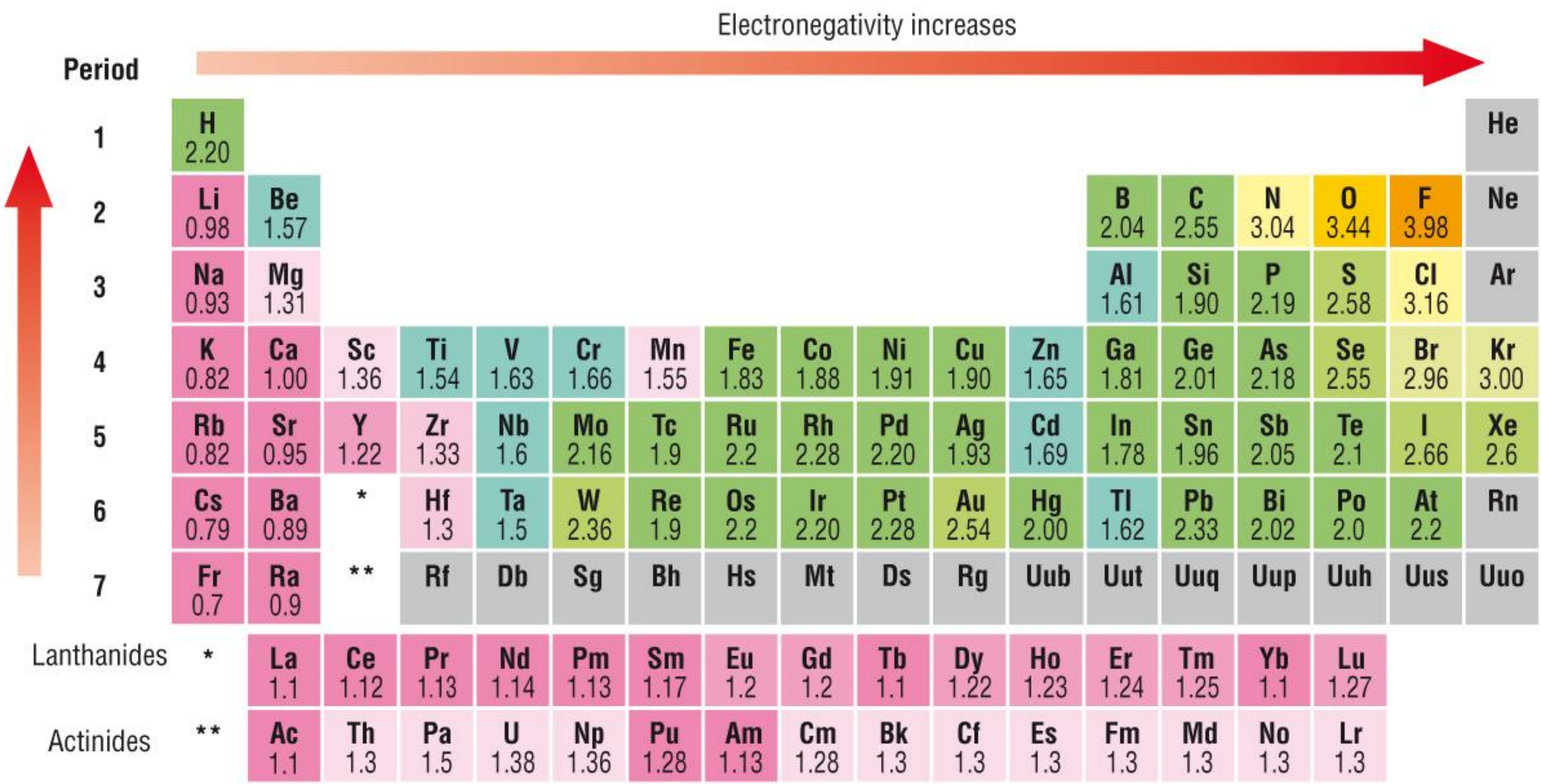
Chang, R. (2010). *Chemistry*: McGraw-Hill.

Electronegativity (EN)





Trends in Electronegativity



F > O > Cl > N > Br

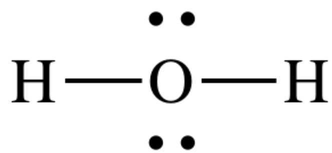
Lewis structure

Lewis structure is a representation of a molecule that shows how the valence electrons are arranged among the atoms in the molecule.

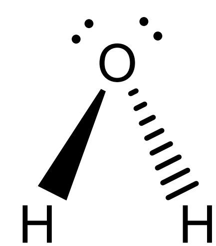
- ❑ Indicate the kind of bonding and which atoms are bonded in molecules and polyatomic ions.
- ❑ Do NOT indicate the molecular shape or structure.

H_2O

Molecular formula



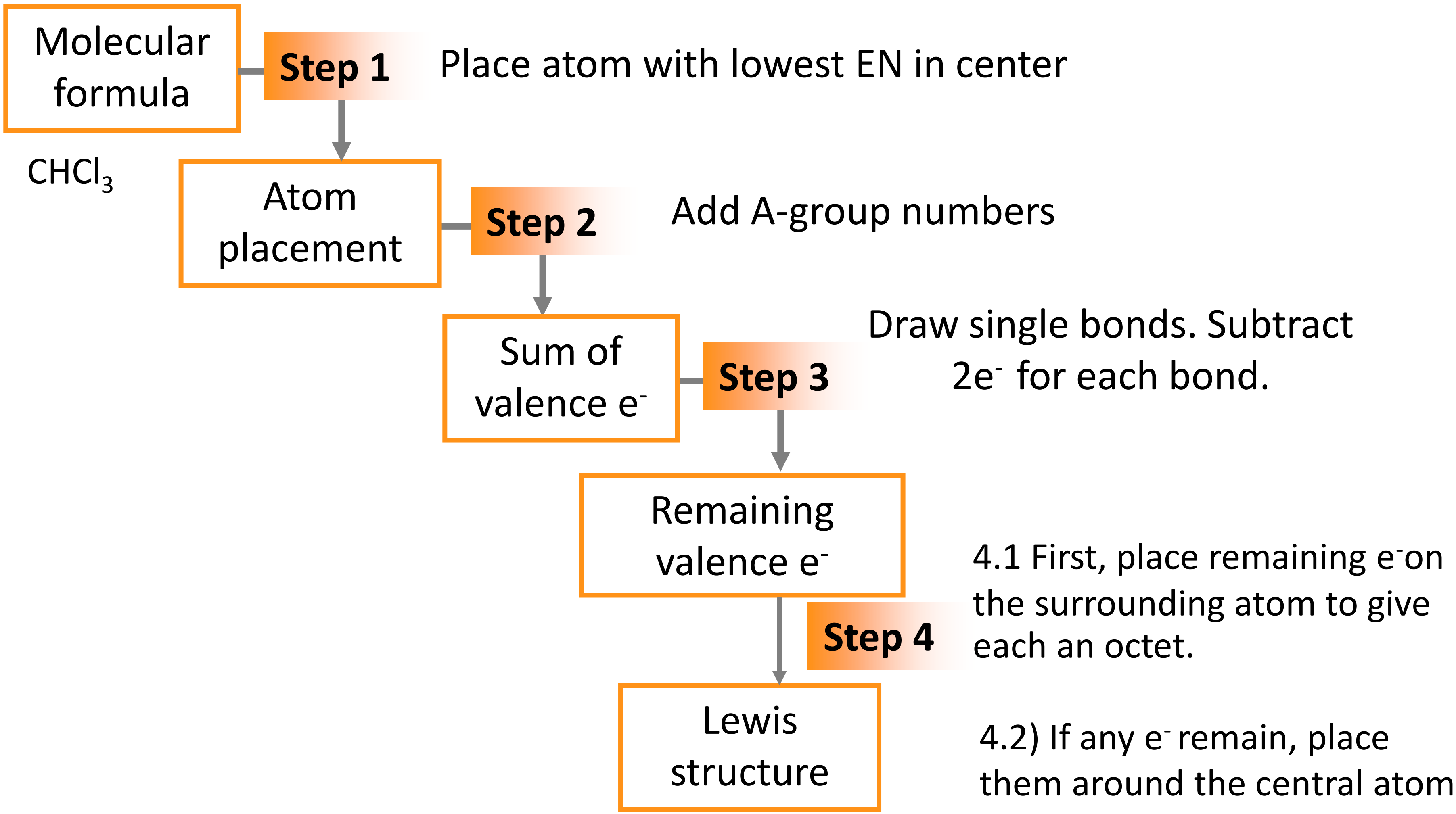
Lewis structure



Molecular shape

Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

Guidelines for Writing Lewis Structures



Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

Example
Lewis structure

Molecular formula

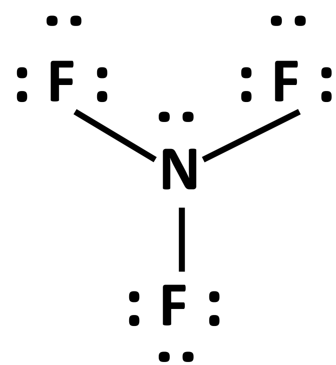
Atom placement

Sum of valence e^-

Remaining valence e^-

Lewis structure

For NF_3



N 5e^-

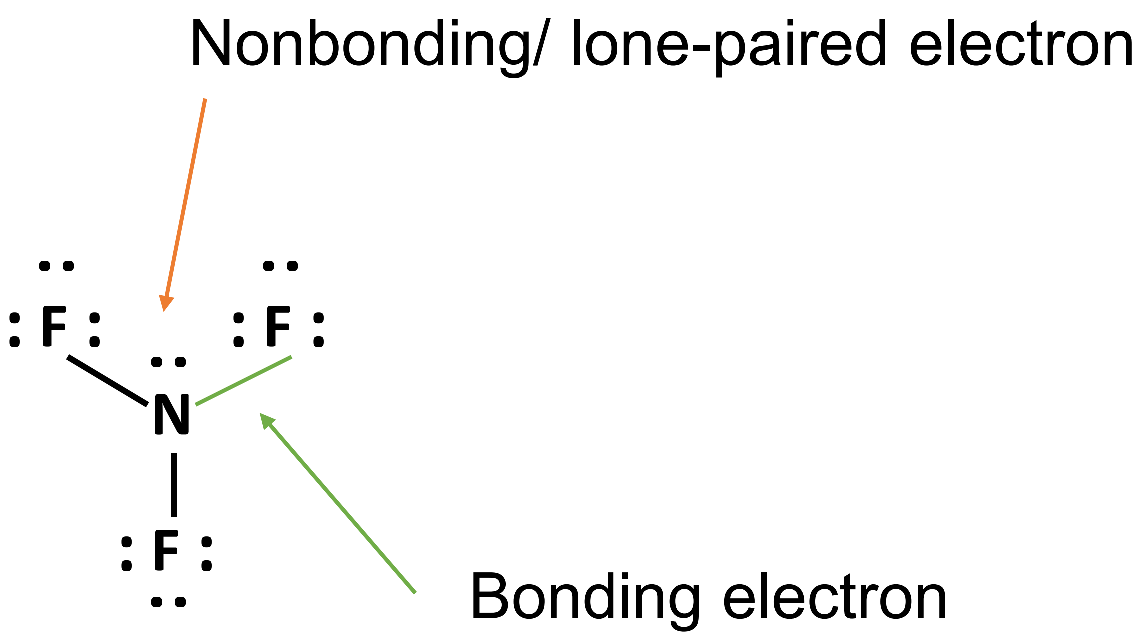
F 7e^- X 3 = 21e^-

Total 26e^-

H atoms form 1 bond.
C atoms form 4 bonds.
N,P atoms form 3 bonds.
(sometime N, P form 5 bond)
O,S atoms form 2 bonds.
(sometime S form 6 bond)
F, Cl, Br, I form one bond.

Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

Example
Lewis structure



SAMPLE PROBLEM 2.11 **Writing Lewis Structures for Molecules with One Central Atom**

PROBLEM: Write a Lewis structure for CCl_2F_2, one of the compounds responsible for the depletion of stratospheric ozone.

SAMPLE PROBLEM 2.12

Writing Lewis Structures for Molecules with One Central Atom

PROBLEM: Write the Lewis structure of each of the following;

CH_4	H_2S	$BeCl_2$
PCl_3	OF_2	

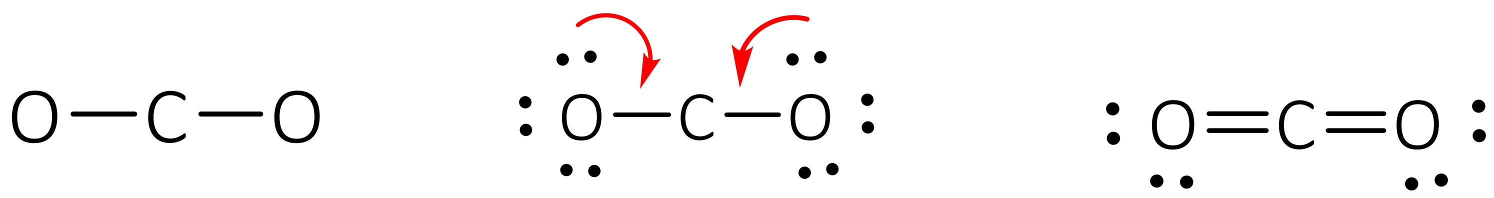
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Writing Lewis Structures for Molecules with Multiple Bonds

For molecules with multiple bonds, there is a ***Step 5***

Step 5 If a central atom does not have 8e$^-$, an octet, then two e$^-$ (either single or nonbonded pair e$^-$)can be moved in to form a multiple bond.

CO_2 : SUM VE = 16 e



Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

SAMPLE PROBLEM 2.13

Writing Lewis Structures for Molecules with Multiple Bonds

PROBLEM: Write the Lewis structure of each of the following;

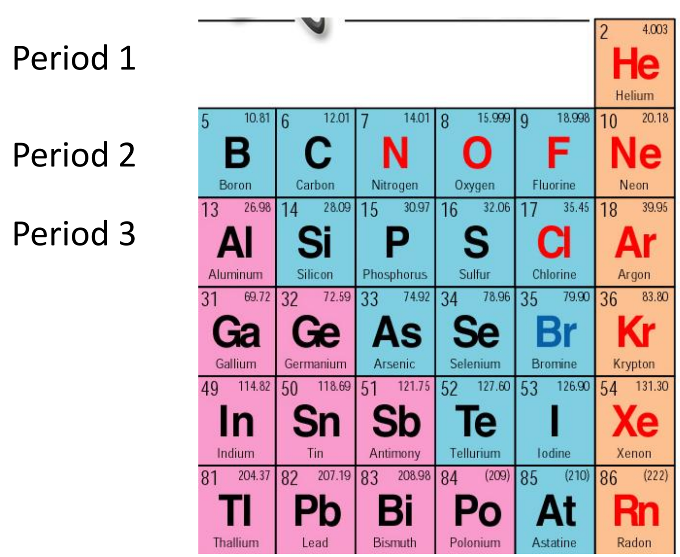
N_2 HCN NOCl

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Writing Lewis Structures for Octet-Rule Exceptions

Expanded Valence Shells

- The central atom must be large and have empty orbitals that can hold the additional pairs.
- Therefore, **expanded valence shells** occur only with *nonmetals from Period 3 or higher because they have d orbitals available*



Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

SAMPLE PROBLEM 2.14 **Writing Lewis Structures for Octet-Rule Exceptions**

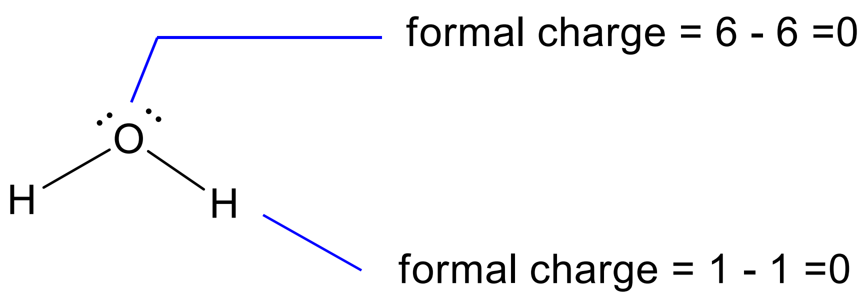
PROBLEM: Write a Lewis structure for;
(a) PCl_5, (b) SF_6, (c) ClF_3 (d) BCl_3

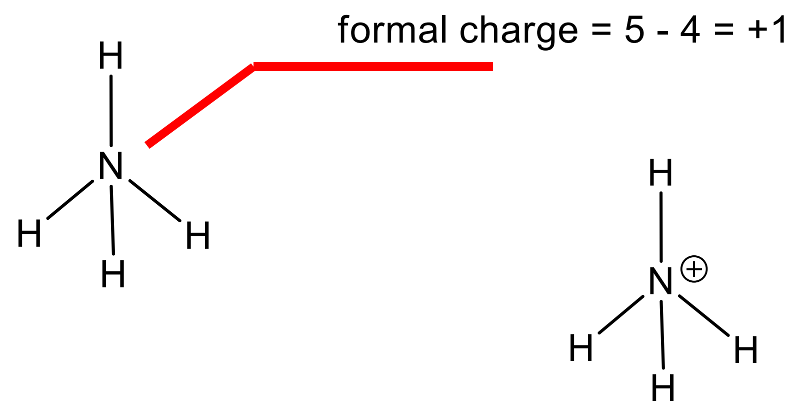
Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

Formal Charge and Lewis structures

Formal charge is the charge assigned to an atom in a molecule, assuming that electrons in all chemical bonds are shared equally between atom.

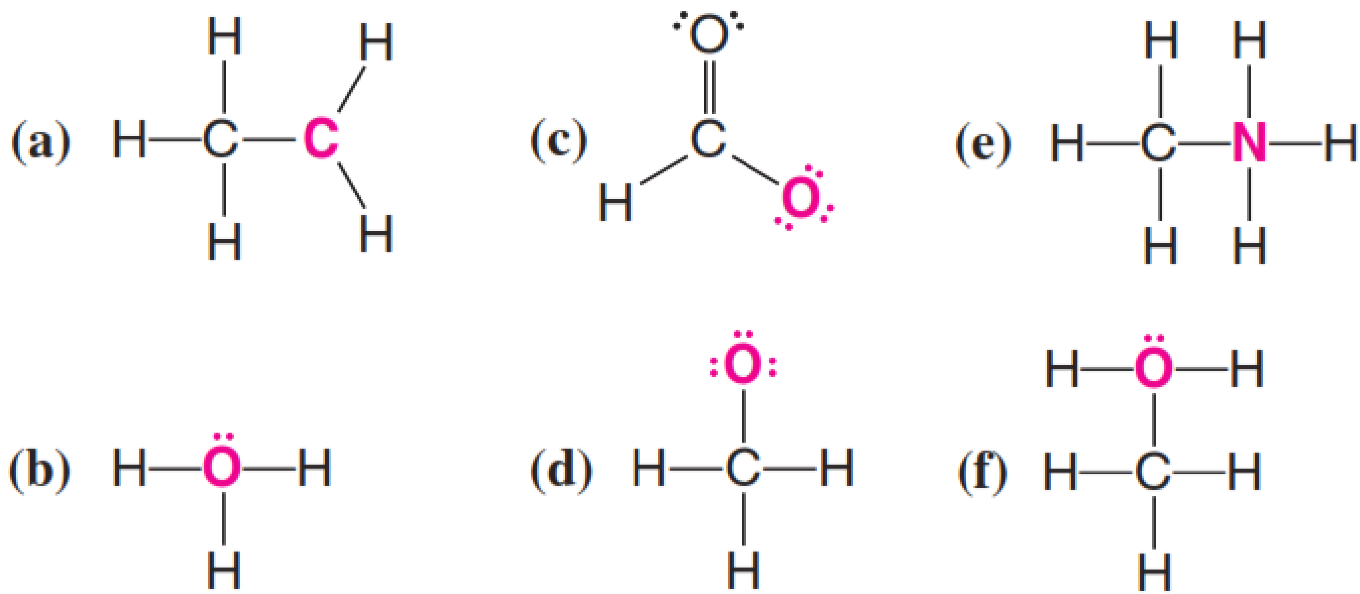
Formal charge = The number of Valence electron – the number of electrons surrounding an atom





SAMPLE PROBLEM 2.15 **Determining formal charge**

PROBLEM: Assign the proper formal charge to the colored atom in each of the following structures:

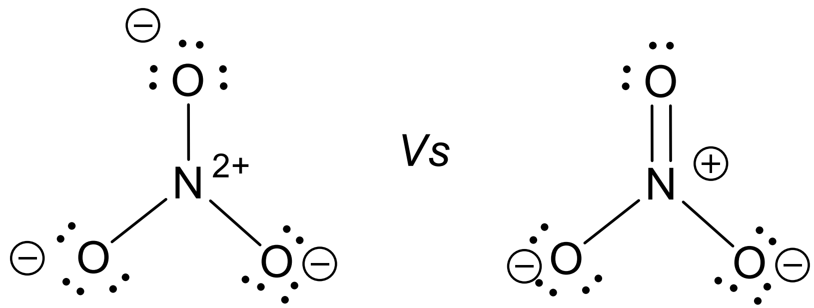


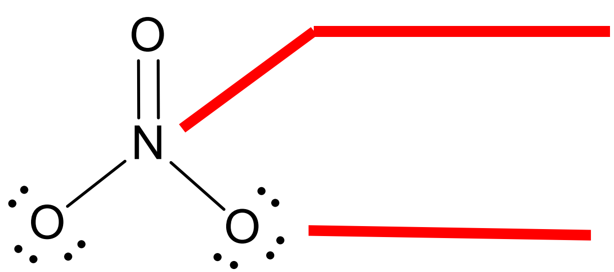
Using Formal Charges to Determine the Best Lewis Formula

We will use a fundamental assumptions about formal charges to evaluate Lewis structures:

- ❑ **Atoms in molecules try to achieve formal charges as close to zero as possible**

NO_3^-





formal charge = 5 - 4 = +1

formal charge = 6 - 7 = -1

formal charge = 6 - 7 = -1

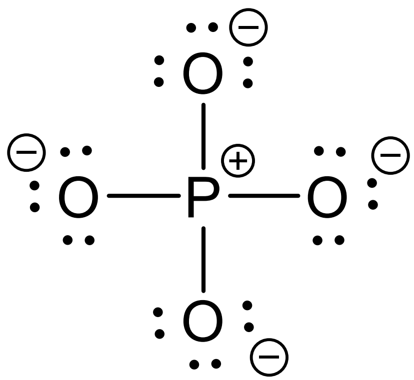
over all charge = -1

Ebbing, D., & Gammon, S. D. (2007). *General Chemistry*: Cengage Learning.

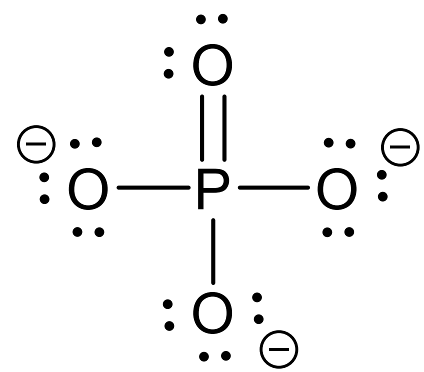
SAMPLE PROBLEM 2.16A

Using Formal Charges to Determine the Best Lewis Formula

PROBLEM: Which Lewis structure are most appropriate according to the formal charges?



Vs



Ebbing, D., & Gammon, S. D. (2007). *General Chemistry*: Cengage Learning.

SAMPLE PROBLEM 2.16C

Using Formal Charges to Determine the Best Lewis Formula

PROBLEM: Write the Lewis structure of each of the following;

(a) BH_4^- (b) $AlCl_4^-$ (c) NO_2^- (d) SO_2

Shape of Molecules

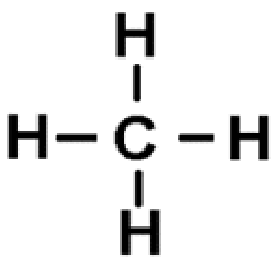
(VSEPR Theory)

Outline

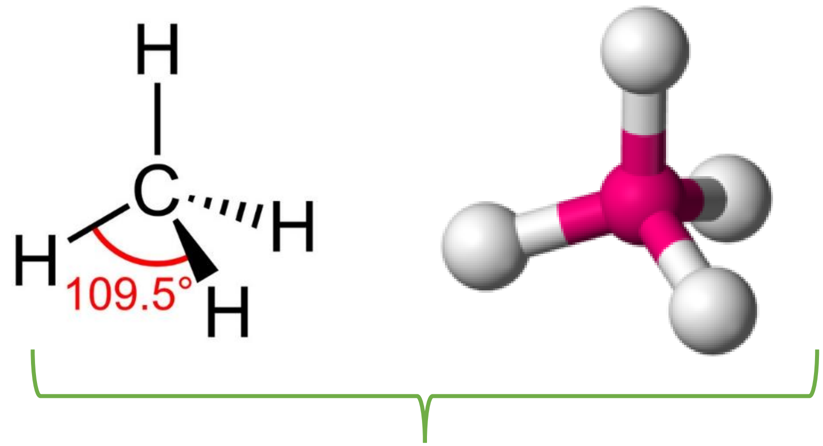
- Molecular shapes
- VSEPR Theory
- Classify molecular shapes.
  - Molecules in Which the Central Atom Has no Lone Pairs
  - Molecules in Which the Central Atom Has One or More Lone Pairs
- Determining a molecular shape.
- Molecular shape and Molecular polarity
- Intermolecular force
- Metallic bond

Molecular shape (Molecular geometry)

- The **molecular shape** is the three-dimensional arrangement of nuclei joined by the bonding groups.



Lewis structure



Molecular shape

- To obtain the molecular shape, chemists start with the Lewis structure and apply valence-shell electron-pair repulsion **(VSEPR) theory**.

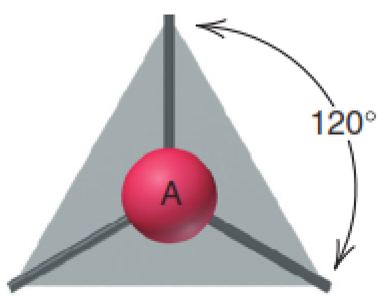
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

VSEPR theory

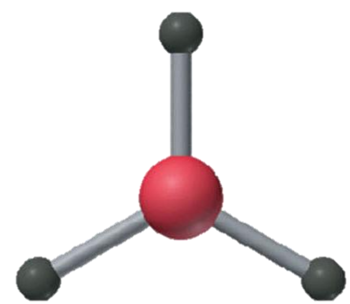
- **VSEPR** principle is that, to minimize repulsions, each group of valence electrons around a central atom is located as far as possible from the others.

- The **electron-groups arrangement** is defined by the bonding and nonbonding electron groups around the central atom, but the molecular shape is defined by the relative positions of the atomic nuclei.

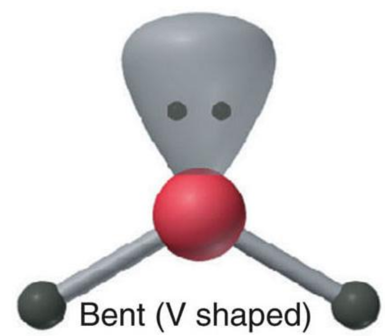
- the same electron-group arrangement can give rise to different Molecular shapes:



trigonal planar arrangement



Trigonal planar shape



Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Classify molecular shapes

To classify molecular shapes, we assign each a specific;

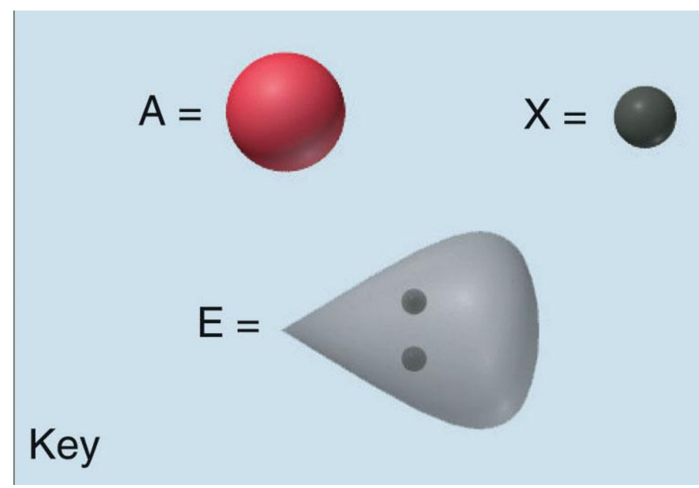
$$AX_mE_n$$

integers

A - central atom

X -surrounding atom/bonding electron

E -nonbonding valence electron-group (lone-pair electron)

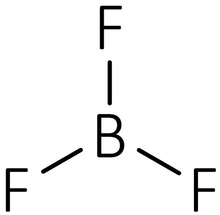


Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Classify molecular shapes

- ❑ Molecules in Which the Central Atom Has **No** Lone Pairs

AX_2 AX_3 AX_4 AX_5 AX_6



No Lone Pairs

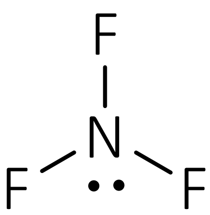
- ❑ Molecules in Which the Central Atom Has one or more Lone Pairs

3 e$^-$ groups
- AX_2E

4 e$^-$ groups
- AX_3E
- AX_2E_2

5 e$^-$ groups
- AX_4E
- AX_3E_2

6 e$^-$ groups
- AX_5E
- AX_4E_2



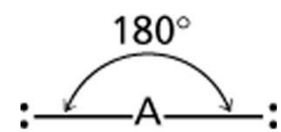
Has Lone Pairs

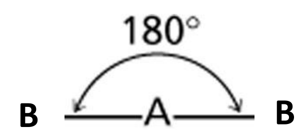
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Classify molecular shapes

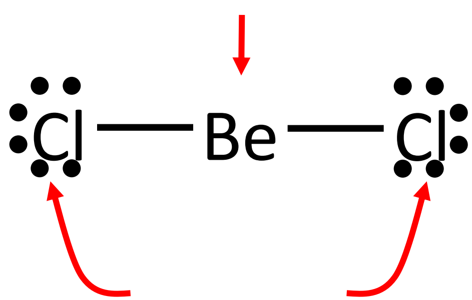
(Molecules in Which the Central Atom Has No Lone Pairs)

Class	# of surrounding atom	# lone pairs on central atom	Electron group arrangement	Molecular shape
AX_2	2	0	linear	linear

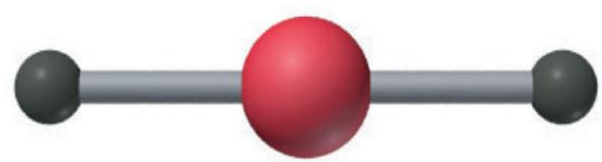




0 lone pairs on central atom



2 atoms bonded to central atom

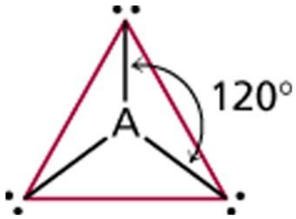
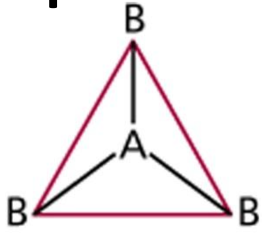


Linear

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Classify molecular shapes

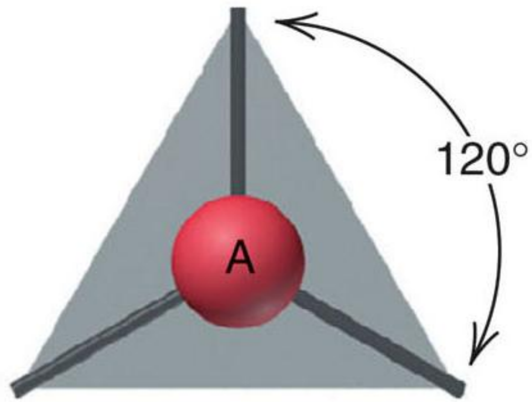
(Molecules in Which the Central Atom Has No Lone Pairs)

Class	# of surrounding atom	# lone pairs on central atom	Electron group arrangement	Molecular shape
AX_2	2	0	linear	linear
AX_3	**3**	**0**	**trigonal planar** 	**trigonal planar** 

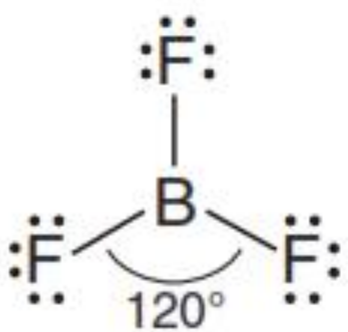
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

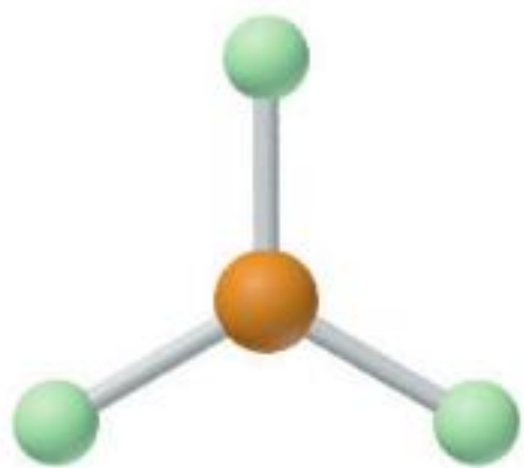
Class: **AX_3**

Trigonal planar arrangement



BF_3





Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Different ways to draw covalent bond

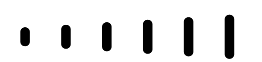
- Bond pair on paper

(normal line/ normal bond)

- Bond pair pointing out the paper

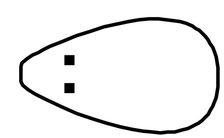
(wedged bond)

- Bond pair pointing into the paper



(dashed bond)

- Lone pair

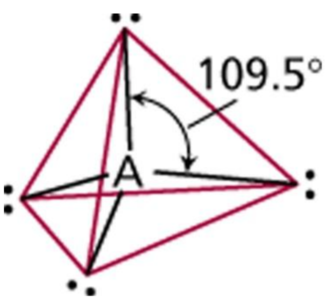


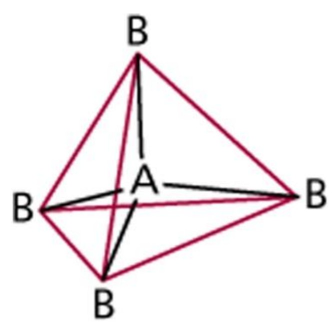
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Classify molecular shapes

(Molecules in Which the Central Atom Has No Lone Pairs)

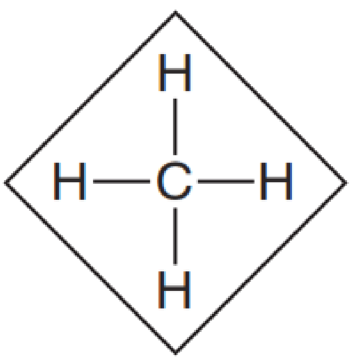
Class	# of surrounding atom	# lone pairs on central atom	Electron group arrangement	Molecular shape
AX_2	2	0	linear	linear
AX_3	3	0	trigonal planar	trigonal planar
AX_4	**4**	**0**	**tetrahedral**	**tetrahedral**

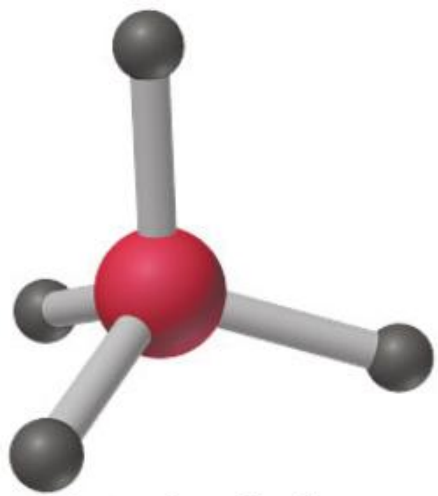




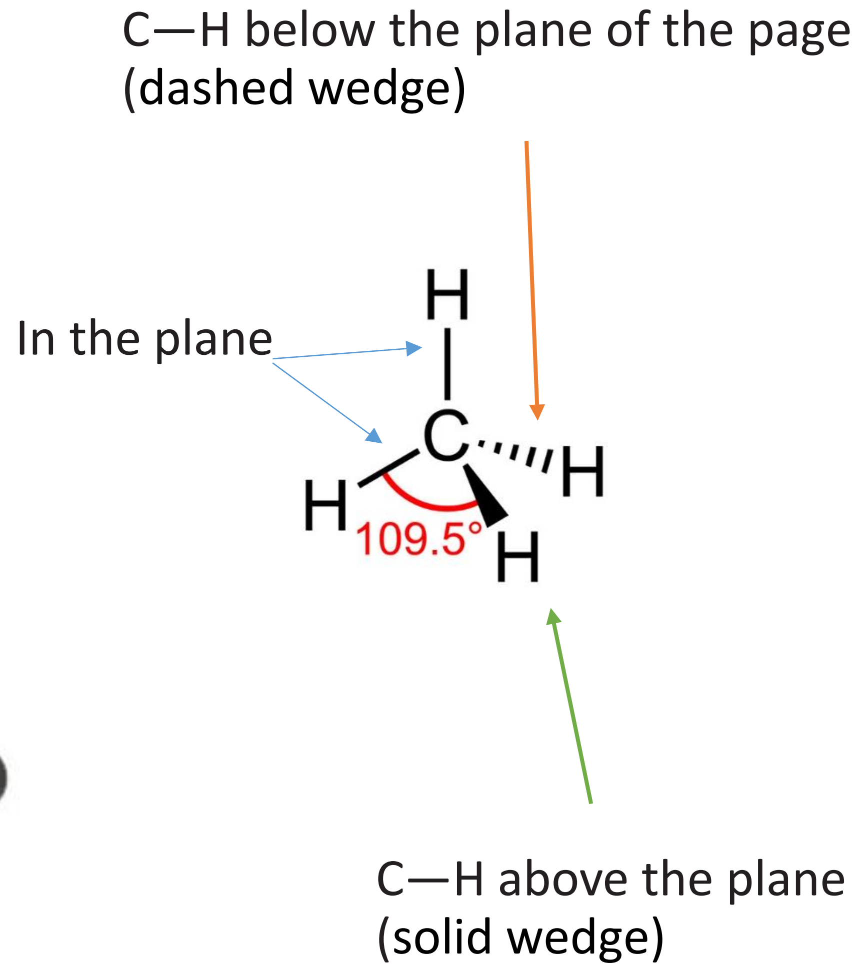
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Class: **AX_4**





Tetrahedral

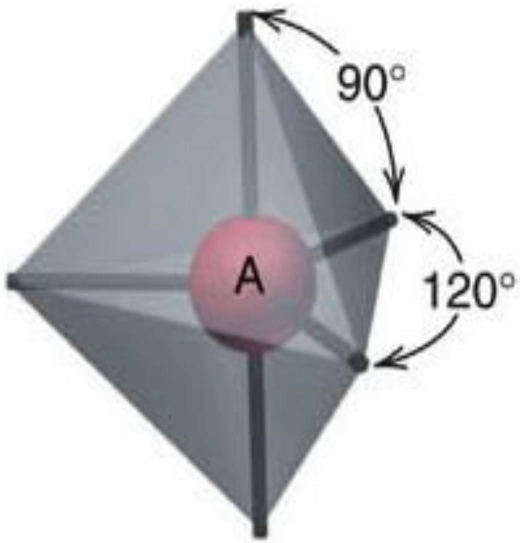


Classify molecular shapes

Class	# of surrounding atom	# lone pairs on central atom	Electron group arrangement	Molecular shape
AX_2	2	0	linear	linear
AX_3	3	0	trigonal planar	trigonal planar
AX_4	4	0	tetrahedral	tetrahedral
AX_5	**5**	**0**	**trigonal bipyramidal**	**trigonal bipyramidal**

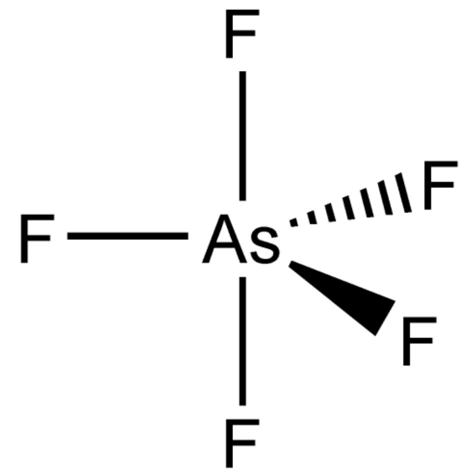
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Class: **AX_5**



Trigonal bipyramidal arrangement

Trigonal bipyramidal shape



AsF_5

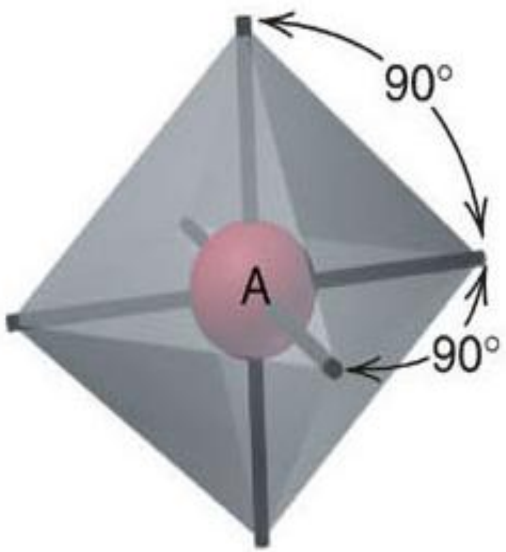
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Classify molecular shapes

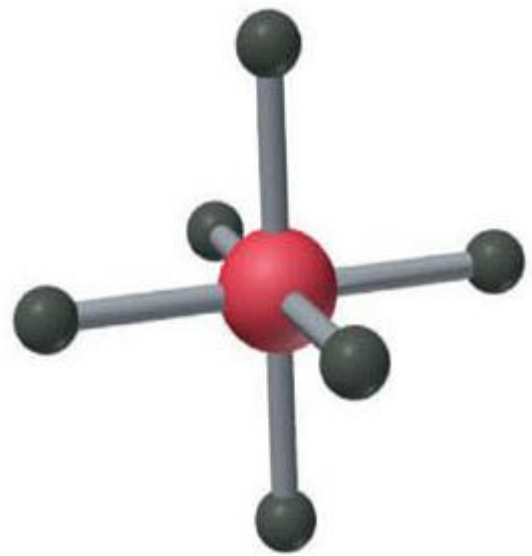
Class	# of surrounding atom	# lone pairs on central atom	Electron group arrangement	Molecular shape
AX_2	2	0	linear	linear
AX_3	3	0	trigonal planar	trigonal planar
AX_4	4	0	tetrahedral	tetrahedral
AX_5	5	0	trigonal bipyramidal	trigonal bipyramidal
AX_6	**6**	**0**	**octahedral**	**octahedral**

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

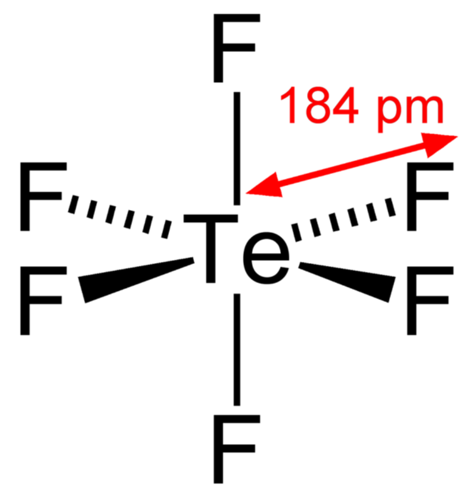
Class: **AX**$_6$



Octahedral arrangement



Octahedral shape



TeF_6

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

The steps in determining a molecular shape.

Molecular formula

Step 1 Draw a Lewis structure

Lewis structure

Step 2 Count *all* e^- groups around central atom (A)

Electron-group arrangement

Step 3 Determine a class of molecule

Class (AX_mE_n)

Step 4 Determine e group arrangement

molecular shape

Determine the name of the molecular structure

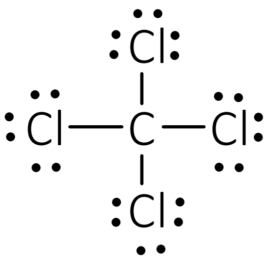
Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

SAMPLE PROBLEM 10.6

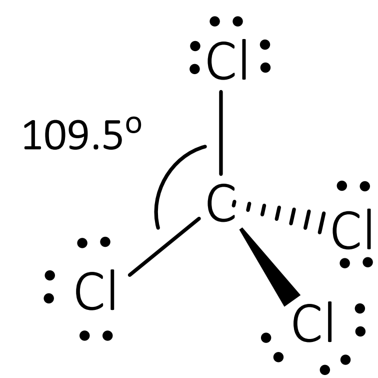
Predicting Molecular Shapes with Two, Three, or Four Electron Groups

PROBLEM: Draw the molecular shape and predict the bond angles (relative to the ideal bond angles) of CCl_4.

CCl_4.



Count e^- group → class AX_4 → 4 e^- group (4 bonding e^-) → Tetrahedral arrangement



→ Tetrahedral shape

PROBLEM 10.6A

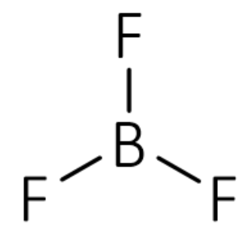
Predicting Molecular Shapes with Two, Three, or Four Electron Groups

PROBLEM: Draw the molecular shape and predict the bond angles (relative to the ideal bond angles) of (a) BCl_3 (b) NH_4^+ (c) PCl_5 (d) SF_6 (e) CO_2

Classify molecular shapes

- ❑ Molecules in Which the Central Atom Has **No** Lone Pairs

AX_2 AX_3 AX_4 AX_5 AX_6



No Lone Pairs

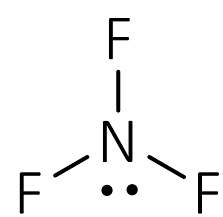
- ❑ Molecules in Which the Central Atom Has one or more Lone Pairs

3 e^- groups
- AX_2E

4 e^- groups
- AX_3E
- AX_2E_2

5 e^- groups
- AX_4E
- AX_3E_2

6 e^- groups
- AX_5E
- AX_4E_2



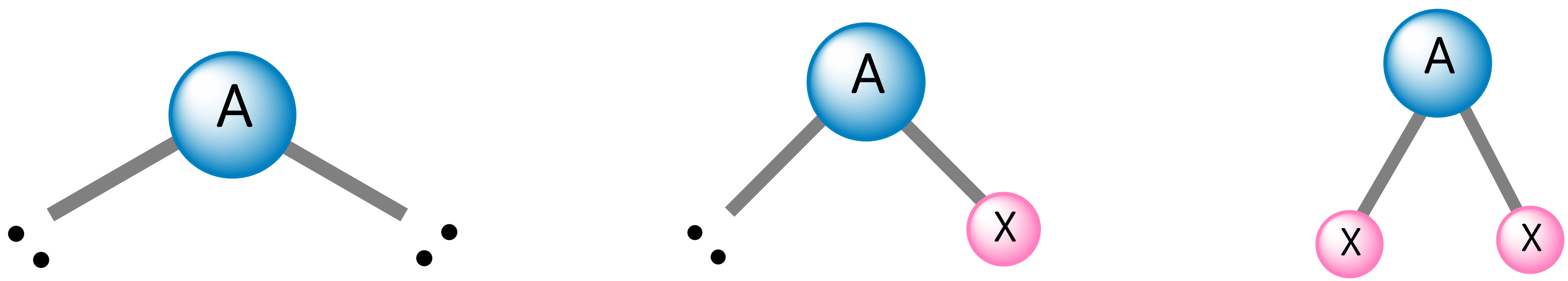
Has Lone Pairs

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Molecules in Which the Central Atom Has One or More Lone Pairs

- In order to predict the shape of a molecule, we can regard lone pair electron the same as bonding electron.

- The only difference is that lone pair electrons produces a strong repulsion.



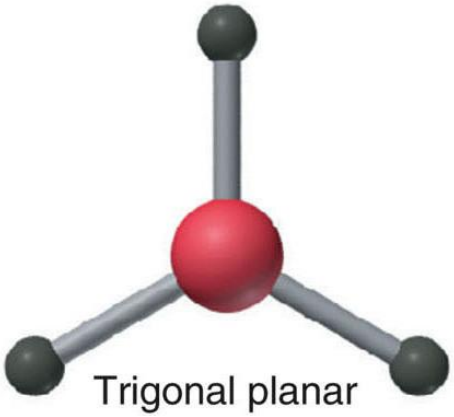
lone-pair *Vs* lone-pair repulsion > lone-pair *Vs* bonding repulsion > bonding *Vs* bonding repulsion

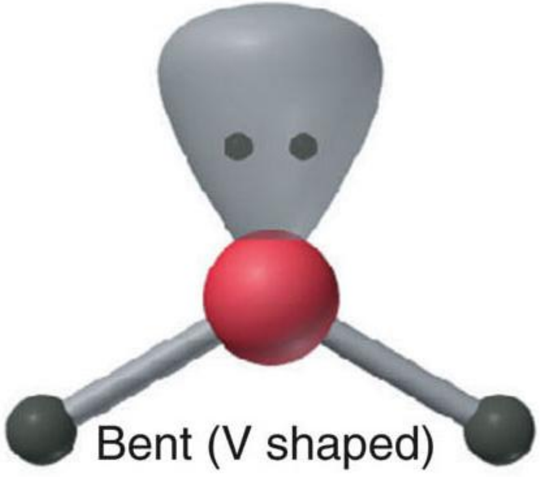
Chang, R. (2010). *Chemistry*: McGraw-Hill.

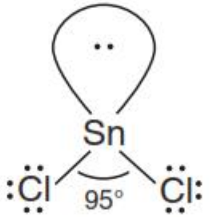
Molecular Shapes with Three electron Groups
(Trigonal Planar arrangement)

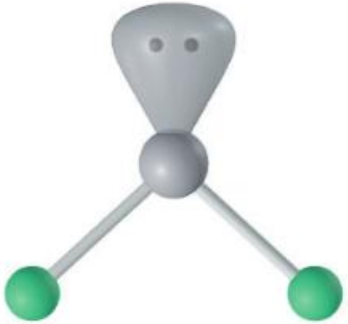
Class: AX_3

Class: AX_2E







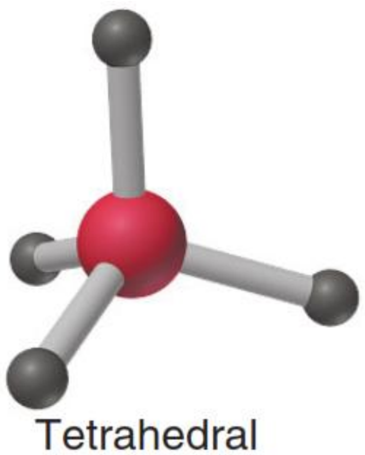


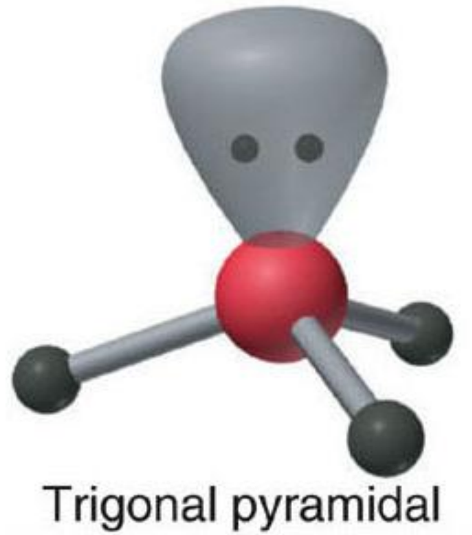
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

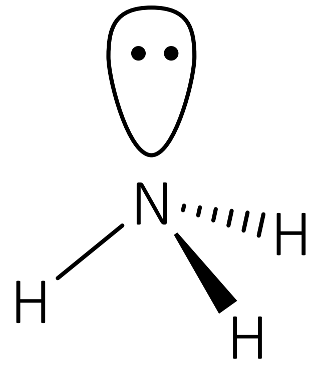
Molecular Shapes with <u>four</u> electron Groups
(tetrahedral arrangement)

Class: **AX_4**

Class: **AX_3E**





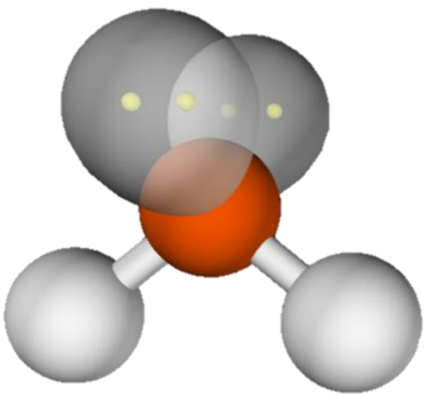


Trigonal pyramidal shape

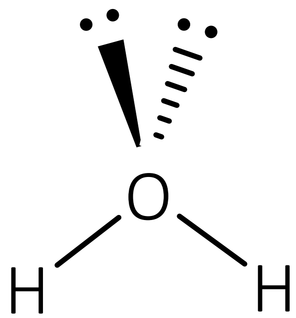
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

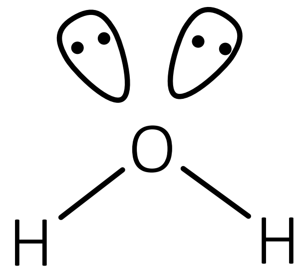
Molecular Shapes with <u>four</u> electron Groups
(tetrahedral arrangement)

Class: AX_2E_2



Bent shape
(tetrahedral arrangement)



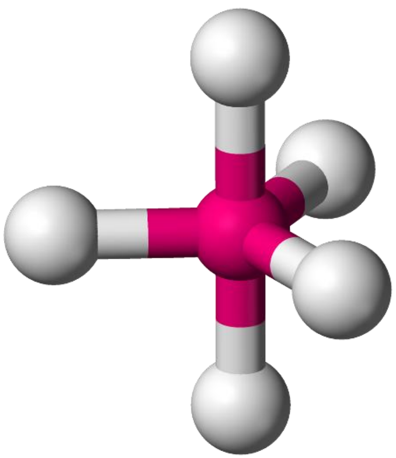


Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

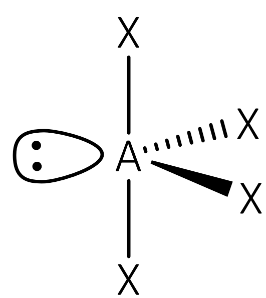
Molecular Shapes with five electron Groups

(Trigonal bipyramidal arrangement)

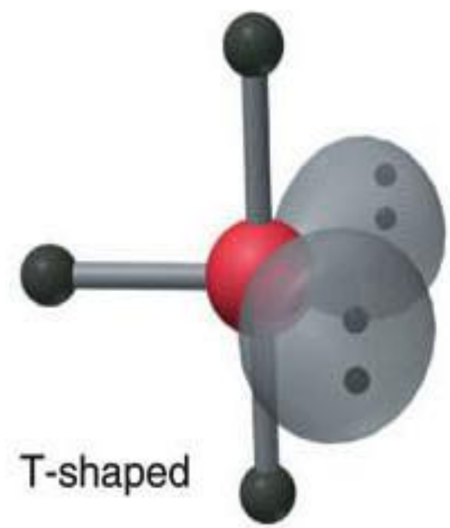
Class: AX_5

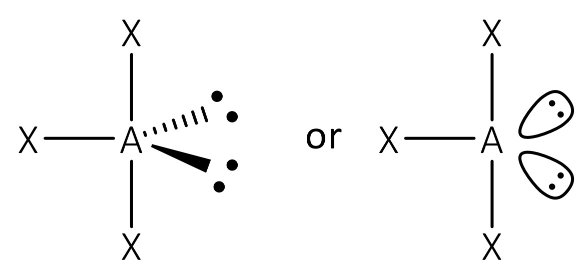


Class: AX_4E



Class: AX_3E_2

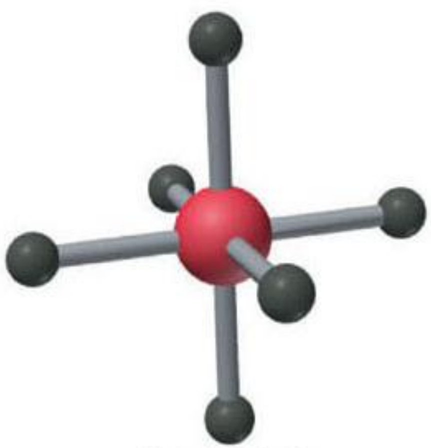




Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

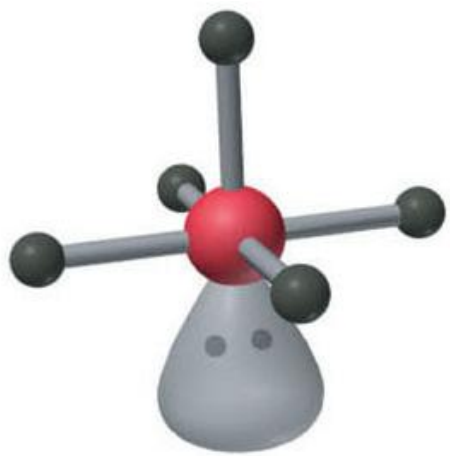
Molecular Shapes with SIX electron Groups
(Octahedral arrangement)

Class: AX_6

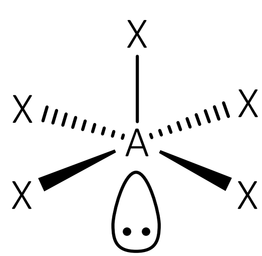


Octahedral

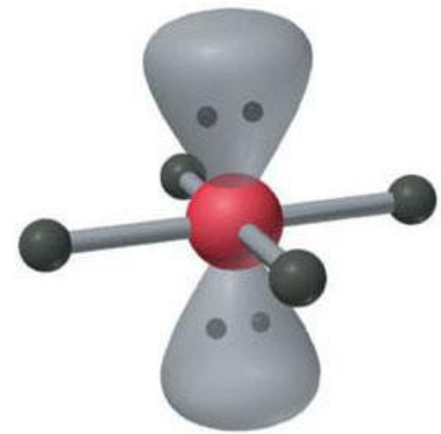
Class: AX_5E



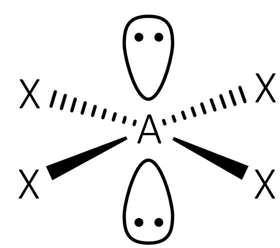
Square pyramidal



Class: AX_4E_2



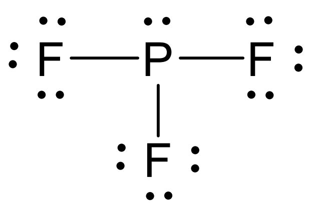
Square planar



Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

SAMPLE PROBLEM 10.7 **Predicting Molecular Shapes with Two, Three, or Four Electron Groups**

PROBLEM: Predict electron group arrangement and draw the molecular shape of PF_3



Count e^- group

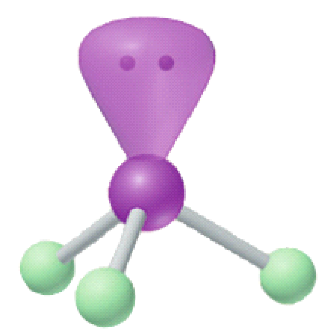
class AX_3E

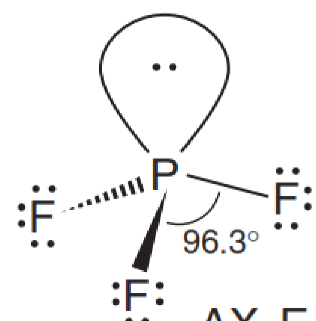
$4\ e^-$ group

❑ 3 bonding e^-

❑ 1 lone pair e

Tetrahedral arrangement





AX_3E

Trigonal pyramidal shape

PROBLEM 10.7A

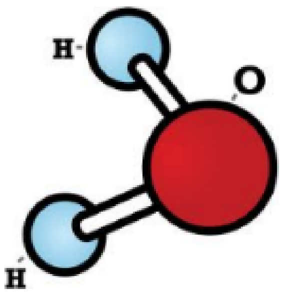
Predicting Molecular Shapes with Two, Three, or Four Electron Groups

PROBLEM: Predict electron group arrangement and draw the molecular shape of (a) H_2S (b) OF_2 (c) $PbCl_2$ (d) SF_2 (e) CS_2

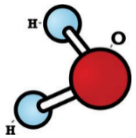
PROBLEM 10.8

Predicting Molecular Shapes with five or sive Groups

PROBLEM: Predict electron group arrangement and draw the molecular shape of (a) $SbCl_5$ (b) BrF_5 (c) XeF_4 (d) IF_3 (e) $SOCl_2$*



MOLECULAR SHAPE
AND
MOLECULAR POLARITY



MOLECULAR SHAPE AND MOLECULAR POLARITY

Knowing the shape of its molecules is key to understanding the molecular polarity of a substance.

MP/BP

Polar molecules have higher MP's and BP's than nonpolar molecules.....Why?

- Magnitude of Dipole moment influences MP and BP

  e.g. H_2O vs H_2S

Solubility

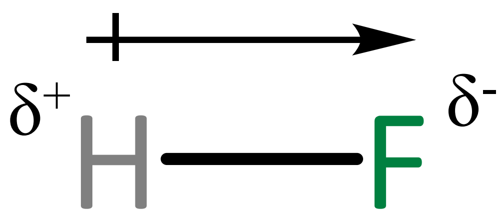
: Like dissolves Like

- Polar solutes dissolve in polar solvents
- Nonpolar solutes dissolve in nonpolar solvents

Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

Relating Dipole moment and Molecular shape

- We can sometimes relate the presence or absence of a dipole moment in a molecule to its molecular geometry.
- We point a polar arrow (⟼) toward the atom with higher EN in each bond.



Polar bond
Polar molecule

nonpolar bond
nonpolar molecule

Polar molecule has dipole moment

Nonpolar molecule don't has dipole moment

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Predicting Polarity of the molecules

The presence of polar bonds does not always result in a polar molecule. Here are three cases:

1) polar bonds, nonpolar molecule.
2) polar bonds, polar molecule
3) Same shapes, different polarities.

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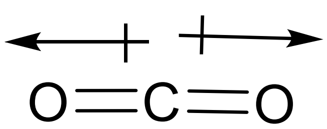
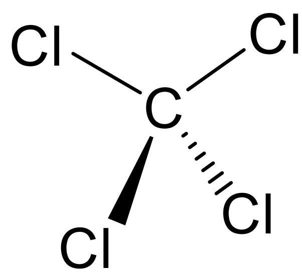
1 polar bonds, nonpolar molecule

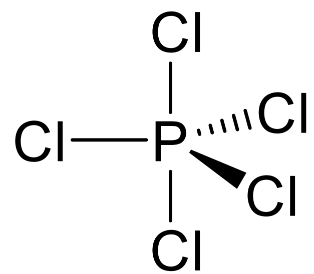
Symmetrical Molecules with Polar Bonds of equal dipole moment

a) CO_2 , BCl_3, and CCl_4

b) PCl_5 and SF_6

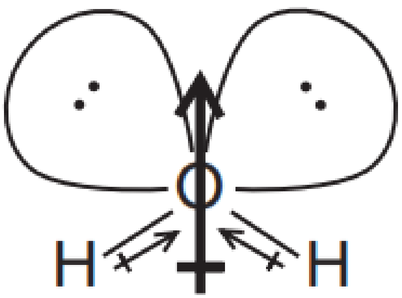


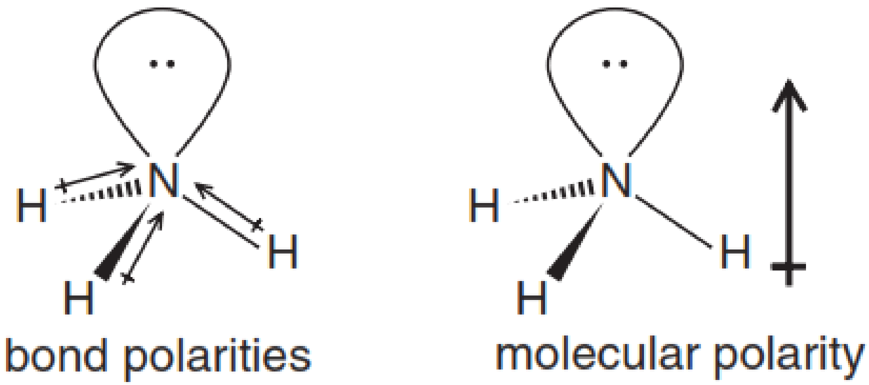




2 polar bonds, polar molecule

H_2O and NH_3 HCl





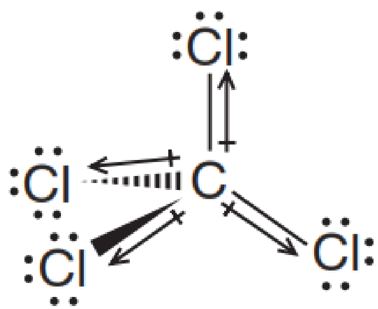
- ❑ **polar molecule**
- ❑ Polar bond
- ❑ Bent

- ❑ **polar molecule**
- ❑ Polar bond
- ❑ Trigonal pyramidal

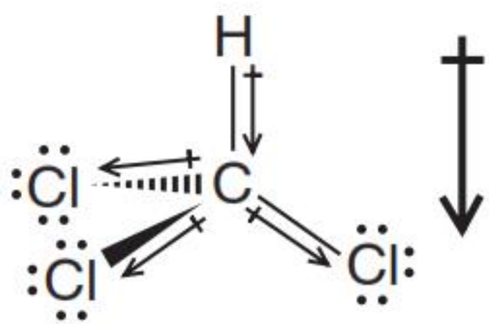
Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

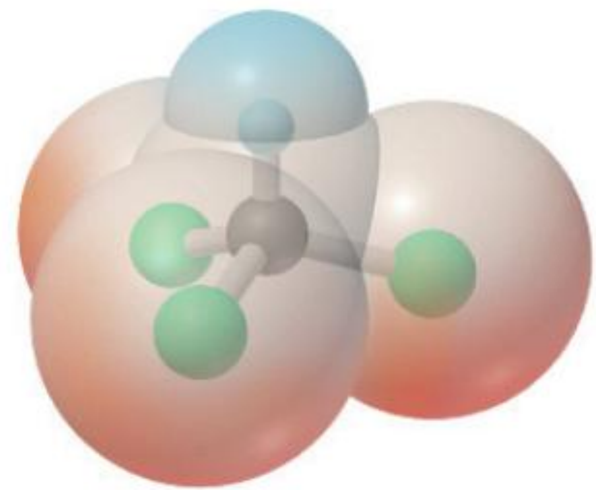
3 Same shapes, different polarities.

When different molecules have the same shape, the identities of the surrounding atoms affect polarity.



- ❑ **Nonpolar molecule**
- ❑ Polar bond
- ❑ Tetrahedral





- ❑ **polar molecule**
- ❑ Polar bond
- ❑ Tetrahedral

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PROBLEM 10.9

Predicting the Polarity of Molecules

PROBLEM: From electronegativity (EN) values (button) and their periodic trends, predict whether each of the following molecules is polar and show the direction of bond dipoles and the overall molecular dipole when applicable:

(a) Ammonia, NH_3

(b) Boron trifluoride, BF_3

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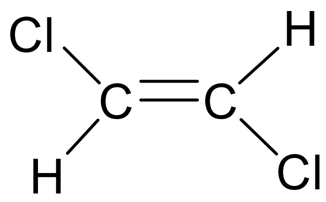
PROBLEM 10.9

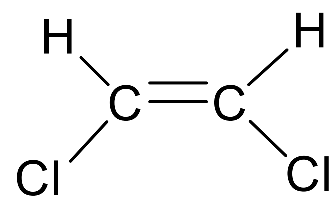
Predicting the Polarity of Molecules

PROBLEM Predict whether each of the following molecules is polar and show the direction of bond dipoles and the overall molecular dipole when applicable

(a)



trans



cis

(b) $SOCl_2$

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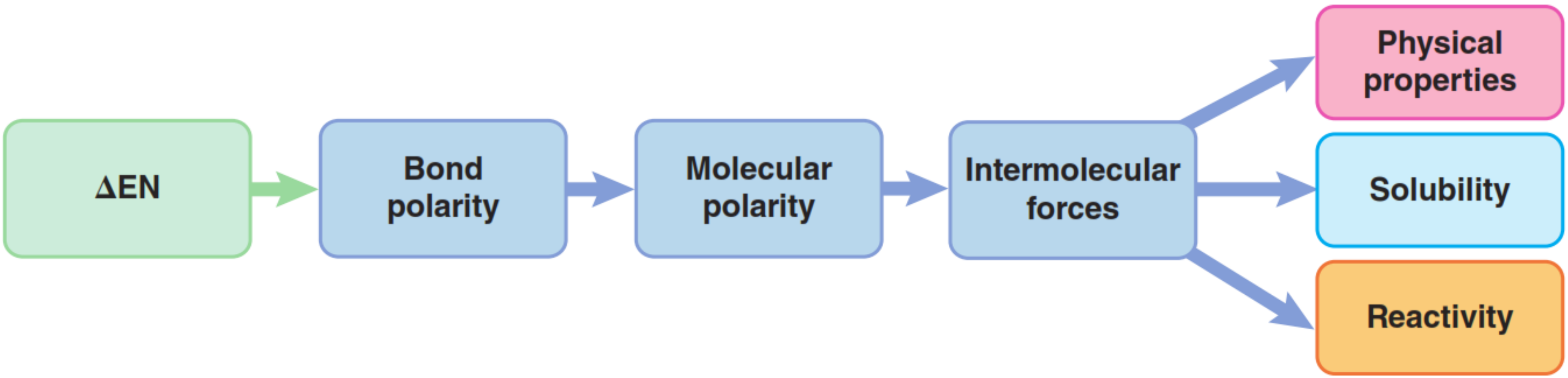
The influence of atomic properties on macroscopic behavior

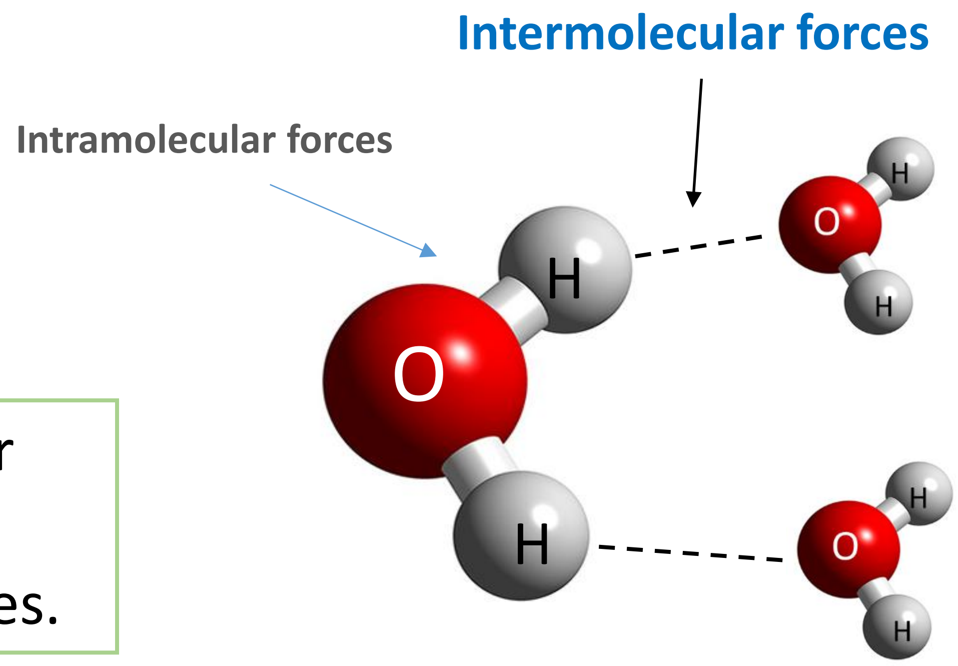


Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

Intermolecular Forces

Intermolecular Forces

- ❑ ***Intramolecular forces*** hold atoms together in a molecule.
  - ionic bond, covalent bond
- ❑ ***Intermolecular forces*** are attractive forces **between** molecules.



Generally, **inter**molecular forces are much weaker than **intra**molecular forces.

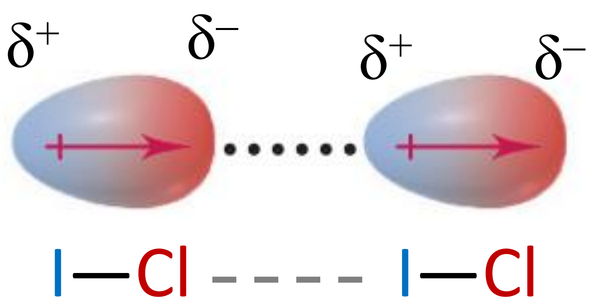
Chang, R. (2010). *Chemistry:* McGraw-Hill.

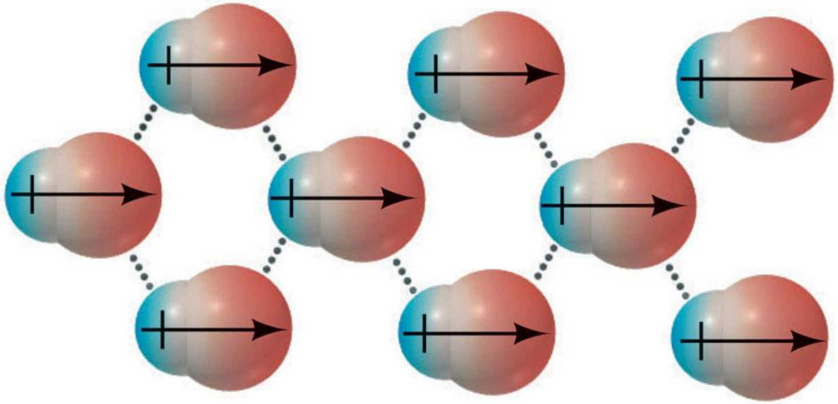
Intermolecular Forces

- Dipole-Dipole Forces
- Dispersion Forces (London forces)
- Hydrogen bond *(A special type of dipole-dipole force)*

Dipole-Dipole Forces

- Attractive forces between **polar molecules.**
- **Dipole-dipole force** occur between oppositely charged poles on polar molecules.

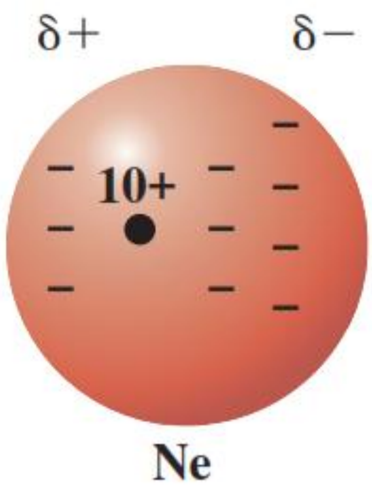




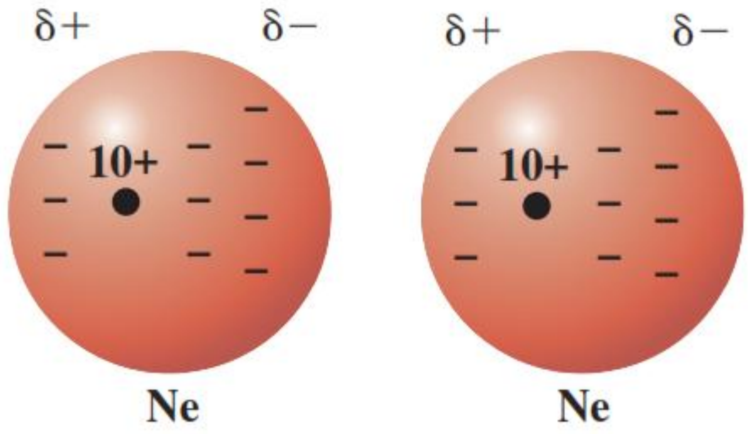
Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

Dispersion Forces (London forces)

- the weak attractive forces between **non-polar molecules** resulting from the small, instantaneous dipoles that occur because of the varying positions of the electrons during their motion about nuclei.



At some instant, there are more electrons on one side of a neon atom than on the other.



If this atom is near another neon atom, the electrons on that atom are repelled. The result is two instantaneous dipoles, which give an attractive force.

Ebbing, D., & Gammon, S. D. (2007). *General Chemistry:* Cengage Learning.

Dispersion Forces (London forces)

- London forces tend to increase with molecular weight.
- This is because molecules with larger molecular mass usually have more electrons, and London forces increase in strength with the number of electrons.

Compounds	Molar mass (g/mol)	Melting point
CH_4	16	-182.5
CF_4	88	-150
CCl_4	154	-23
CBr_4	332	90
CI_4	519.6	171

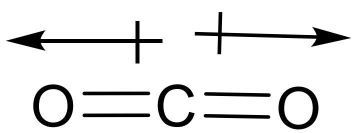
Chang, R. (2010). *Chemistry:* McGraw-Hill.

Ebbing, D., & Gammon, S. D. (2007). *General Chemistry:* Cengage Learning.

SAMPLE PROBLEM 11.1 **Determination of types of intermolecular forces**

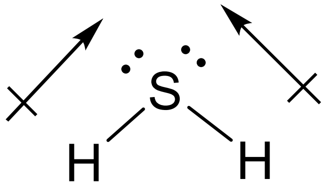
Problem: What type(s) of intermolecular forces exist between each of the following molecules?
CO_2 and H_2S

Strategy:
1) Write Lewis structure
2) Determine its molecular shape
3) Classify the species into three categories: ionic, polar (possessing a dipole moment), and nonpolar



Non-polar molecule

the intermolecular forces present is **dispersion forces**.



polar molecule

the intermolecular forces present **are dipole-dipole forces**, as well as **dispersion forces.**

Chang, R. (2010). *Chemistry:* McGraw-Hill.

SAMPLE PROBLEM 11.1A **Determination of types of intermolecular forces**

Problem: What type(s) of intermolecular forces exist between each of the following molecules?

(a) HBr (b) I_2 (c) PH_3 (d) SF_6

Chang, R. (2010). *Chemistry:* McGraw-Hill.

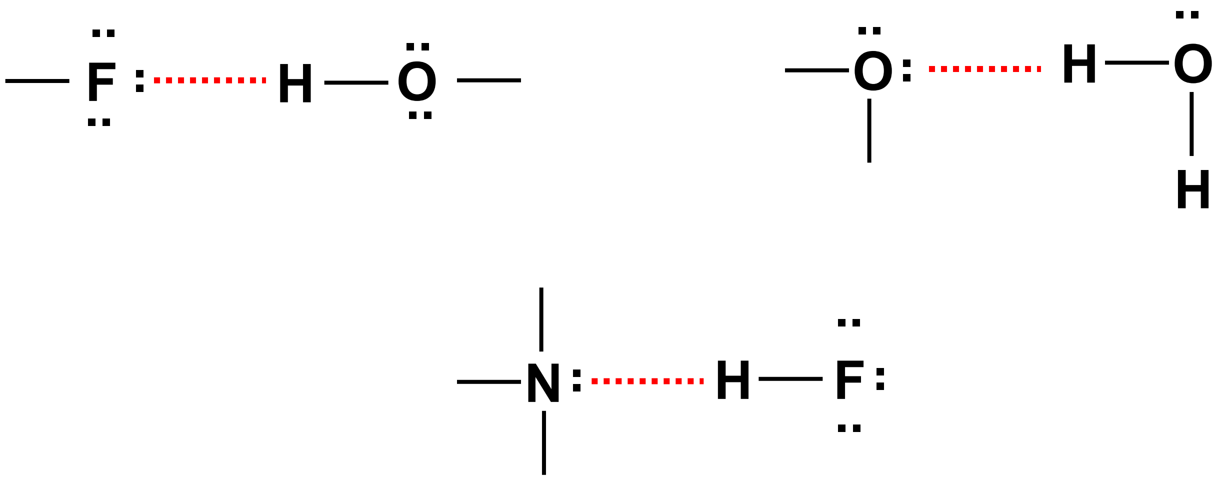
Intermolecular Forces

- ❑ Dipole-Dipole Forces
- ❑ Dispersion Forces (London forces)
- ❑ Hydrogen bond *(A special type of dipole-dipole force)*

Hydrogen bond

A hydrogen bond may occur when an H atom in a molecule, bound to small highly electronegative atom with lone pairs of electrons, is attracted to the lone pairs in another molecule.

The elements which are so electronegative are **N**, **O**, and **F**.



Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

SAMPLE PROBLEM 12.2

Drawing Hydrogen Bonds Between Molecules of a Substance

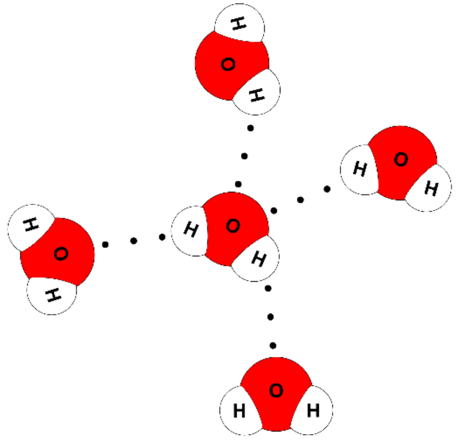
PROBLEM: Which of the following substances exhibits H bonding? For those that do, draw two molecules of the substance with the H bonds between them.

(a) CH_4 **(b)** H_2O **(c)** HCl

PLAN: Find molecules in which H is bonded to N, O or F. Draw H bonds in the format -B: ······ H-A-.

SOLUTION: **(a)** CH_4 has no H bonding sites. **(c)** has no H bonding sites

(b)

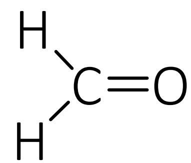


SAMPLE PROBLEM 12.2A

Drawing Hydrogen Bonds Between Molecules of a Substance

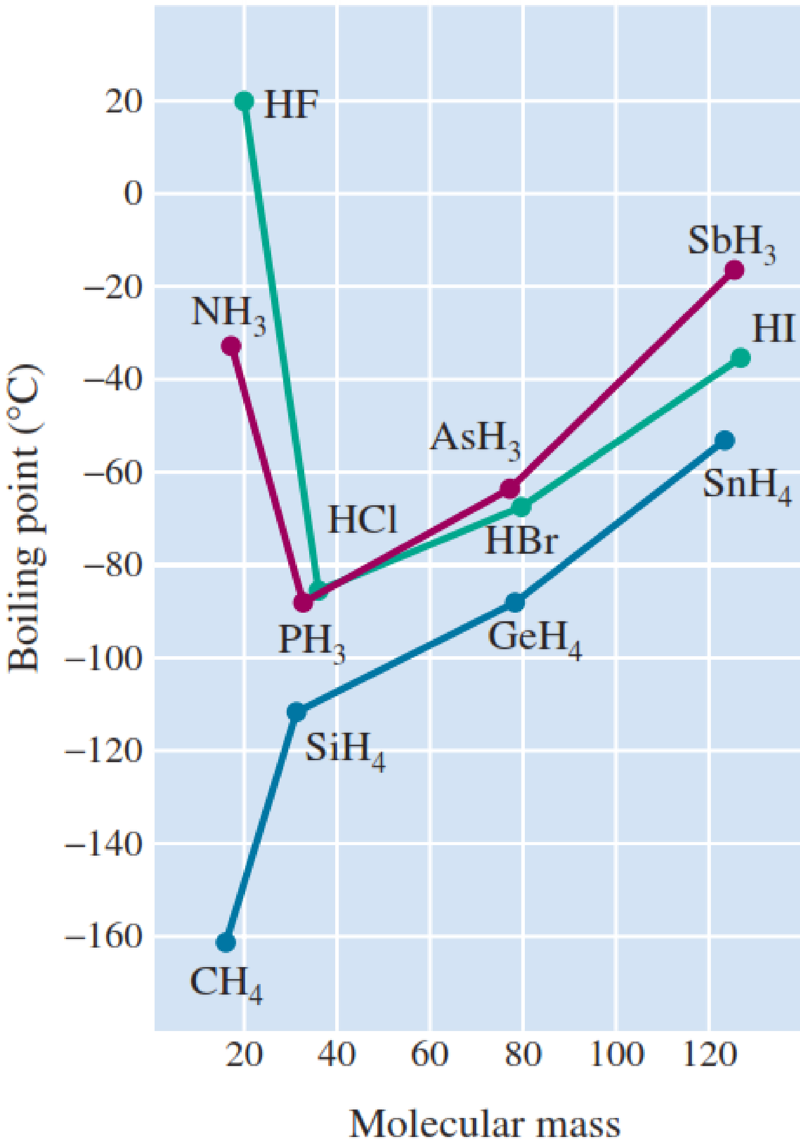
PROBLEM: Which of the following substances exhibits H bonding? For those that do, draw two molecules of the substance with the H bonds between them.

(a) HF

(b) 

(c) $H-C\equiv N:$

Effect of H bonding on the boiling points of the binary hydrides of group 4A, 5A and 7A

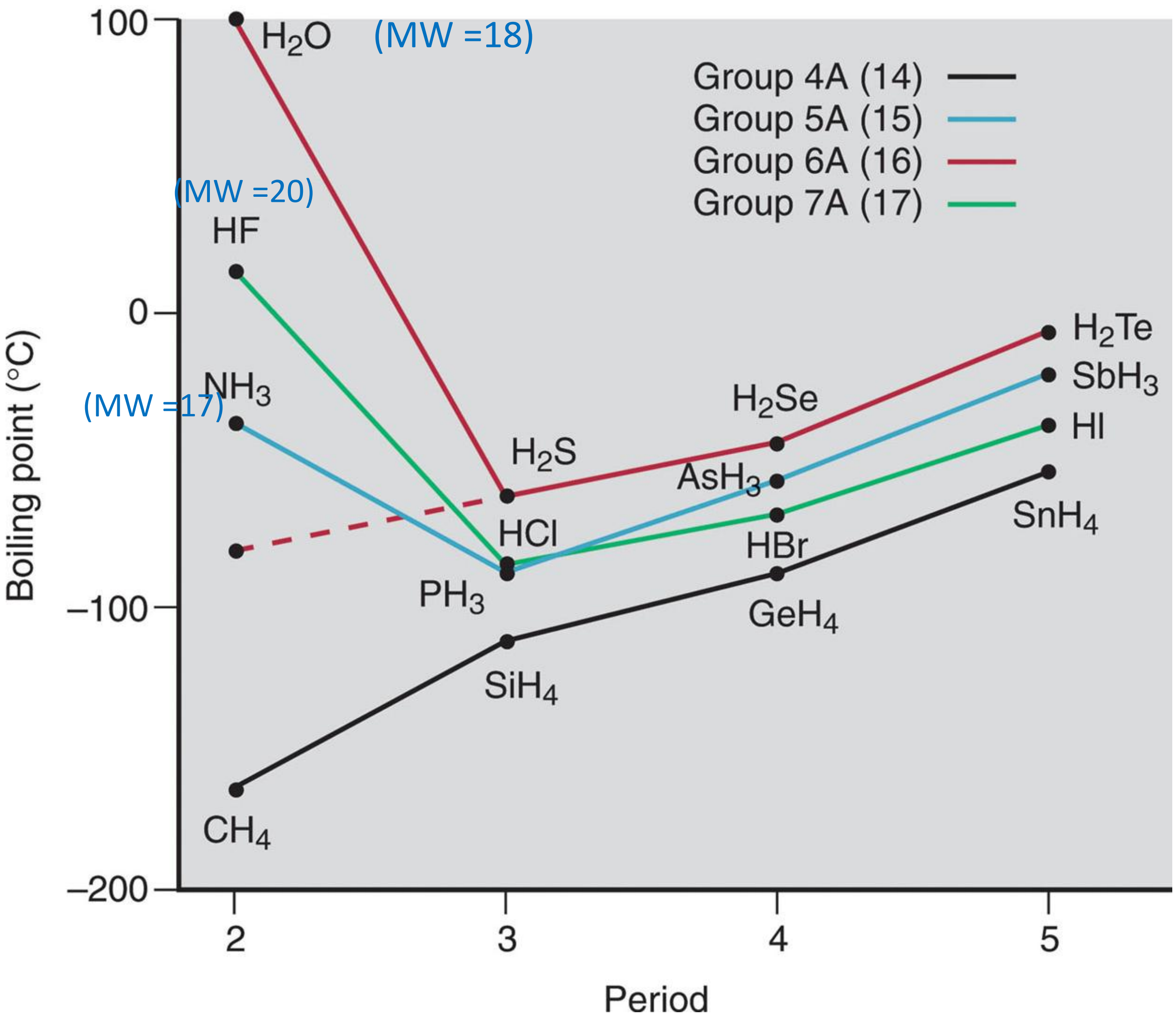


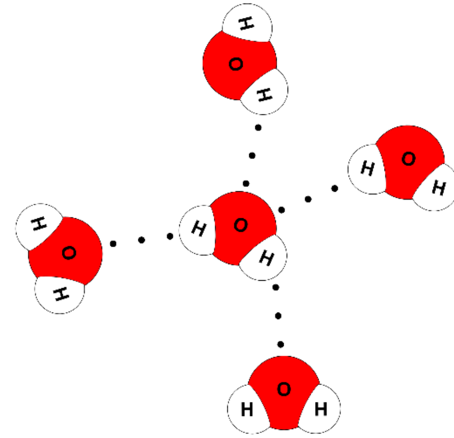
- If London forces were the only intermolecular forces present in this series of compounds, the boiling points should increase regularly with molecular mass.

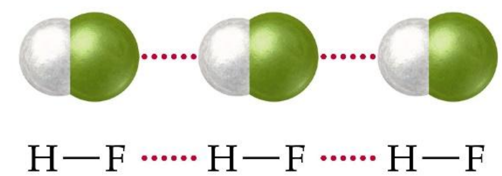
- NH_3, HF and H_2O molecules form strong H bonds, so it takes more energy for the molecules to separate and enter the gas phase.

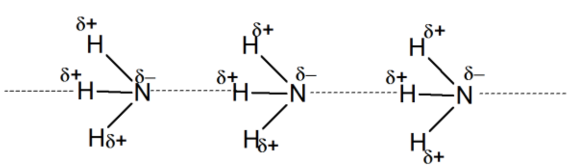
Ebbing, D., & Gammon, S. D. (2007). *General Chemistry:* Cengage Learning.

Effect of H bonding on the boiling points









Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

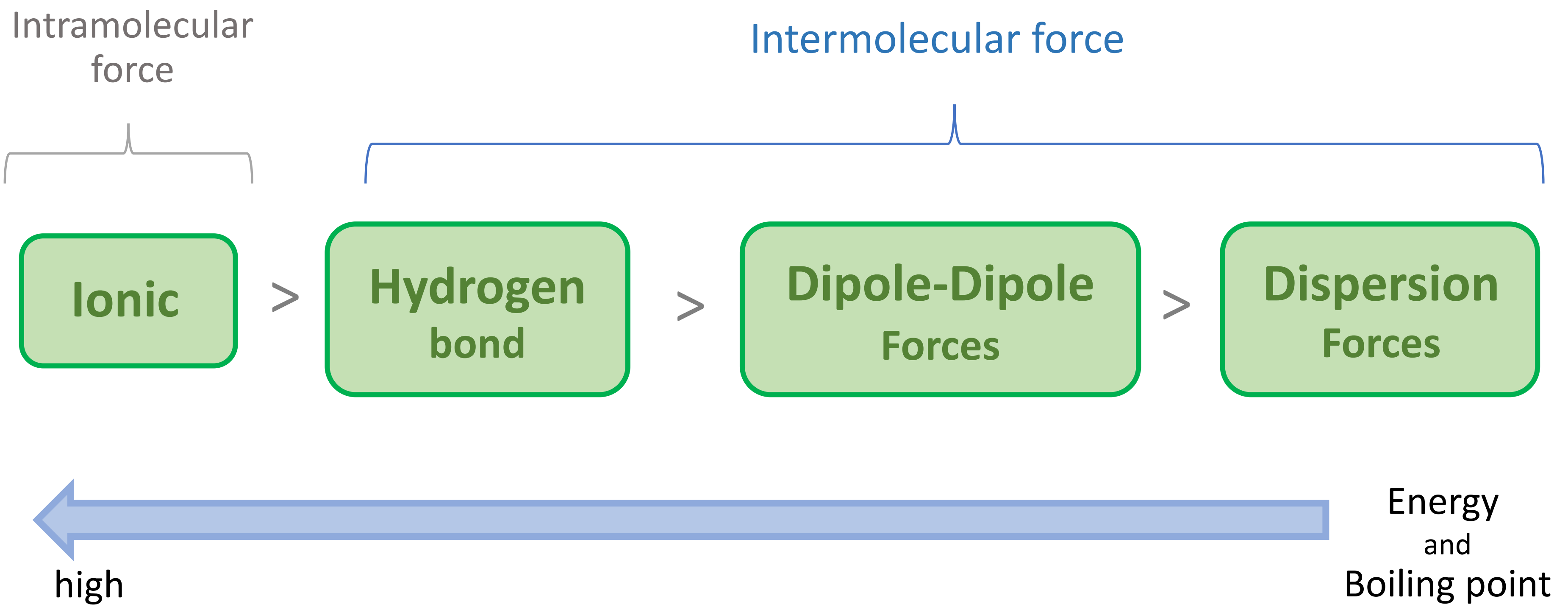
SAMPLE PROBLEM 11.1A **Determination of types of intermolecular forces**

Problem: What type(s) of intermolecular forces exist between each of the following molecules?

(a) CO_2 (b) BF_3 (c) H_2O (d) NH_3

Chang, R. (2010). *Chemistry:* McGraw-Hill.

Relative Strength of Intermolecular Forces



SAMPLE PROBLEM 12.3

Predicting the Type and Relative Strength of Intermolecular Forces

PROBLEM: For each pair of substances, identify the dominant intermolecular forces in each substance, and select the substance with the higher boiling point.

(a) $MgCl_2$ or PCl_3

(b) CH_3NH_2 or CH_3F

(c) CH_3OH or CH_3CH_2OH

PLAN:

- Bonding forces are stronger than nonbonding(intermolecular) forces.
- Hydrogen bonding is a strong type of dipole-dipole force.
- Dispersion forces are decisive when the difference is molar mass or molecular shape.

Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

SAMPLE PROBLEM 12.3

Predicting the Type and Relative Strength of Intermolecular Forces

PROBLEM: For each pair of substances, identify the dominant intermolecular forces in each substance, and select the substance with the higher boiling point.

SOLUTION:

(a) Mg^{2+} and Cl^- are held together by ionic bonds while PCl_3 is covalently bonded and the molecules are held together by dipole-dipole interactions. Ionic bonds are stronger than dipole interactions and so $MgCl_2$ has the higher boiling point.

(b) CH_3NH_2 and CH_3F are both covalent compounds and have bonds which are polar. The dipole in CH_3NH_2 can H bond while that in CH_3F cannot. Therefore CH_3NH_2 has the stronger interactions and the higher boiling point.

(c) Both CH_3OH and CH_3CH_2OH can H bond but CH_3CH_2OH has more CH for more dispersion force interaction. Therefore CH_3CH_2OH has the higher boiling point.

Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

SAMPLE PROBLEM 12.3A

Predicting the Type and Relative Strength of Intermolecular Forces

PROBLEM: For each pair of substances, identify the dominant intermolecular forces in each substance, and select the substance with the higher boiling point.

(a) CH_3Br or CCl_4

(b) H_2O or $CHCl_3$

(c) H_2O or NaCl

(d) SF_6 or PCl_5

(e) NH_3 or F_2

Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

SAMPLE PROBLEM 12.3B

Predicting the Type and Relative Strength of Intermolecular Forces

PROBLEM: Arrange the following in order of decreasing boiling point

(a) H_2O, HCl, HBr, CH_4

(b) F_2, HF, CaF_2

(c) HF, H_2S, H_2O, Cl_2, Ne

Silberberg, M.; Amateis, P. *Chemistry The Molecular Nature of Matter and Change 7th edition*; McGraw-Hill Science, 2014.

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4) Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.